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A MECHANICAL SYSTEM FOR GRAPE VINE DEBRIS REMOVAL

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B. F. Cargill
Major professor

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A MECHANICAL SYSTEM FOR GRAPE VINE DEBRIS REMOVAL

By

Carter D. Clary

A THESIS

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ABSTRACT

During the 1975 and 1976 Michigan grape harvests, an experimental grape vine debris removal system was tested. This unit included a cluster breaking device which fed onto a chain belt sorting surface. With the aid of vibration, the grapes fell through the chain belt and the vine debris (leaves, petioles, wood, post parts, and other non-grape material) rode over the end of the belt. Extensive stationary tests resulted in nearly 90 percent petiole removal and grape losses due to the sorting process of less than 1 percent. Petioles in mechanically harvested grapes is of primary concern to the juice processing industry as they cause serious plugging problems at the processing plant. In limited down-the-row testing, the vine debris removal system approximately 60 percent of the vine debris. Grape losses due to sorting were less than 1/3 percent. These results warrant further analysis of the chain belt vine debris removal system and possible incorporation into a mechanical harvesting system.

Approved: B. F. Cargill
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I. INTRODUCTION

A. History of Grapes

Of all the cultivated fruits, history tells us grapes are one of the oldest. The Bible tells that Noah planted a vineyard as one of his first acts after safely completing his stay in the ark. Grape seeds have been found in Egyptian tombs 3,000 years old and in the remains of Bronze period lake dwellings of Switzerland and Italy, where grapes were introduced into Europe by the Phoenicians (Sears, 1920).

Undoubtedly, grapes were first used as fresh fruit, and large quantities of grapes are still consumed each year as fresh fruit. However, the largest quantity of grapes is used for processing wines, juice, jelly and raisins ("Wines and Vines", May, 1976).

Early American explorers found the continent abounding in wild grapes; they called it "vineland". The first successful domestic production of grapes was on the Atlantic coast, harvested in 1820 in the vineyard of John Adlum in Georgetown, D. C. (Harvest, 1946).

No group of fruits is more interesting botanically, and perhaps more complicated, than grapes. It is beyond the scope of this thesis to discuss in detail the more than 60 varieties of grapes and their characteristics. Yet a brief discussion is advisable as varietal characteristics influence mechanization.

Probably the best known species of Vitis is the European species Vitis vinifera; it makes up 90 percent of the world grape culture

(Encyclopedia Britannica, 1973). This species is important in the production of many hybrids grown in the United States as well as an important species grown in California. Some of the important hybrid varieties of vinifera and American species are 'Baco Noir' and 'Cuvee' (Winkler, 1974).

The single species of grape with the greatest acreage grown in the northern parts of the United States is the northern fox grape, vitis lubrusca. It was developed from native species grown in the northern sections of this country and includes the well-known 'Concord' grape. The Concord grape was developed in 1849 by Ephraim Bull of Concord, Massachussetts (Sears, 1920).

B. Production and Utilization

About 10 million hectares (25 million acres) of grapes are cultivated in the world today; 75 percent of the grapes produced are grown in Europe, 11 percent in Asia, 5 percent in South America, 5 percent in Africa, 3 percent in North America, and 1 percent in Oceana (Encyclopedia Britannica, 1973).

California is the major grape state producing 90.5 percent of the United States total in 1975. Of the 3,559,800 metric tons (3,924,000 tons) of grapes produced in California, 56.3 percent was crushed exclusively for wine ("Wines and Vines", May, 1976).

Grape juice in the United States is produced almost exclusively from Concord grapes. The crushed grapes are heated, pressed, stabilized with sulfur dioxide, clarified, and bottled hot. Grape jelly is usually made from Concord grape juice (Sears, 1920).

Primarily, the Concord is grown in the Great Lakes region consisting of New York, Pennsylvania, Ohio, Michigan and Ontario (Canada). Washington also has a sizeable acreage of Concords. Production statistics for these states are shown in Table 1. Michigan is the fourth largest producer of grapes in the United States, producing 49,900 metric tons (55,000 tons) in 1975; accounting for 1.3 percent of the national production. Over 90 percent of the grapes harvested in Michigan are crushed for juice, jellies, and jams (Table 1) ("Wines and Vines", 1976).

The commercial production of Concords in Michigan is located in the southwest counties of Berrien and Van Buren, centered near Benton Harbor and Paw Paw. Michigan production since 1967 is outlined in Table 2.

C. Background of Grape Harvest

Traditionally, grape harvesting has been done by cutting the fruit bunches from the vine by hand. Grapes for processing into wine and juice were normally hand harvested into boxes, and transported directly to the processor for crushing and pressing (Figures 1 and 2). Grapes for fresh market are harvested by hand and packed directly into shipping containers.

Economic studies in New York indicate that the harvesting cost of hand harvested Concord grapes delivered to the processors or wineries averaged $35 per ton in 1968. Hand harvesting required about half of the total hourly labor input per acre of vineyard (Berlage and Black, 1969). California harvesting and hauling costs ranged from $11 to $25 per ton for wine grapes (Studer and Olmo, 1969).

Until the mid 1960's, much of the commercial harvesting of fruits and vegetables in the Midwest was performed by a migrant labor force. It was

Table 1. United States grape production and utilization of the commercial crush, by states, 1975 ("Wines and Vines", May, 1976).

STATE	TOTAL PRODUCTION 1,000 Metric Tons	OF U.S. PRODUCTION (Percent)	TOTAL CRUSHED[1] (Percent)	UTILIZATION OF CRUSHED GRAPES: OF WINERIES (Percent)	UTILIZATION OF CRUSHED GRAPES: OF PROCESSORS[2] (Percent)
California	3,559.8	90.5	56.3	100.0	00.0
New York	138.8	3.5	98.6	49.4	50.6
Washington	98.4	2.5	—[3]	—[3]	—[3]
Michigan	49.9	1.3	94.5	9.6	90.4
Pennsylvania	43.6	1.1	96.4	14.0	86.0
Ohio	13.3	0.3	92.5	20.0	80.0
Arizona	11.2	0.3	00.0	00.0	00.0
Other States[4]	21.0	0.5	97.3	12.2	87.8
United States	3,935.6	100.0	59.9	89.0	11.0

[1] Balance represents utilization for other purposes.

[2] Crushed mostly for unfermented juices, jams, and jellies. Some of the processed grape material may be shipped to wineries and distilled spirits plants.

[3] Only total grape production was available for Washington.

[4] Includes Arkansas, Georgia, Missouri, North and South Carolina.

Table 2. Mechanical grape harvesting and production history - Michigan.

YEAR	PRODUCTION (1000 metric tons)	MECHANICAL HARVESTERS[1]	PRODUCTION MECHANICALLY HARVESTED[1] (percent)
1967	35.4	0	0
1968	20.9[2]	1	1
1969	34.5	11	25
1970	56.3	25	65
1971	62.6	37	87
1972	48.1	44	90
1973	21.3[2]	50	92
1974	43.1	58	92
1975	49.9	64	92
1976	13.2	66	92

[1]Industry estimate based on correspondence with industry representatives.

[2]Low yield due to spring frost damage.

Figure 1. Traditional Hand Harvesting Prior to Mechanical Harvesting.

Figure 2. Conventional Method of Transferring Grapes from Vineyard to Processor Prior to Mechanical Harvesting.

considered unlikely that field labor would increase in availability, or decrease in cost in the future. During the summer season, the migrant labor force moves north from the Southwest and Southeast (Texas and Florida), into the fruit and vegetable areas of New York, Pennsylvania and Michigan. Until recently, plenty of work was available during July, August and September in Michigan. The migrant worker depends on continuous work from spring to fall. Breaks in this work occurred when the cherry, cucumber and blueberry harvests were mechanized. Therefore, labor for the grape harvest was in jeopardy (Berlage and Black, 1969).

The grape harvest comes relatively late in the summer season and requires a high number of workers concentrated into a period of only 4 to 5 weeks. It was apparent to the migrant labor force that it was no longer profitable to wait idly through mid-summer for the grape harvest in September. Therefore, labor supplies for grape harvest began to dwindle promoting the investigation of mechanizing the grape harvest.

Experimental mechanical harvesting of grapes began in California in 1952. The approach was to train the grapes so they could be removed with a cutter bar head. By 1957, shake harvesting trials were underway in New York. California shake harvesting trials began in 1961. Platform type harvesting aids were tested in California from 1965 to 1967. As a result of early emphasis on grape harvesting research, several commercial harvesters are now available (Berlage and Black, 1969; Studer and Olmo, 1969).

Initial attempts in New York to modify the vine to fit a machine led to the concept of developing an optimum vine system and then designing a machine to fit the vine. Trellising systems such as the Geneva Double Curtain and the Duplex System provided yield as well as mechanization advantages (Winkler, 1974).

The first commercial harvesting of any extent was done in 1967. Commercial grape harvesters are used exclusively in processing grape varieties. These over-the-row harvesters basically apply a vertical or horizontal shake to the vines or supporting wires (Figures 3 and 4). Labor replacement ratios varied from 10 to 1, to 15 to 1. Limited data taken in New York from 1968 indicated that during the most efficient operation, one harvester with crew replaced 95 hand harvesters. In New York, the average 1968 harvesting cost for four machines harvesting Concord grapes was $20 per ton delivered to the processor compared to $35 per ton for hand harvesting (Berlage and Black, 1969).

Use of mechanical grape harvesters in southwestern Michigan has increased since the introduction of one harvester in 1968 to 66 harvesters in 1976. Approximately 92 percent of the Michigan crop was harvested mechanically in 1976 (Table 2)(industry estimate based on correspondence with industry representatives).

The rate of adoption of mechanical grape harvesting was affected by: (1) the labor availability, (2) economics of mechanical harvesting and handling, (3) the quality of mechanically harvested grape, (4) the readiness of processors to accept mechanically harvested grapes, and (5) the readiness and ability of growers to change to mechanical grape harvesting (Shepardson, et al. 1969).

D. Physical Properties of Mechanically Harvested Grapes

The vibratory action of the shaker head used to detach the grapes from the vine also detaches leaves, leaf stems (petioles), and cane wood, tendrils, trellis post parts, and other non-grape material. This

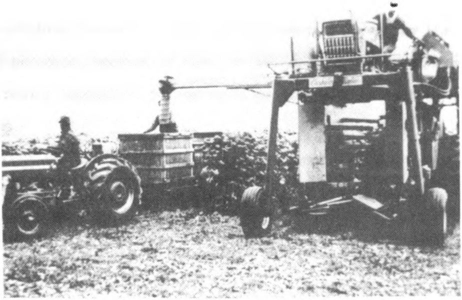

Figure 3. Conventional Mechanical Harvesting System.

