RECENT ADVANCES IN MECHANIZATION OF FRESH MARKET TOMATO HARVESTING IN FLORIDA

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ABSTRACT

A stationary harvester and more recently an experimental mobile harvester were developed by the University of Florida's Institute of Food and Agricultural Sciences (IFAS) to evaluate the effectiveness of various machine components for harvesting fresh market tomatoes on sand and rockland soils of Florida. The mobile harvester was tested on sandy soils in Fort Pierce and Immokalee and on rock soils in Homestead in 1969 and 1970. A harvester for processing tomatoes developed by Clemson University was tested for fresh market harvest in the Fort Pierce area in 1969. A modified Button-Johnson harvester was tested on both rock and sandy soils in 1970. Main emphasis was on detecting sources of fruit injury and observing general harvester effectiveness.

INTRODUCTION

Mechanical harvesting is essential if Florida's $100 million fresh market tomato industry is to meet the serious problems of rising labor and material costs, reduced labor availability, and increasing foreign competition. Machine harvesting of processing tomatoes in California helped greatly reduce labor requirements (7). The University of Florida's Institute of Food and Agricultural Sciences (IFAS) has a statewide research program designed to develop varieties, cultural practices, and harvesting and handling systems needed for machine harvesting of ground grown, fresh market tomatoes. This report covers the engineering and machinery development phases of the project.

In 1966 a harvester developed by FMC Corporation for processing tomatoes was field tested with fresh market tomatoes in both sand and rock soils with limited success (2). A survey in 1966 of machine harvesting in California and discussions with manufacturers of harvesters for processing tomatoes indicated very little interest in developing machinery for the Florida fresh market tomato industry (5). Hence, the machinery development and testing phase of Florida's tomato program was initiated. Several experimental components were developed and tested and in 1969 an experimental mobile harvester was constructed and field-tested on both sand and rock soils. In 1969 a FTC-Clemson harvester was field tested on sandy soils in Florida. A modified Button-Johnson harvester was field-tested on both rock and sandy soils in 1970. Main emphasis was on detecting sources of and reducing fruit injury and observing general harvester effectiveness.

DEVELOPMENT OF IFAS EXPERIMENTAL HARVESTER

Studies with the FMC Machine in 1966 demonstrated that the plant cut-off and pickup operations caused considerable fruit damage and introduced sand and rock onto the harvester (2). Because of this problem, several principles for mechanically lifting the vines of an intact plant and allowing stem severing about ground were tried, but found unsatisfactory because of the erratic vine growth patterns. Cutting below ground was more suitable. The most successfully tested component for plant pick-up was a 4-foot-wide conveyor of rubber covered, parallel rods, 1 5/8" apart. Every fifth bar had four 3-inch-long rubber covered fingers attached 12 inches apart. When used in conjunction with a below
ground, rigid cut-off blade and a flat-top bed, the fingers provided satisfactory plant pick-up action with a minimum of soil introduced into the machine. Extensive studies were conducted with a tractor drawn, finger pick-up elevator unit. One of the commercial harvesters used with processing tomatoes had been observed in California utilizing this principle, and one objective was to determine which components commercially manufactured in other areas could be modified and used under Florida conditions.

Trials with the FMC Machine in 1966 had shown that a widely-spaced, parallel-bar reciprocating conveyor could effectively shake mature green fruit from the plant. A stationary shaker was constructed which utilized this principle. Through a series of fruit-drop tests, cushioning materials were evaluated and used for covering the parallel bars to minimize fruit damage. The experimental pick-up unit and a mobile, simulated plant bed were attached to the shaker to provide a stationary harvesting system which would allow study of cumulative fruit damage, trash build-up and handling of mechanically harvested fruit (Fig. 1). A conveyor, inclined at 25° and positioned beneath the shaker bars, transferred leaves, soil and other trash upward for a side discharge while allowing loose fruit to roll downward onto a side conveyor or into a water tank. A 100 gallon water tank (circulating at 35 gpm) with all inner surfaces padded was an effective method for removing the abrasive sand usually adhering to fruit grown on sandy soils. Air blasting did not adequately remove sand from loose fruit. Neither water dipping nor water spraying the entire plant removed enough sand to reduce injury during the subsequent shaking operation. The stationary harvesting system was a valuable research tool to pinpoint specific sources of fruit damage and allow the numerous refinements necessary to reduce mechanical injury to an acceptable level. Several fruit damage samples from the stationary harvesting system compared favorably with hand-harvested fruit. One very encouraging result was that the valuable pink tomatoes came through the harvesting system with the least amount of sand damage (1).