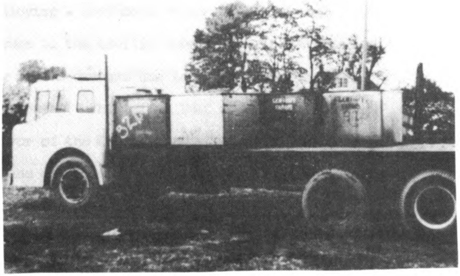

Figure 4. Existing 0.9 Metric Ton Handling System for Mechanically Harvested Grapes.

debris falls onto the catching conveyor and is collected with the grapes. Most mechanical harvesters have an airstream separation system at the end of the catching conveyor. This system removes much of the light debris, but petioles, because of their unfavorable surface area to mass ratio, are nearly impossible to remove in an airstream without unacceptable grape losses.

The amount of vine debris that separates from the vine with the grapes varies greatly with maturity, vineyard, and year. Probably the most significant factor affecting the quantity of vine debris in the mechanically harvested product, other than incorrect harvester operation, is a frost prior to harvest which is common in the eastern United States. After a frost, the leaves on the grapevine loosen and/or separate from their petioles and minimal vibration is required to separate the petiole from the cane. Mechanical harvesting at this time results in very large quantities of petioles separating from the vine with the grapes.

Vine debris and disintegration of fruit may be increased by the machines employing a horizontal slapping action over machines using a vertical stroke to the trellis wire to remove the fruit from the vine. The slapping action damages the fruit and damaged fruit wets the leaves with a sticky juice. This makes leaf separation by air difficult.

The flavor of the Concord grape is unique among all grapes. The grape juice and its allied industries are based on this flavor uniqueness; assurance is needed that the end products of mechanically harvested Concord grapes do not suffer either by loss or alteration of flavor due to mechanical damage and/or presence of debris in the mechanically harvested product.

II. REVIEW OF LITERATURE

The purpose of this chapter is to set the stage for the subsequent chapters; to build a foundation of literary information describing vine debris, its effect on quality and processability, and methods of removing the debris from the mechanically harvested product.

A. Vine Debris in the Mechanically Harvested Product.

Since the first application of the concept of shaking grapevines to remove the fruit, researchers have observed the problem of vine debris falling from the vine with the fruit. This debris includes leaves, leaf petioles, vine-parts and other foreign material. In initial New York tests as reported by Shepardson (1969), it was noticed that the vibration of the shaker head also loosened leaves and pieces of the vine which fell off onto the catching frame conveyor along with the grapes.

Most of this debris can be removed when it falls through an airstream having a velocity of 4,000 feet per minute. Moyer (1968) found that up to 8 percent of the weight of the material discharged from the catching frame conveyor belt, was vine debris. Most of this debris can be eliminated by use of an air separation system. Moyer also points out the ineffectiveness of the air system in removing leaf petioles because of their lack of buoyancy.

After a frost during the harvest season, excessive quantities of petioles come off of the vine during the mechanical harvest operation. This condition results in serious complications at the processing plant (Norton, 1977).

Presence of vine debris can foul pumps and cause other stoppages at the processing plant (Shepardson et al., 1969; Moyer et al, 1969). The fibrous nature of the grape leaf petioles make it difficult to handle this product in the processing plant equipment. Breakdown of pumps, stoppages in heat exchangers, and plugging of transport pipes are primarily caused by accumulation of petioles in the processing system (Norton, 1977) (Appendix B).

The effect of vine debris on juice and wine quality is also evident in Vitis vinifera cultivars grown in the western United States (Petrucci and Siegfried, 1976). Wildenradt et al. (1975) describe tests conducted using taste-panel evaluation of wines produced from the 'Chenin Blanc' grapes with various proportions of leaves. Wines made with more than 5 percent macerated leaves were of significantly lower quality.

Studies completed by Noble et al. (1975) at University California-Davis, indicated no overall adverse effect on wine quality was produced by mechanically harvesting grapes or adding shredded (not macerated) grape leaves. Nevertheless, white wines made from damaged or machine harvested grapes were significantly darker by visual assessment.

Johnson and Grgich (1976) carried out field studies comparing hand and mechanically harvested grapes and resultant wine quality. Of the two varieties analyzed, the 'Cabernet Sauvigon' wines were of no significant difference in quality, while mechanically harvested white 'Riesling' grapes and the resultant wine was of slightly higher quality compared to the hand harvested. Interestingly, the mechanically harvested lots of both varieties contained fewer leaves than the hand harvested lots.

It is apparent from the above studies that mechanically harvested grapes contain less vine debris than hand harvested grapes. The controversy appears to be over the quality of the wine made from mechanically harvested grapes. Variability in results could be explained by the skill of the harvester operator, and the method of handling the grapes following harvest. Operating the harvester at high beater speeds will result in excessive damage, especially in white varieties which will show post-harvest oxidation much more readily than red varieties. Furthermore, the mechanical harvesting process does not macerate grape leaves to the degree tested by Wildenradt et al. (1975).

B. Bulk Handling Systems.

Presently, the majority of the mechanically harvested grapes in Michigan are handled in 106.68 x 119.38 x 96.52 cm deep (42 x 47 x 38 in) wood bulk boxes with 0.32 cm (1/8 in) polyethylene liners. These bulk containers hold 0.9 metric tons (1 ton) of mechanically harvested grapes (Marshall et al., 1971).

Development of suitable handling systems have not kept pace with harvester development. During the 1969 season, studies were conducted on the physical properties of grapes in order that work could begin on the investigation of more expedient forms of bulk handling (Marshall et al., 1971).

Several types of alternative bulk handling systems were tested during 1970 in southwestern Michigan (Williams et al., 1971). The best system included a conventional harvester, unloading into a 3.2 metric ton capacity high-lift bulk vineyard trailer, and a 7.3 metric ton capacity rear dumping bulk tank truck. This harvesting system required 3 workers.

The major advantages of the high-lift bulk handling system were that:

1) it reduced manpower and equipment requirements by eliminating the need for a forklift in the vineyard and at the processing plant;
2) it offered a potential savings of $4,000 per harvester per year (Williams <u>et al</u>., 1971 and Snobar <u>et al</u>., 1976), and;
3) the quality of the Concord juices was equal to or better than juices made from grapes handled in the conventional 1 metric ton capacity pallet boxes (Whittenberger <u>et al</u>., 1971; Marshall <u>et al</u>., 1972; Marshall, 1973).

The major disadvantage of the new high-lift bulk handling system was that it did not permit removal of vine debris as was done previously by the bin attendant on the vineyard trailer.

C. Methods of Removal of Vine Debris from Mechanically Harvested Grapes.

At present, the largest United States Concord grape processor has attempted to reduce the vine debris from mechanically harvested grapes by requiring a bin attendant with each harvester. The bin attendant rides on the vineyard trailer and manually removes vine debris from the 0.9 metric ton (1-ton) capacity pallet box as it fills. It is apparent that a bin attendant is unable to function satisfactorily when the pallet box is filling at a rate of 4.5 metric tons per hour (5 tons per hour) for a typical Michigan crop.

An attempt to improve manual debris removal was made by relocating the bin attendant from the vineyard trailer to an improved vantage point on the harvester. This new system was fully tested in 1974 (Marshall, et al., 1975). Relocating the bin attendant on the harvester increased debris removal from removal of 8 percent achieved by the conventional bin attendant, to a range of 22 to 34 percent removal of vine debris. Relocating the bin attendant on the harvester would permit use of the 3.2 metric ton bulk handling system.

In spite of the 3 to 4 fold increase, the improved man-aid sorting system did not substantially increase the bin attendant's efficiency because of the variation of dedication of the bin attendant. A better method of removing debris from mechanically harvested grapes was needed.

Marshall et al. (1975) described two mechanical systems that were tested (Figures 5 and 6). One system tested by the National Grape Cooperative in 1971 and 1972 (Figure 5), consisted of a vibrating grid with 3.49 x 5.08 cm (1.375 x 2.00 in) openings, 45.72 cm (18 in) wide, and 107 cm (42 in) long, built into a trough 267 cm (105 in) long. The mechanically harvested product consisting of single grapes, clusters, and vine debris, was fed into the higher end of the trough. With the assistance of vibration of 700 to 800 Hz, 0.64 to 0.79 cm (1.6 to 2.0 in) vibration amplitude, the grape material moved down the trough over the separation grid. The model was modified slightly in 1974 by placing a device over the grid to keep it clear. The 1974 shaker system in Concords averaged 81 percent removal of leaves, 61 percent of the petioles, and 70 percent of the cane wood in 26 tests during the 1973 season. Losses of clusters and single grapes averaged 12.3, 13.2, and 6.8 percent for 'Niagara', 'Delaware', and 'Concord', respectively; this high grape loss was unacceptable.

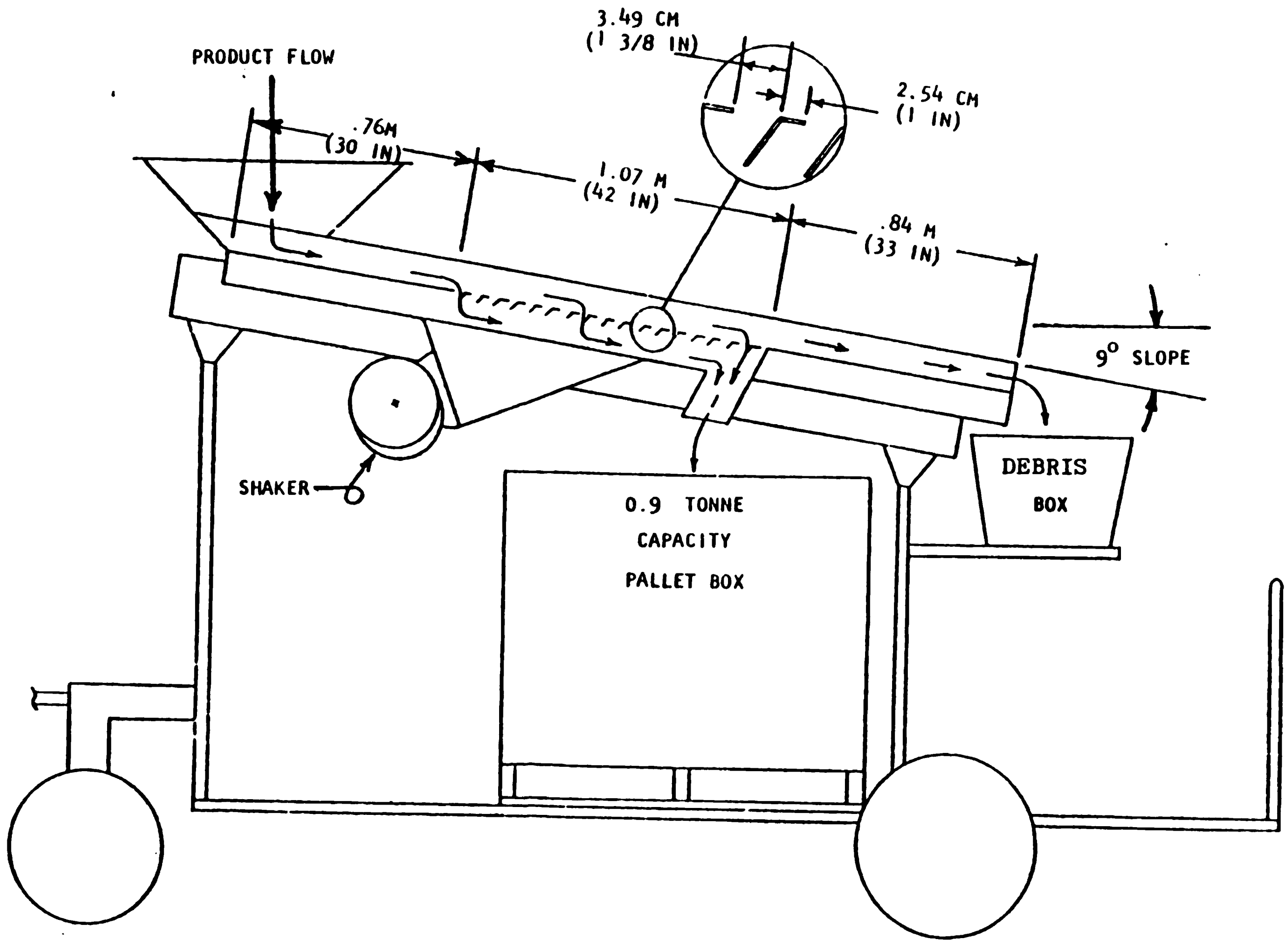

Figure 5. Side view of experimental shaker showing major details and material flow.