In 1969, there was still little active interest by manufacturers to develop machinery for Florida. Therefore, the most promising components tested in the University program were incorporated into a mobile experimental harvester (Fig. 2) to:

1. Demonstrate the feasibility of commercial machine harvesting of fresh market-tomatoes.
2. Analyze economics of a harvesting-handling system, including handling of the various maturities, i.e., mature green, vine ripe or breaker, red-ripe for processing and possibly undersize or mature green fruit for processing.
3. Study the feasibility of a water washing, sand-removal system on a mobile harvester since earlier studies indicated the necessity of such a system for tomatoes harvested in sandy soil.
4. Evaluate components not available on commercial processing harvesters, but which may be needed to modify them for fresh market use.
5. Evaluate the durability and effectiveness of various cushioning materials under commercial conditions.

Figure 1.—Side view of IFAS stationary harvesting system showing mobile, simulated plant bed, pickup-elevator unit, and parallel rod fruit-vine separator.

Figure 2.—Fruit samples for damage evaluation being collected from several points of IFAS experimental harvester.
6. Study the effect of various varieties and cultural practices on machine harvesting.

RESULTS WITH IFAS EXPERIMENTAL HARVESTER

The IFAS harvester was field-tested in the Ft. Pierce, Dade County, and Immokalee areas (3, 4). The effects of plant dessication obtained by cutting off plants beneath the soil surface with a tractor drawn blade from 1 to 24 hours prior to harvest were studied in rock soils. When properly conducted pre-cutting eliminated the necessity of a cut-off blade attached to the harvester, reduced damage during pick-up as there was much less rock disturbance, and reduced the amount of agitation necessary to obtain fruit-plant separation as properly timed plant wilting reduces attachment forces between fruit and stem. Also, since the 6-foot-long blade undercuts the entire bed, its use allowed effective pickup of triple-row beds. A disadvantage was that the flaccid, dessicated plant often fell between the shaker bars. Successful pre-cutting depended upon bed condition, timing and exact blade adjustment. Since its effects on fruit damage and system economics require further study, a harvester attached stem severing blade is still recommended.

A level bed surface was proven necessary for the pick-up principle employed on the experimental harvester. Damage ratings (% of unacceptable fruit due to machine injury) on fruit collected on the elevator varied from 0 to 24% in rock soils and from 1 to 25% in sand soils depending on bed shape and proper adjustment of the elevator and cut-off blade. Gage wheels were needed to maintain proper positioning of the pick-up unit and the cut-off blade.

The effect of the jointless pedicel character on stem removal of machine harvested fruit varied with breeding line and weather conditions. At times, over 90% of the machine harvested fruit were stemless. Rubber retaining strips perpendicular to the shaker bars were effective in preventing plant fall-through. However, large plants often tended to ride entirely on top of the reciprocating shaker bars, thereby preventing some fruit from hanging below the bars and being subjected to the deceleration forces required for removal. Preliminary observations indicated that a combination of wider bars, and short, soft upright appendages on the shaker bars will substantially alleviate this problem.

An inclined trash disposal belt directly below the shaker bars was generally effective in separating the fruit from soil, however, several disadvantages were encountered. Alignment and belt tension were critical. Jointless fruit often remained in clusters when mechanically removed from the plant and, hence, did not quickly roll down the belt as intended. Rocks often remained on the belt momentarily and injured falling fruit. In wet conditions, keeping the inclined trash belt brushed free from adhering sand and marl was a major problem. The inclined trash belt has been replaced by a cushioned horizontal belt for future test.

Three parallel brushes were originally used to clean fruit emerging from the inclined trash belt. In extended operations, adherence of considerable soil, moisture and fruit juices hindered the brushes' effectiveness. They were replaced by a 24-inch-wide by 6-foot-long 100 gallon water tank with treated water circulating at 35 gpm. The water tank was effective in sandy soils for cleaning the fruit and cushioning its drop. In rockland soils, rocks became lodged in the tank and damaged falling fruit. Furthermore, the water tank may not be necessary in rock soils because the adhering soil is not as abrasive as sand. A 16-inch-wide elevator at one end of the tank discharged washed fruit onto a sizing belt. A sizing belt with round holes was used because it was more accurate than a parallel rod conveyor-sizer on varieties with oblate fruit shape.

Most mechanically harvested fruit samples exhibited greater mechanical injury than hand harvested samples. However, several fruit damage sources were identified and modifications of several components will be conducted to reduce this injury.

FTC-CLEMSON HARVESTER

Food Technology Corporation (FTC) of Reston, Virginia, manufactures a tractor mounted tomato harvester (Fig. 3) which was developed at Clemson University (6). An FTC-Clemson machine was field tested on sandy soils in the spring and fall of 1969 and its problem areas were analyzed. The tractor mounted harvester cuts and elevates plants beneath the tractor, separates fruit from vines with a vertical oscillating, parallel bar inclined conveyor, and has a side delivery discharge conveyor. Fruit, collected in pallet bins containing either no water, untreated water or water treated with chlorine, re-
received critical evaluations for mechanical and sand injury, post-harvest decay and ripening quality (3). The harvester was tested in growers' fields with beds not designed for the machine. Machine performance was substantially hindered by the high plant beds, wide row spacing, and dense tomato foliage. Sand adhered to all machine components and caused extensive fruit damage. Fruit-vine separation was generally satisfactory except when large, dense plants were encountered.