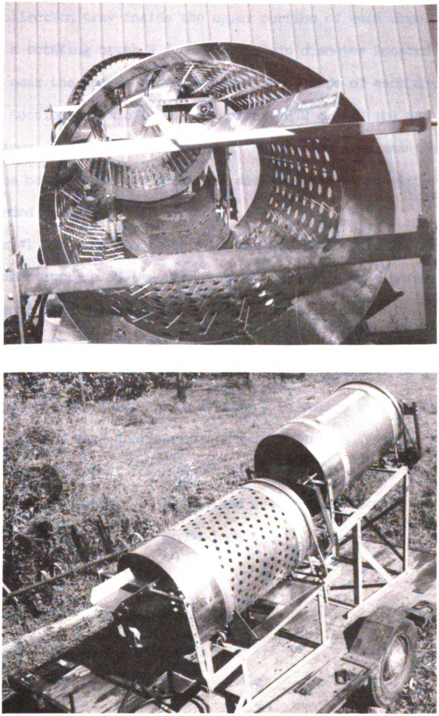

Figure 6. Rotary Drum Vine Debris Removal Systems - 1974.

A second concept consisted of two rotary drums (Figure 6) tested in 1974. Each drum was 73.7 cm (29 in) in diameter and 121.9 cm (48 in) long with a collection tray inside the upper portion of each drum. Drum #1 also had a rotating brush 8.9 cm (3.5 in) in diameter located under the tray and near the inside drum surface. The inside of each drum was composed of three sections, a middle working area, 76.2 cm (30 in) and two smooth end portions. The characteristics of the working area was the major difference between the two drums and differed in design with respect to the intended purpose.

Drum #1 was designed to extract the small vine debris using small hooks on the inner surface of the drum, which would drop this material onto the collection tray above.

Drum #2 was designed with holes to permit the single grapes and free run juice to pass through the drum and be collected in a hopper below while the large internal hooks were to remove grape clusters.

The maximum vine debris removal was 72 percent, however, grape recovery was 93 percent for drum #1 and 83 percent and 91 percent, respectively, for drum #2. We decided that another method of debris removal was needed to lower grape losses.

III. JUSTIFICATION OF RESEARCH

A. Vine Debris, Juice Quality, and Processability.

The adverse effects of vine debris have been described in Chapter II. In summary, detailed testing has shown that the amount and exposure of vine debris can have negative effects on the juice and/or wine quality. Mechanical harvesting yields equal or lower quantities of vine debris in the product delivered to the processor.

Potential problems of vine debris include impartation of extracts from the vine debris into the refined juice or wine, and reduction of juice yield due to absorption by the vine debris. Both these problems could be alleviated if the vine debris were eliminated from the mechanically harvested product in the field.

The juice processing industry has shown concern about the presence of vine debris found in the product delivered to the processor (Norton, 1977). Leaves, cane wood, trellis post parts and above all, petioles, because of their fibrous nature, cause plugging of processing equipment and reduced operational efficiency. When a pre-harvest frost occurs, the petiole problem is dramatically increased. Removal of vine debris before processing would help to reduce plant breakdown and improve processing efficiency.

B. Bulk Handling Systems.

The grape industry in Michigan has rapidly adopted mechanical harvest of grapes for juice and wine. Unfortunately, a systems approach was not initially evaluated when mechanical grape harvesters were introduced into Michigan. More efficient bulk handling systems are needed to expedite the harvest process.

Currently, a 0.9 metric ton capacity wooden pallet box is used to hold mechanically harvested grapes discharged from the harvester (Figure 7). These boxes are handled by fork trucks in the vineyard and at the processing plant. Studies have indicated that Concord grapes handled in a new bulk handling system and processed within 8 hours after harvest, produced juice of equal or better quality (both flavor and color) than the system presently used (Whittenberger et al., 1971 and Marshall et al., 1972).

The proposed bulk handling system includes a 3.2 metric ton capacity hydraulic self-dumping vineyard trailer to receive the grapes from the harvester (Figure 8). When the hydraulic vineyard trailer is full, it is pulled alongside a 7.3 metric ton capacity bulk tank truck. The truck is covered in the field with a canvas before the grapes are delivered to the processing plant. At the plant, the self-contained hydraulic hoist on the truck elevates the load and dumps the grapes into the processor's receiving hopper (Figure 9).

A major drawback of the new bulk handling system is the requirement that a bin attendant be present to hand sort vine debris from the grapes. The 3.2 metric ton capacity vineyard trailer is not suited for the bin attendant to work safely. Therefore, if the new bulk handling

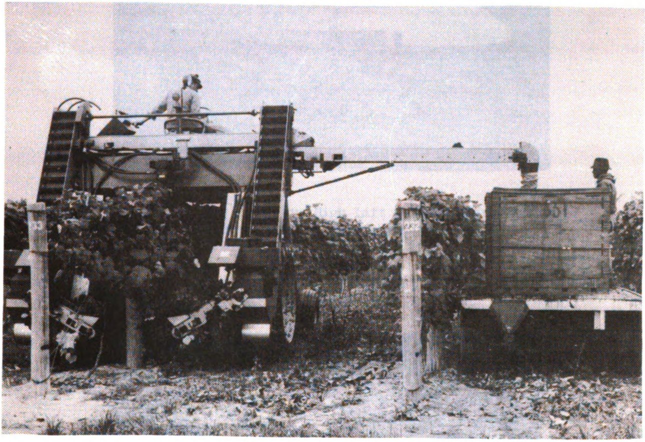

Figure 7. Conventional 0.9 Metric Ton Capacity Handling System for Mechanically Harvested Grapes.

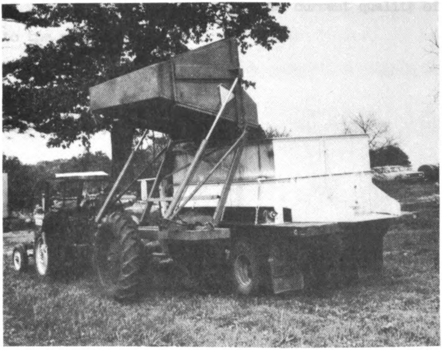

Figure 8. 3.2 Metric Ton Capacity, High Lift Bulk Handling System to Replace Conventional Vineyard Trailer - 1973.

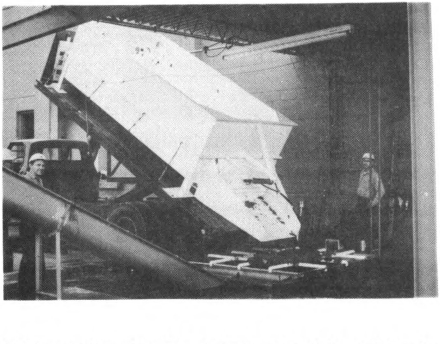

Figure 9. 7.3 Metric Ton Capacity, Self-Dumping Bulk Tank Truck - 1973.

system is to be successful, some other debris removal system is essential in order to maintain or improve the current quality of grapes delivered to the processor.

IV. OBJECTIVES

A. Overall Objectives.

The overall objective of this project is to design and develop a mechanical grape vine debris removal system that will separate vine debris from mechanically harvested grapes. At the same time, this system must minimize grape losses and damage to the product delivered to the processing plant due to extra handling.

Marshall et al. (1975) found from testing previous mechanical vine debris removal systems that the device must be self-cleaning and the grapes must be in the form of single grapes. If these two conditions are not met, the system will suffer extensive losses due to plugging and grape clusters being sorted as vine debris.

B. Specific Objectives.

The specific objectives of this project are:

1) to develop a self-cleaning method of separating vine debris from mechanically harvested grapes,
2) to develop a method of separating grapes from their stems and minimize damage and juicing from additional handling,
3) to minimize losses due to individual grapes being discarded along with the vine debris, and

4) to evaluate the efficiency and capacity of the mechanical vine debris removal system.

V. DEVELOPMENT OF A CONCEPT

It is the purpose of this chapter to trace the steps of analyzing past experience, and the process of formulating a new concept of removing vine debris from mechanically harvested grapes.

A. The Concept of Breaking Grape Clusters into Single Grapes.

It is apparent from the first studies on mechanical vine debris removal by Marshall et al. (1975), that current levels of grape losses are unacceptable to the industry. Continued work with two forms of grapes (singles and clusters), complicates the separation process. Instead, the mechanically harvested grapes should be assembled into one category: single grapes.

This concept was initially attempted in 1974 by placing the brush adjacent to the interior of the rotary drum (Figure 6). It was decided that a more aggressive method of breaking up grape clusters was needed. If the grid type system of separating vine debris from grapes was to be further investigated, more aggressive vibration would be necessary, and the grapes must be in single form so as not to plug the grid and subsequently be sorted as vine debris (Marshall et al., 1975).

B. Development of a Self-Cleaning Grid.

As previously mentioned, the separation grid as used on the vibrating bed system had potential for further investigation. However, the clusters must be singulated and some means must be devised to keep the grid openings clear. System capacity could be increased by applying more aggressive vibration to prevent bridging of the grid openings.

VI. PROJECT PROCEDURES

This chapter includes the description of the experimental vine debris removal system that we designed at Michigan State University and tested during 1975 and 1976. In 1975, a basic unit was constructed and tested in southwestern Michigan to examine the potential of the new concept. In 1976, a slightly modified 2nd Generation model was constructed on a vineyard trailer and tested extensively in southwestern Michigan and Pennsylvania.

In addition to the equipment description, this chapter includes a review of the testing procedures. Two types of tests were completed:

1) exhaustive stationary tests in which samples were brought to the unit, and
2) preliminary trial down-the-row tests in which the unit was pulled through the vineyard collecting and processing the material directly from the discharge conveyor of a mechanical harvester.

A. Description of Operation.

The vine debris removal system was first tested in 1975 in southwestern Michigan (Figure 10). This unit consisted of a grape cluster breaking device, which fed the single grapes onto a chain belt separating surface. When grape material was fed into the cluster breaker, it would

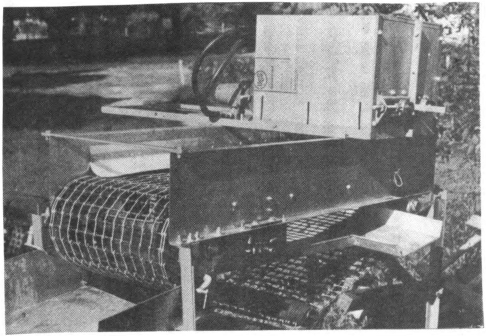

Figure 10. Chain Belt Vine Debris Removal System - 1975.

break up the clusters into single grapes. Next, the singulated grape material was discharged from the cluster breaker onto a vibrating transfer pan (not visible in Figure 10) which fed the material onto a chain belt. Here the single grapes would fall through the openings in the chain belt; the vine debris would span the chain belt openings and ride over the end of the belt. A vibrating unit was incorporated into the chain belt separator to minimize plugging of the chain belt openings and prevent single grapes from riding over the end of the belt on top of the leaves, thus not falling through the openings.

The principle of operation of the system constructed for the 1976 season was the same as that used in 1975 (Figure 11). This system was built onto a trailer and included its own hydraulic power unit to operate the vine debris removal system, so it could be pulled through the vineyard (Figure 12). In addition to the basic components tested in 1975, a catching conveyor was mounted above the cluster breaker which would catch the material from the harvester discharge conveyor and feed it into the cluster breaker. The trailer mounted model was built to accommodate a 0.9 metric ton (1 ton) capacity pallet box to hold the grapes processed by the vine debris removal system.

The transfer pan which caught material from the cluster breaker and fed it onto the chain belt on the 1975 model, was replaced by a small conveyor belt on the 1976 model. The 1976 model was tested in southwestern Michigan and Pennsylvania.

B. Description of Equipment.

1) Cluster breaker - The cluster breaker consisted of two cylindrical

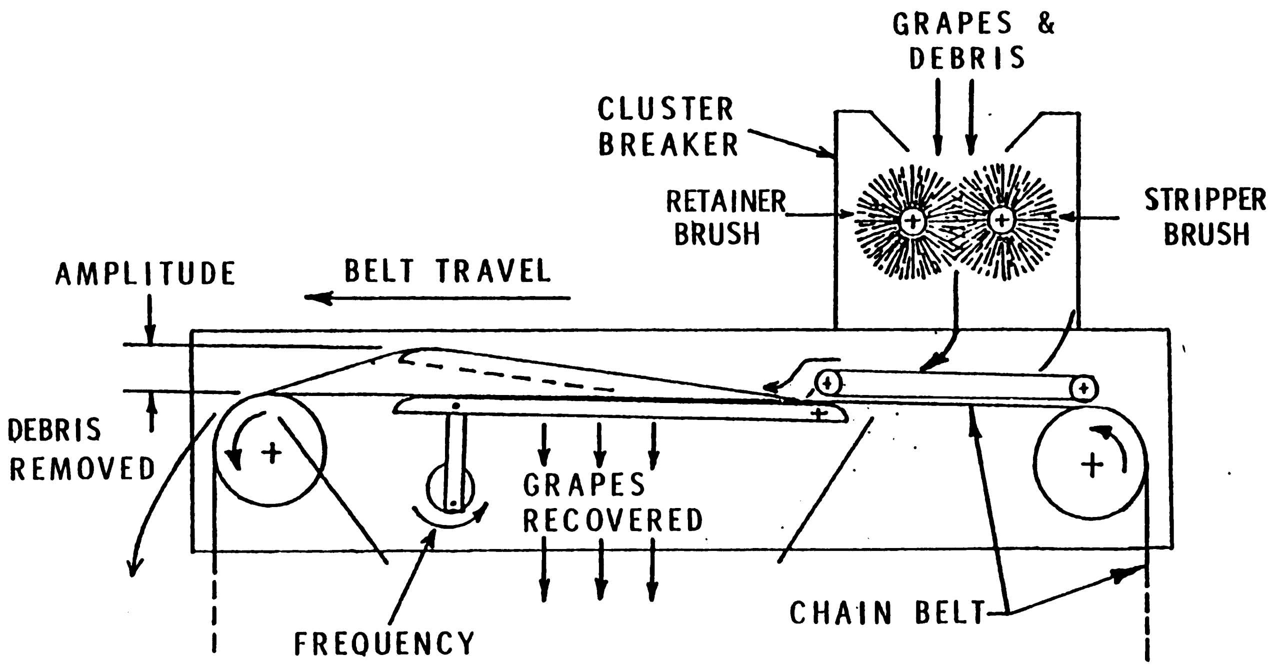

Figure 11. Cross-Section Diagram of Chain Belt Debris Removal System - 1976.

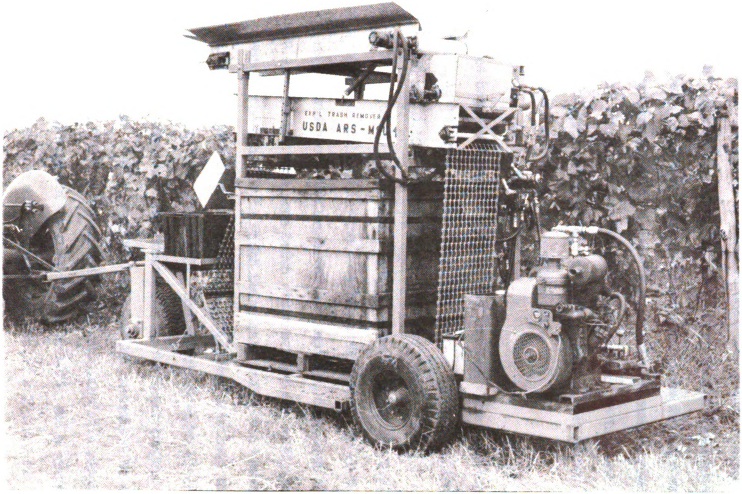

Figure 12. Chain Belt Vine Debris Removal System - 1976.

plastic brushes 203 mm (8 in) in diameter and 457 mm (18 in) long that intermeshed 12.7 to 50.8 mm (1/2 to 2 in) (Figure 11). The separation principle of the cluster breaker is based on the difference in speeds of the brushes: the retainer brush (slow brush) holds the grape clusters fed into the intermesh[1] while the stripper (fast brush) brush strips the grapes from the stems. The aggressiveness of the cluster breaker depends on the speed ratio of the brushes, the absolute speed of the brushes (measured by the slow brush speed), the amount of brush intermesh, and the bristle stiffness.

Three bristle textures were tested in 1975. The polypropylene bristles [76.2 mm (3 in) long] were oval in cross-section; 2.7 mm x 2.0 mm (0.105 x 0.080 in) for the stiffest, 1.8 x 1.3 mm (0.070 x 0.050 in) for the medium texture, and 0.9 x 0.6 mm (0.035 x 0.025 in) for the soft brush texture. The 45.7 cm (18 in) width of each brush was divided into two brush textures 22.9 cm (9 in) wide; one brush width being half stiff, half medium, the other brush width being half stiff, half soft. The effective width of any brush combination was only half the width, or only 22.9 cm (9 in). The effective width of the cluster breaker was also controlled by the input hopper. Testing of all brush combinations was obtained by reversing the ends of one brush. The brushes used in 1976 consisted of a polypropylene brush of the stiffest texture tested in 1975, and a nylon brush of similar texture with a cross-section of 2.3 x 1.9 mm (0.100 x 0.0075 in).

[1]Intermesh is the overlap of the bristles.

2) Chain belt feed conveyor - In 1975, a piece of sheet metal was installed between the discharge end of the cluster breaker and the upper surface of the chain belt. This was replaced in 1976 with a small conveyor belt (Figures 11 and 13). Its purpose was to decelerate and reorient the material discharged from the cluster breaker. Thus, vine debris which was discharged from the cluster breaker in a vertical orientation, was transferred to the chain belt in a horizontal position. In the horizontal position, the vine debris would span the chain belt openings and not fall through.

The chain belt feed conveyor was 45.7 cm wide, 38.1 cm long (18 x 15 in) and set to operate at a surface speed approximately 10 percent slower than the chain belt.

3) Chain belt - The vibrating chain belt (Figure 13) consisted of a wire link belt 45.7 cm (18 in) wide with an effective width of 38.1 cm (15 in) and an effective length of 132 cm (52 in). The belt had square openings 32 x 32 mm (1.25 x 1.25 in). The extreme outer edges of the belt were supported by stationary rails. A secondary rail framework 112 cm (44 in) long was mounted inside of the stationary rails and hinged at the input end of the chain belt. At the discharge end of the chain belt, the secondary rail framework was supported by the vibrating source consisting of two cam-follower bearings mounted 3.81 cm (1.5 in) off-center (Figure 11).

When the secondary rail framework was in its lower position, the outer stationary rails supported the chain belt. In its higher

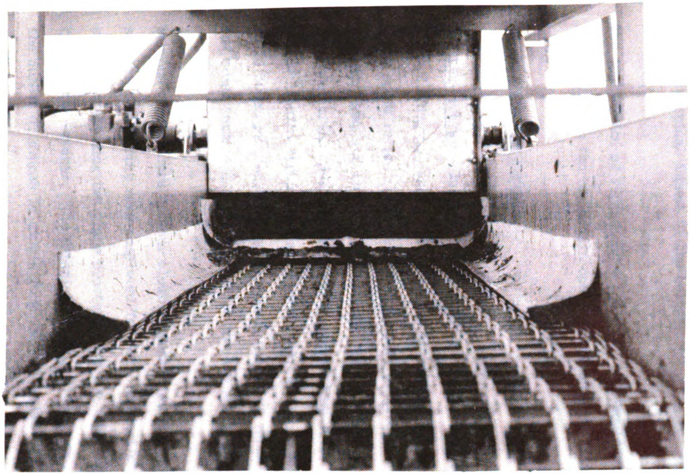

Figure 13. Chain Belt and Chain Belt Feed Conveyor - 1976

position, the secondary rail framework, supported by the cam-follower bearings, would apply a vertical impact to the chain belt. As the cam-follower bearings rotated, the secondary rail framework would drop below the stationary rails; supplying another vertical impact to the belt.

The application of vibration to the chain belt would shake the grapes through the chain belt openings and into the container below.

C. Stationary Testing Procedures.

1) Cluster breaker - In 1975, the cluster breaker was tested on Concord, Niagara, and Delaware grapes at various stripper/retainer brush speed ratios, retainer brush speeds, bristle stiffness combinations, and amounts of brush intermesh. The stripper/retainer brush speed ratios[2] tested ranged from 10:1, 15:1, 25:1 and 40:1, with retainer brush speeds of 4, 15 and 24 RPM (4.25 to 25.50 cm per sec, peripheral speed) using the three textures, and brush intermesh at 2.54 and 3.81 cm (1.0 and 1.5 in).