**BUTTON-JOHNSON HARVESTER**

The Johnson Manufacturing Company of Woodland, California, manufactures the Button-Johnson (BJ) harvester for processing tomatoes. In 1970 a BJ harvester was modified and field tested in the Homestead and Immokalee areas (Fig. 4). The main modifications included:

1. Padding over all metal components which could have fruit impact. These included the elevator pickup fingers, shaker chains, shaker chain fingers, chutes covering the shaker chain return and the cross conveyor beneath the shaker.
2. A water spray system to remove sand from the fruit.
3. Partial elimination of undersized fruit by increasing the spacing between parallel bars of the cross conveyor beneath the fruit separator.

Results with this machine were very encouraging. Fruit-vine separation was satisfactory. Packing house samples which had been harvested in Dade County exhibited only 10% greater damage than a check hand-harvest sample. The harvester satisfactorily harvested tomatoes grown on paper mulched beds. However, the 12 to 15-inch high beds used in sandland areas created a clearance problem. All components of this machine were thoroughly analyzed for effectiveness and fruit damage potential, and modifications were suggested to the manufacturer. Recommended changes included a new attachment method for cut-off blade, additional padding, a circulating water spray system to allow considerably more volume, additional provisions for sizing fruit, removal of sharp edges on several components, and provisions for keeping grading belts free from sand. It is felt that these modifications can make the BJ harvester suitable for commercial use in Florida if the proper varieties and cultural practices are employed.

**SUMMARY**

Several years of intense study, development and testing indicate that machine harvest of fresh market tomatoes in Florida will be possible. The most rapid approach to an acceptable harvesting system seems to be in modifying a processing tomato harvester. Converting from multiple hand harvest to non-selective machine harvest involves many factors beyond development of a harvester. Bulk or bin handling of tomatoes will be an economic necessity and will affect post-harvest operations. New varieties with the jointless pedicel character, flat top beds, uniformity of maturity in a given planting, and scheduling for maturity dates will also be required for a successful machine harvest operation.
FRUIT CHILLING AND RIPENING STUDIES FOR EVALUATION OF BREEDING LINES OF FRESH MARKET TOMATOES

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ABSTRACT

In both the spring and fall growing seasons replicated trials of fresh market tomato stocks are grown at the Gulf Coast Experiment Station in Bradenton. Green mature harvested fruit from these tests are ripened in two ways. Fruit of a line are divided into two lots. One lot is stored at 40°F for 1 week and then transferred into a 68°F ripening room with 85% relative humidity. The other lot is placed in the ripening room immediately. Fruit are evaluated after 3, 7, and 14 days in the ripening room. Evaluation of green mature fruit of ten lines in the spring of 1969, ten in the fall of 1969 and 12 in the spring of 1970 indicate that a high percentage of Florida hybrid lines are not tolerant of chilling. Evidence presented points to the genotypes involved and the necessity of using predetermined resistance to chilling injury in a breeding program is discussed.

INTRODUCTION

The effect of chilling injury to tomato resulting from pre- and post-harvest temperatures is well known. Pre-harvest chilling studies were conducted by DeRosa (3) as early as 1927 and by Morris (6) and Barger, et al (1) in more recent times. In 1952 Florida workers (2) reported on the chemical composition and ripening characteristics of fruit obtained at different seasons from several locations. Hall (4) reported that green-mature tomato fruits held at 40°F for 4 or more days were more subject to breakdown when subsequently placed at 70°F after storage than fruit placed at 70°F without post-harvest chilling. Segall, et al (7) and Hall (5) demonstrated significant differences in tolerance of tomato varieties as regards their tolerance to chilling injury which resulted in delayed ripening and an increased incidence of Alternaria stem-end decay.

The information reported here results from a continuing study of genetic material (advanced, fixed lines having possible variety status) produced by Florida tomato breeders. The effect of chilling on fruit ripening and susceptibility to various types of post-harvest fruit rots was studied in this series of tests.

MATERIALS AND METHODS

Fruit harvested green-mature from the STEP (Southern Tomato Exchange Program) replicated trials were utilized in the 1969 spring test. A list of these is shown in Table 1. Twenty-five fruit from each of 4 replications of each variety were held in a room at 40°F for 7 days and then moved to a room at 68°F and 85% relative humidity for ripening. At the time fruit were stored in the 40°F room similar lots of fruit were placed in the 68°F room for ripening. Evaluation of fruit in the 68°F room was made after 3, 7, and 14 days. The number of ripe, pink, green, and decayed fruit was recorded and the ripe and decayed fruit was removed at 3