Various combinations of four cluster breaker variables were selected. Two runs were completed for each combination, consisting of feeding two grape clusters into the input hopper of the cluster breaker. The material discharged was examined for the number of grapes in single form and the number still attached to the rachis. The removal efficiency was calculated by dividing the number of single grapes discharged from the cluster breaker

[2]Stripper/retainer brush speed ratio = fast/slow brush speed ratio.

by the total number of grapes on the clusters placed in the input hopper.

The grapes were subjectively analyzed for damage on a scale of 0 to 5; ranging from no damage to individual grapes, to extreme disintegration, respectively. The data sheet for the cluster breaker test is shown in Appendix A.

2) Chain belt

a. Definition of variables - The chain belt was evaluated in stationary tests in 1975 and 1976 to determine the optimum combinations of five variables:

(1) Belt speed - the velocity of the chain belt (0.41 to 0.69 m/s, 1.35 to 2.26 ft per sec),

(2) Vibration frequency - the speed of rotation of the off-center cam-follower bearing shaft (2.0 to 5.4 Hz),

(3) Vibration amplitude - the maximum distance the cam-follower bearings lifted the chain belt above the level of the stationary rails (3 to 25 mm, 0.125 to 1 in),

(4) Belt angle - angle of incline from the input to output end of the chain belt surface (0, 4, 8 degrees from the horizontal), and

(5) Feed rate - the quantity of grape material fed into the debris removal system [(sample size simulating 4.5 and 9 metric tons/hour (5 and 10 tons per hr)].

Belt speed, vibration frequency, vibration amplitude, and belt angle were tested in 1975 at a constant feed rate equal to 4.5 metric tons per hour. In 1976, feed rates of 4.5 and 9.0 metric tons per hour were tested (sample sizes of 2.3 and 4.5 kg) in place of belt angle. Selection of the ranges of each variable was completed in preliminary tests.

b. Testing procedures - The purpose in testing all possible combinations of the chain belt variables was to determine the settings that would maximize the number of grapes that would fall through the belt. If the system were too aggressive, less than 100 percent of the petioles would ride over the end of the belt. If the system were not aggressive enough, single grapes would ride over the belt with the vine debris.

For each combination of four machine adjustments, a sample of mechanically harvested grapes containing 15 to 30 petioles was fed into the cluster breaker. Extra petioles were added to each sample to ensure an adequate number present. The primary concern was to evaluate the petiole removal efficiency of the debris removal system in the stationary tests. When each sample was evaluated, the material was examined for any grapes still attached to stems, thereby evaluating the cluster breaker in each chain belt test. Introduction of the feed rate variable in 1976 also tested the capacity of the cluster breaker.

Petiole removal efficiency was calculated in petioles removed (percent) by dividing the number of petioles which rode over the end of the belt by the total number of petioles fed into the system. The grape recovery efficiency was calculated as "grapes recovered" (percent) by dividing the weight of grapes that fell through the belt by the total fresh weight of the original sample.

Juice losses were too small to measure accurately because of the small test samples used in the stationary tests. Data forms for 1975 and 1976 stationary tests are shown in Appendix A.

D. Down-The-Row Testing Procedures.

Further evaluation of the debris removal efficiency was carried out under field conditions in down-the-row tests alongside the harvester in 1976.

The procedure consisted of replacing the conventional tractor drawn vineyard trailer and pallet boxes with the debris-removal-system trailer. Grapes were harvested, and processed with the debris removal system set for operation at predetermined settings, at feed rates of 1.8 to 9.1 metric tons/hour (2 to 10 tons/hour). During each down-the-row test, three 13.6 kg (30 lb) control samples were collected directly from the discharge conveyor of the harvester to determine the average debris content of the grapes before they were processed by the debris removal system. The data sheet for the down-the-row test is shown in Appendix A.

The total debris removed by the debris removal system was separated by hand into six categories: petioles, leaves, grape stems, coarse and fine miscellaneous debris and grapes (including juice). A seventh category, "total fiber", consisted of the portion of the total debris considered to have the potential for plugging processing plant equipment. This category was formulated by summing the weight of all the petioles, fine miscellaneous debris and 1/2 the weight of the leaves separated by the debris removal system. The last item, "1/2 of the leaves", was included as being the estimated weight of the leaves that consisted of petioles, because the petiole category did not include the petioles still attached to the leaves. Separation of the vine debris into six categories was a tedious process. Occasionally, time did not permit complete separation of the debris separated from 0.9 metric tons (1 ton) of grapes processed by the debris removal system. Better procedures for analysis of debris is needed in future testing.

Depth of the free juice in each pallet box processed by the debris removal system was measured, as well as the juice depth of several adjacent pallet boxes in the load that were not processed by the debris removal system.

Product loss in the down-the-row tests included all grape products (grapes, grape skins, and juice). Down-the-row samples were large enough to provide a measurable loss of juice in the debris.

Since the debris removal system removed much of the grape stems, this category was measured to determine how much less product weight the grower would obtain when using the debris removal system. All of the grape stems were included in the grower weights of the hand harvested product. The processing industry has shown no concern about the presence of grape stems in the raw material received at the plant.

VII. DISCUSSION OF RESULTS

It is the purpose of this chapter to describe the results obtained from evaluating the cluster breaker and chain belt in stationary and down-the-row tests. A discussion of the general characteristics and trends of the cluster breaker and chain belt is also included.

A. Cluster Breaker.

The cluster breaker performed very well during initial tests. Graphic representations for some of the results are shown in Figures 14, 15, 16 and 17. All the test results are not shown for the sake of brevity. Results shown are at a brush intermesh of 3.81 cm (1.5 in) which was found to be better than the 2.54 cm (1.0 in) intermesh. The results of the cluster breaker tests on Concords is of primary concern in Michigan because this variety makes up the majority of the acreage. Nevertheless, results from testing several other varieties will be discussed.

1) Test results with Concord - 1975 - Figure 14 shows selected results for 1975 tests with Concords. As shown in the figure, the high retainer brush speed demonstrates the optimum results. At a slow brush speed of 15 to 24 RPM and a stripper/retainer brush speed ratio of 10 to 25:1 (stripper brush speed of 225 to 375 RPM), 100 percent of the Concord grapes were removed from the clusters.

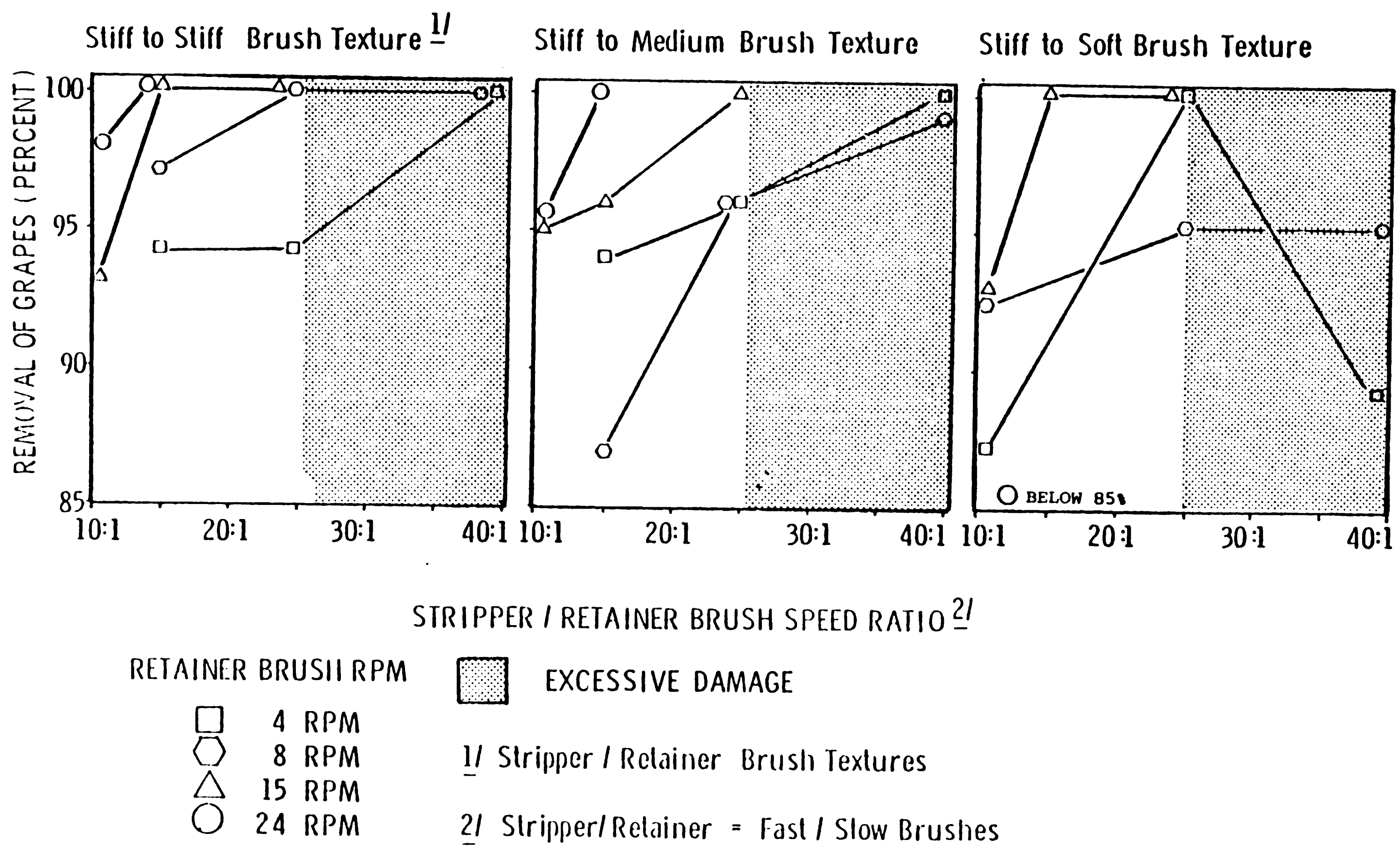

Figure 14. Cluster Breaker Efficiency with Respect to Brush Texture, Fast/Slow Brush Speed Ratio, and Slow Brush Speed - Concord - 1975.

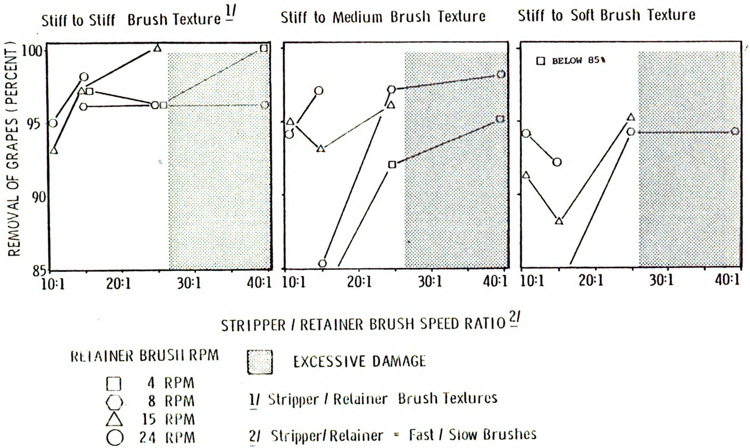

Figure 15. Cluster Breaker Efficiency with Respect to Brush Texture, Fast/Slow Brush Speed Ratio, and Slow Brush Speed - Niagara - 1975.

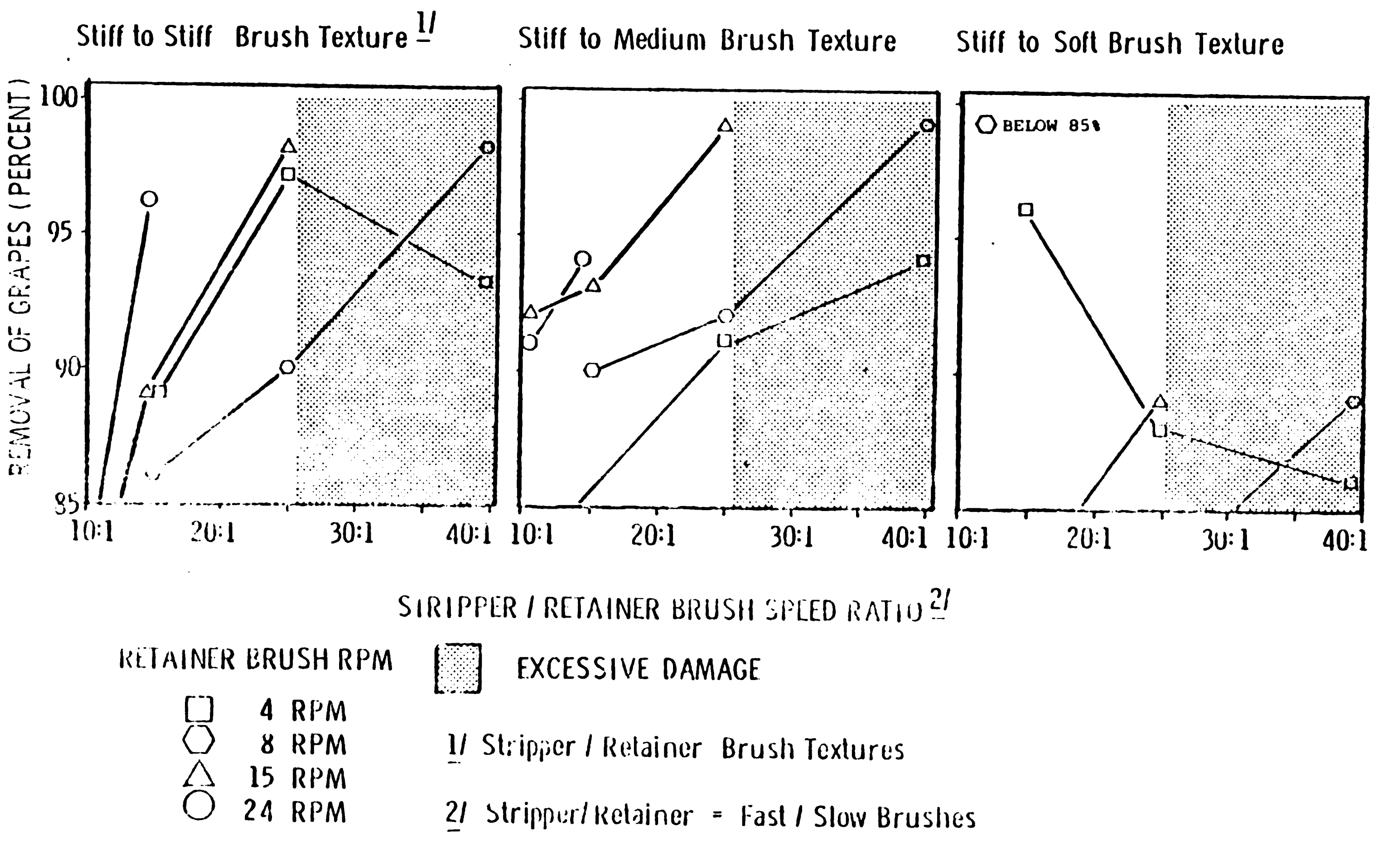

Figure 16. Cluster Breaker Efficiency with Respect to Brush Texture, Fast/Slow Brush Speed Ratio, and Slow Brush Speed - Delaware - 1975.

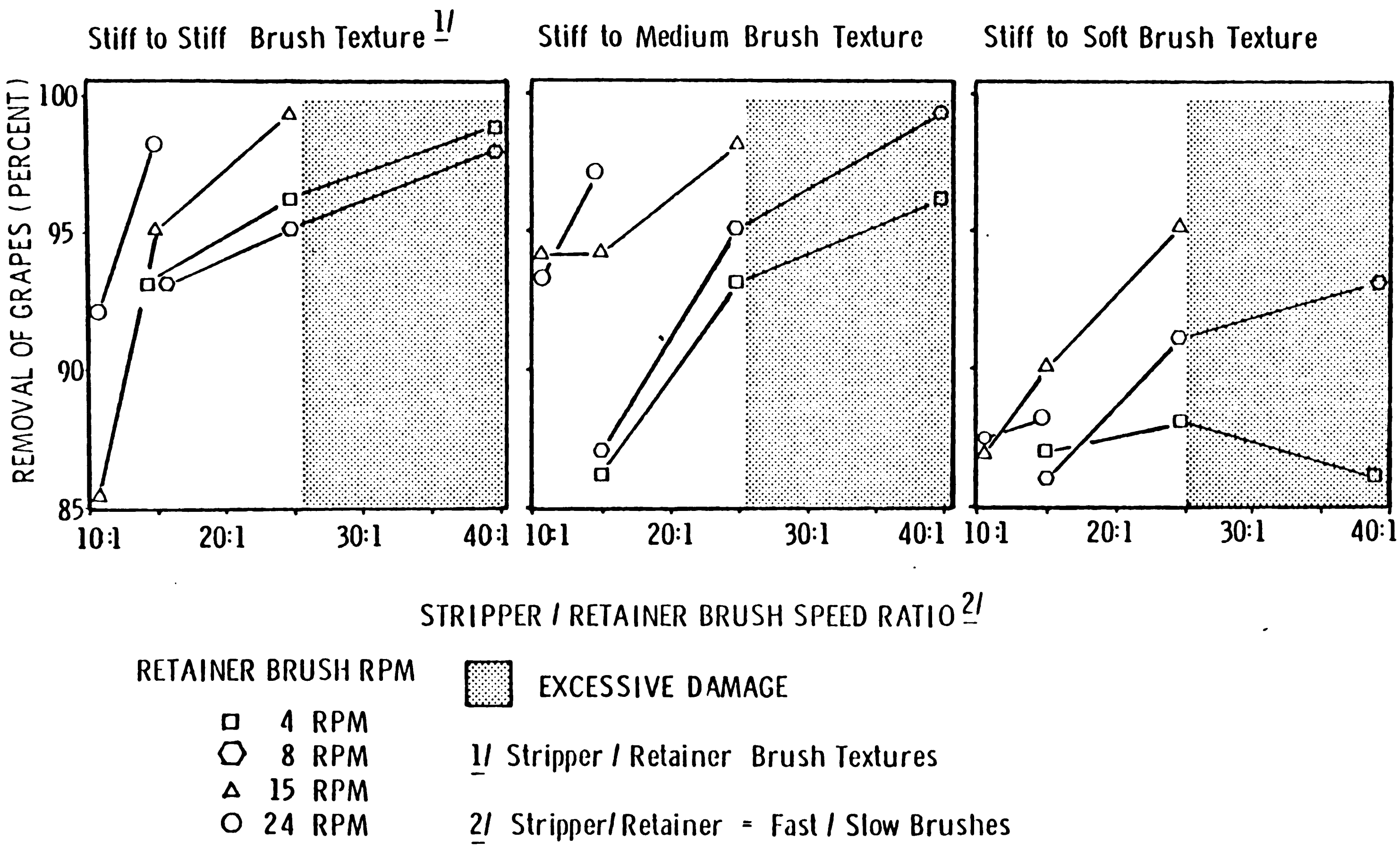

Figure 17. Cluster Breaker Efficiency with Respect to Brush Texture, Fast/Slow Brush Speed Ratio, and Slow Brush Speed - Mean of Concord, Niagara, and Delaware - 1975.

These results were obtained from brush textures of stiff-to-stiff and stiff-to-soft. The stiff-to-medium texture combination ranged 95 to 100 percent removal of grapes at the above settings.

The stiff-to-stiff brush texture combination demonstrates the best potential for removing all the grapes from any clusters. The range of settings for 100 percent removal is fairly wide; ranging from a retainer brush speed of 8 RPM, stripper/retainer brush speed ratio of 25 to 40:1, to 15 RPM, 15 to 25:1, respectively. It is important to note that exceeding a retainer/stripper brush speed ratio of 25:1, and/or a retainer brush speed of 15 RPM was found to cause excessive damage and juicing. According to the subjective damage analysis, this was determined by consulting with industry representative during the tests. The optimum setting for Concords was a retainer brush speed of 15 RPM, and a stripper/retainer brush speed ratio of 25:1.

2) Test results with Niagara and Delaware varieties - 1975 - Figures 15, 16 and 17 show 1975 test results for Niagara, Delaware, and mean results for all three varieties, respectively. The Niagara grapes are the same size as Concord, but the Niagara clusters are more compact. The Delaware cluster consists of smaller grapes and the clusters are very compact. The cluster breaker responded noticeably to cluster compactness and berry size as shown in consecutively less satisfactory results for Niagara and Delaware. This response is related to the spacing of the bristles on the brushes and bristle stiffness.

The Niagara cluster responded in much the same way as the Concord cluster because of similar berry size. It can be seen in Figure 15 that optimum cluster breaker settings and bristle texture for Niagara are similar to those for Concord.

On the other hand, tests with the Delaware grapes (Figure 16) showed a maximum removal of grapes of less than 100 percent at a retainer brush speed (15 RPM) and stripper/retainer brush speed ratio (25:1) settings similar to Concord and Niagara grapes. Grape removal of 98 percent was also obtained at a stripper/retainer brush speed ratio of 40:1, but, as with Concord and Niagara, juicing was excessive. Unlike the Concord and Niagara, these settings were applied using the stiff-to-medium brush texture combination. The bristles on the medium bristle texture brush are spaced closer than the stiff bristle texture brush. It appears the medium bristle texture brush (with bristles spaced closer together) trapped the smaller Delaware grapes more efficiently than the wider spaced bristles of the stiff brush, pulling them from the clusters.

The overall mean results for all three varieties (Figure 17) demonstrates the general characteristics of the cluster breaker. A brush speed of 15 RPM consistently showed the best results in removal of grapes from clusters without causing excessive damage as was found with the slow brush speed of 24 RPM. Through-put was controlled by the retainer brush speed because the retainer brush tended to hold the grape clusters while the stripper brush pulled the single grapes from the clusters. Overall, as retainer brush speed, stripper/retainer brush speed ratio, bristle stiffness, and/or brush intermesh were increased, single grape removal efficiency improved and is under further investigation.

3) Test results - 1976 - The cluster breaker was further tested in July, 1976 using California 'Thompson Seedless' grapes (Table 3). These tests demonstrated the effect of shorter bristles and closer brush intermesh on grape removal efficiency. At a retainer brush speed of 16 RPM and a stripper/retainer brush speed ratio of 27:1, the Thompson Seedless responded in much the same way as the Michigan varieties tested. However, shorter bristle length and/or intermesh greater than 3.81 cm (1.5 in) demonstrated no improvement over the previously discussed settings; only increasing damage.

The cluster breaker was operated at optimum settings throughout the 1976 Concord tests. No partial or whole clusters were found with the vine debris indicating that the cluster breaker was breaking up 100 percent of the clusters it encountered. It was noted that the cluster breaker did not break up the undesirable "second crop" grape clusters which are immature at harvest time and very high in acid. An appreciable quantity of "second crop" in the mechanically harvested product can effect quality. Since these clusters passed unharmed through the cluster breaker, they were sorted as vine debris.

Table 3. Cluster breaker efficiency with respect to brush diameter, and brush intermesh - Thompson Seedless - 1976.

Grape Cluster Breaker Efficiency Results Testing Different Brush Diameters[1]

TEST	RETAINER BRUSH DIAMETER	STRIPPER BRUSH DIAMETER	MESH	CENTER TO CENTER	AVERAGE BY NUMBER			EFFICIENCY REMOVAL
	cm	cm	cm	cm	LEFT ON CLUSTER	SINGLE	SINGLE WITH STEM	%
1	20.3	20.3	3.8	16.5	0	47	2.6	100
2	20.3	20.3	6.4	14.0	2	34	3	95
3	16.5	20.3	3.8	14.6	9.6	20.2	0.2	68
4	16.5	20.3	6.4	13.3	4.4	45.4	1	91
5	16.5	16.5	3.8	12.7	0.2	48	0	100
6	16.5	16.5	5.1	11.4	2.2	30	1.4	93
7	12.7	16.5	3.8[2]	10.2	1.6	46	0.2	97

[1]Grapes tested were California Thompson Seedless, July 28, 1976.

[2]3.8 cm (1.5 in) = maximum intermesh possible. 5 replications per test, retainer brush speed = 16 RPM, stripper brush speed = 435 RPM (ratio = 27).

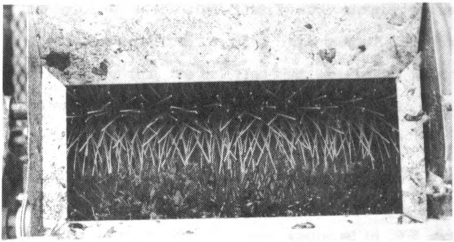

Figure 18. The Polypropylene and Nylon Cluster Breaker Brushes - 1976.

4) Bristle durability - It was found in the 1975 tests that the polypropylene bristles would not withstand extended use without splitting. The polypropylene bristle is fibrous and when the end splits, it would soon separate down to the base of the bristle, reducing the effectiveness of the cluster breaker. Two alternatives were pursued in 1976; heat sealing the ends of the polypropylene bristles and testing a nylon bristle brush (Figure 18).

Heat sealing the polypropylene bristles did not reduce splitting. The nylon brush was significantly more durable, but some splitting still occurred. Upon detailed inspection of the nylon bristles, it was found that the bristles that were split, were hollow. This problem has been discussed with the bristle manufacturer.

B. Chain Belt Stationary Test Results.

Extensive chain belt evaluation was completed in 1975 and 1976. After gaining experience with the chain belt, statistical analysis verified the trends observed during testing.

The influence of five system variables (vibration frequency, vibration amplitude, belt speed, belt angle and feed rate) on grape recovery and petiole removal was studied using a factorial analysis of variance computer program from the Statistical Package for the Social Sciences (Nie et al., 1975). The influence of these five system variables is shown in Table 4 for 1975, 1976, and both years combined.

The four-way factorial analysis of variance indicated that petiole removal was influenced by vibration frequency and vibration amplitude for

Table 4. Factorial analysis of variance of five system variables on experimental vine debris removal system, 1975 and 1976.

YEAR	SYSTEM VARIABLES	SIGNIFICANCE* Petiole Removal	Grape Recovery
1975	Vibration frequency	S[1]	S
	Vibration amplitude	S	S
	Belt speed	NS[2]	S
	Belt angle[3]	NS	S
1976	Vibration frequency	S	S
	Vibration amplitude	NS	S
	Belt speed	NS	NS
	Feed rate[4]	NS	S
1975 & 1976	Vibration frequency	S	S
	Vibration amplitude	S	S
	Belt speed	NS	NS

[1]S = Significant (F-Statistic ≤ 0.05).

[2]NS = Not Significant (F-Statistic > 0.05).

[3]Belt Angle tested in 1975 only.

[4]Feed rate tested in 1976 only.

the 1975 data and for both years combined (Table 4). In 1976, petiole removal was affected by vibration frequency, but there was insufficient evidence to show any influence from vibration amplitude, belt speed, or feed rate. However, more limited ranges of vibration frequency and vibration amplitude were tested in 1976. The analysis of variance for 1975 data indicated that grape recovery was influenced by vibration frequency, vibration amplitude, belt speed and belt angle. The 1976 analysis of variance showed that grape recovery was influenced by vibration frequency, vibration amplitude and feed rate. The three-way factorial analysis of variance for the two years combined indicated that grape recovery was influenced by vibration frequency and vibration amplitude. These system variables appeared to contribute to the aggressiveness of the chain belt. Feed rate was important in that the more grapes fed onto the belt, the more would tend to stick to the belt.

The 1975 and 1976 data indicated a trade-off between optimum petiole removal and optimum grape recovery. As shown in Figures 19 and 20 for 1975, and 21 and 22 for 1976, an inverse relationship exists between petiole removal and grape recovery. This relationship is particularly evident in the 1976 data (Figures 21 and 22). As vibration amplitude and/or vibration frequency increased, the percentage of grapes recovered generally increased and the percentage of petioles removed generally decrease.

Determination of maximum grape recovery and maximum petiole removal is difficult. Figure 23 and Table 5 combine into one graph and table the data for petiole removal and grape recovery for 1975, and Figure 24 and Table 6 for 1976. Coordinates closest to the origin of each graph represent the most satisfactory results. Each letter indicates a data point, unless a point is present adjacent to a letter. Coordinate G (Figure 24, Table 6) (25 mm vibration amplitude, 2.0 Hz vibration frequency) represents an

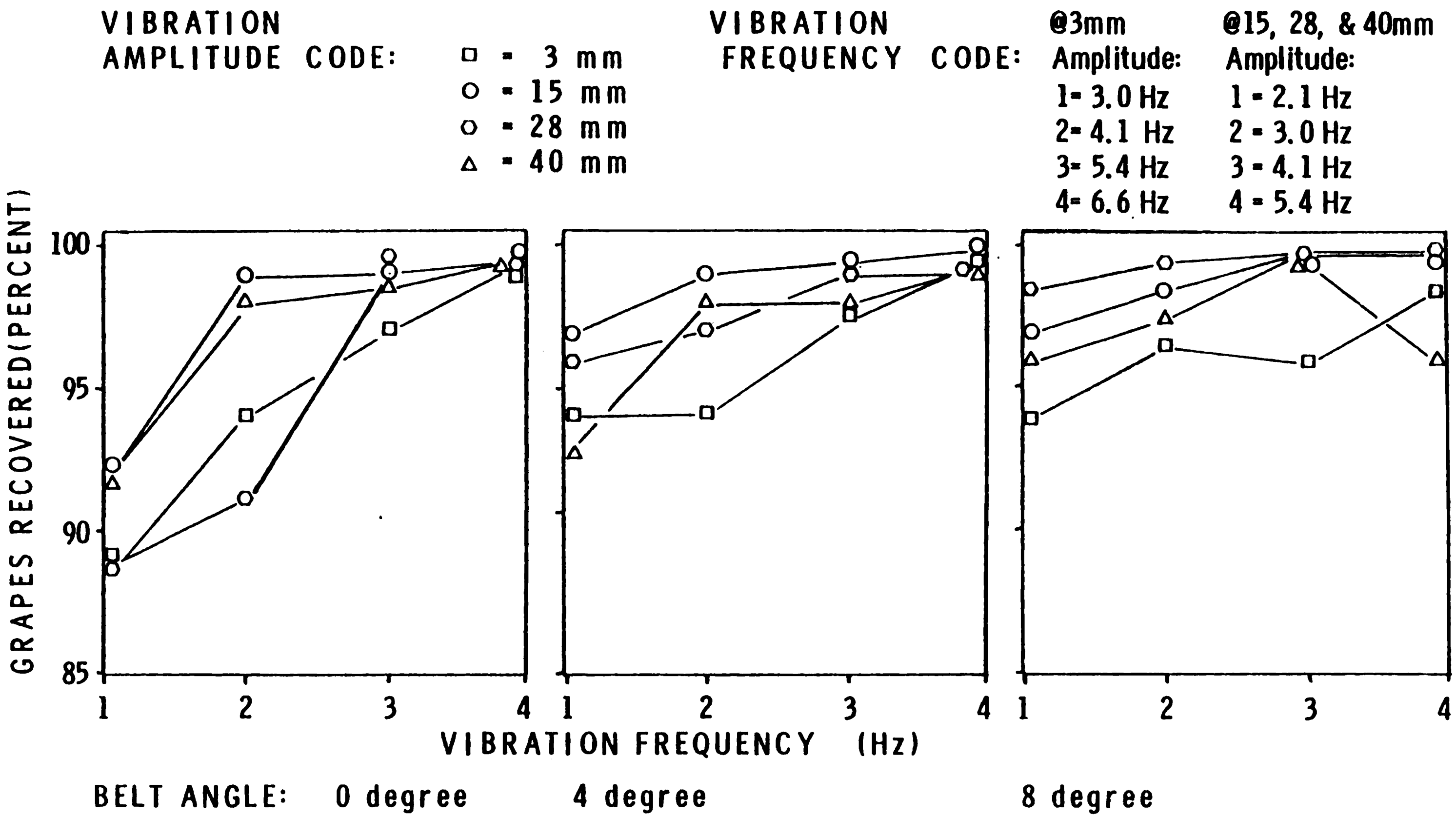

Figure 19. Effect of Amplitude, Frequency, and Belt Angle on Grape Recovery - 1975.

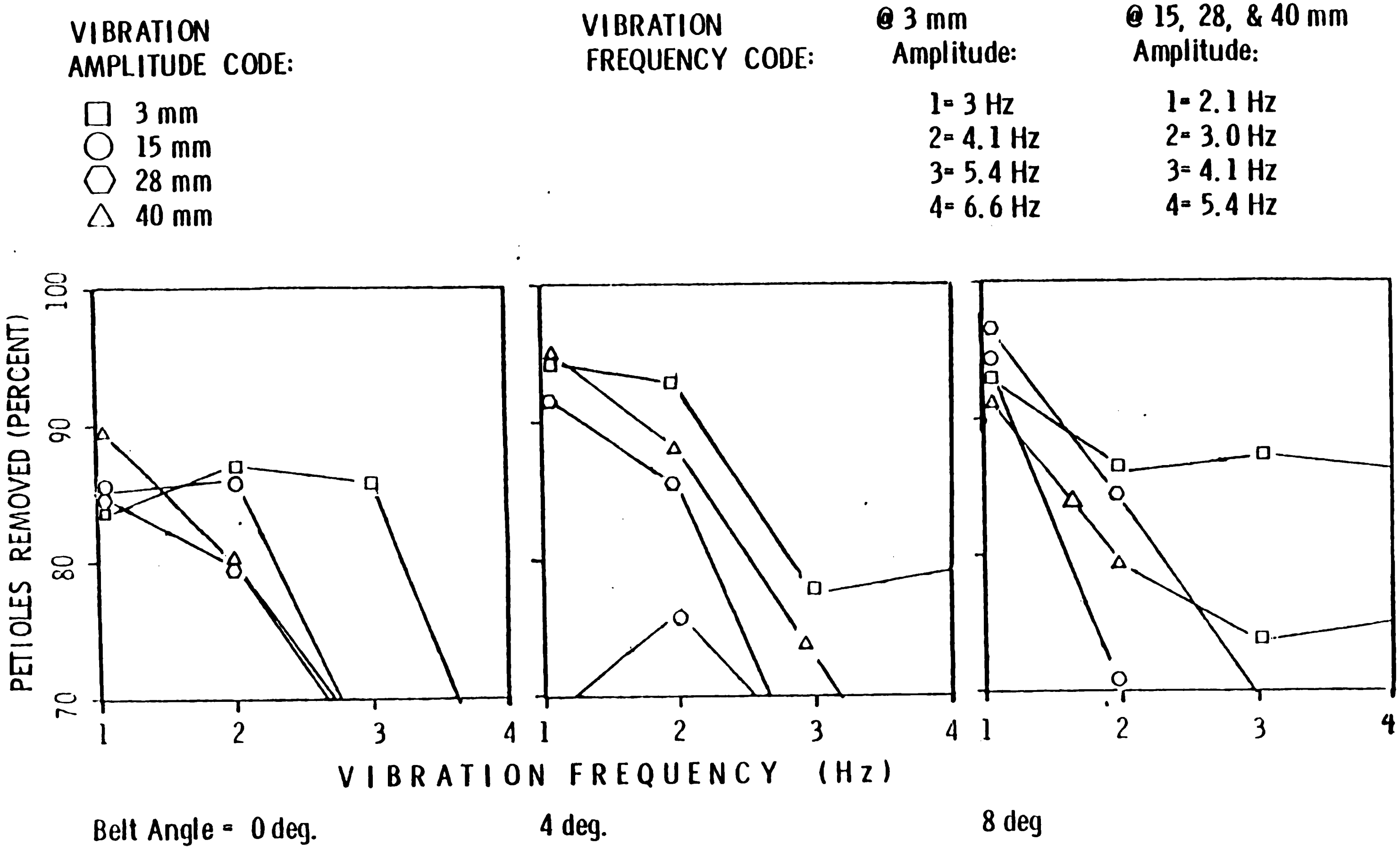

Figure 20. Effect of Amplitude, Frequency, and Belt Angle on Petiole Removal - 1975.

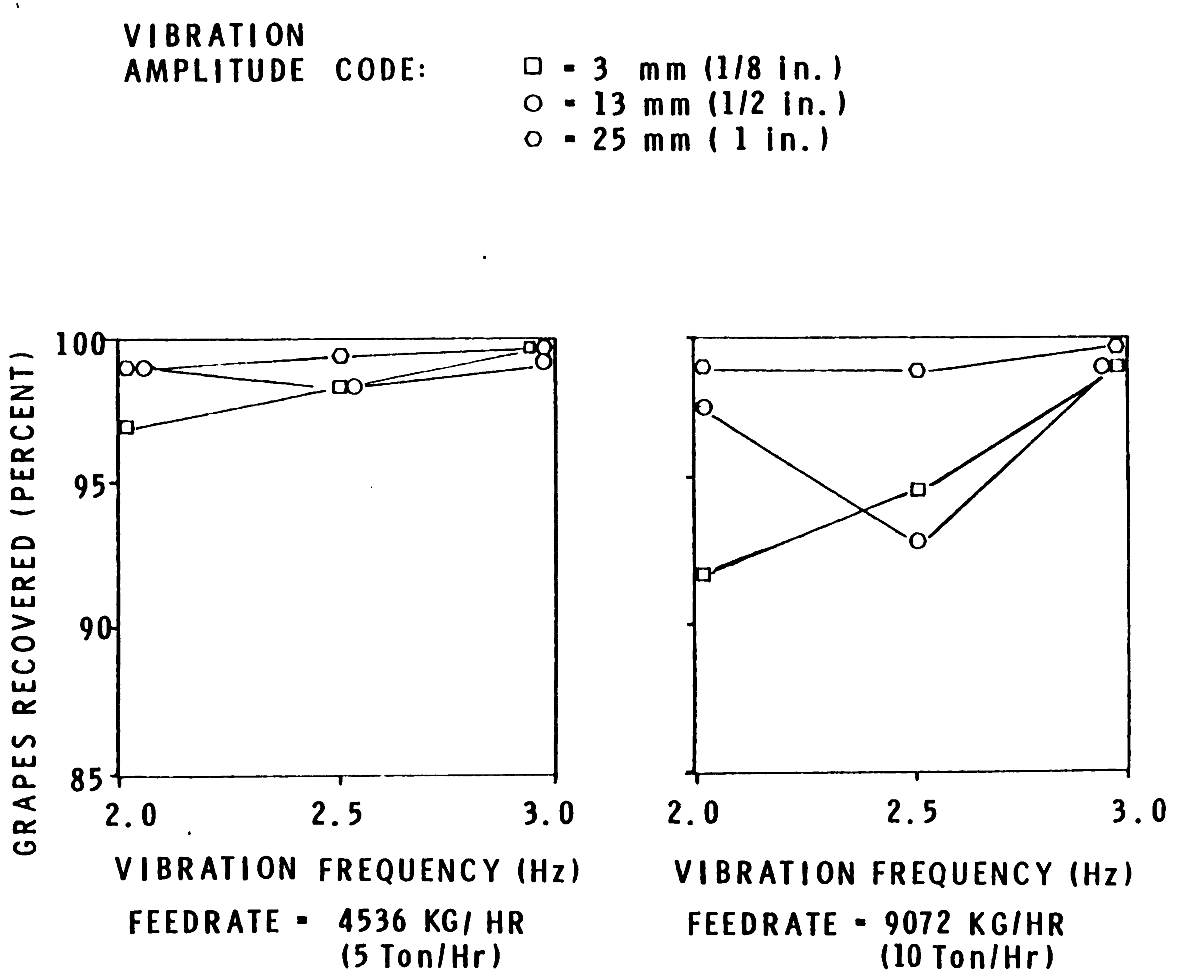

Figure 21. Effect of Amplitude, Frequency, and Feed Rate on Grape Recovery - 1976.

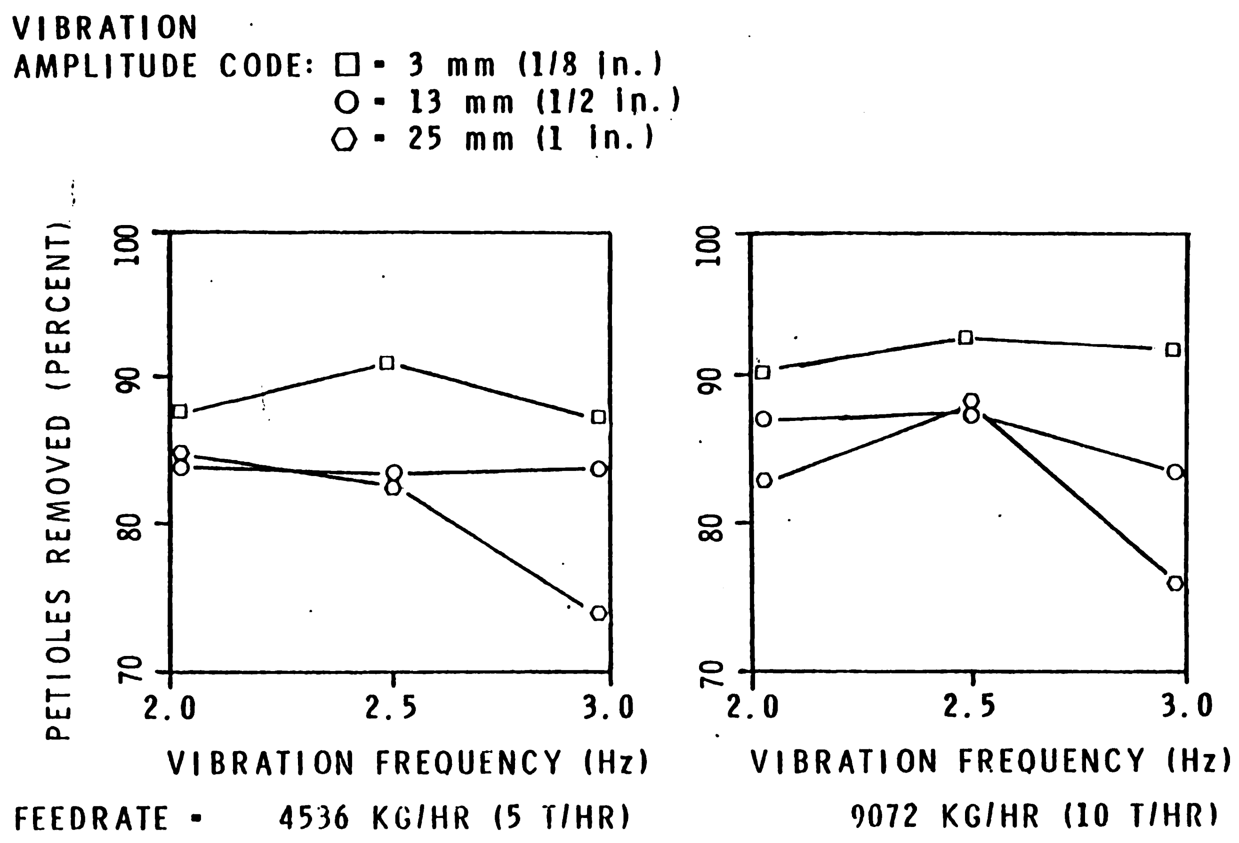

Figure 22. Effect of Amplitude, Frequency, and Feed Rate on Petiole Removal - 1976.

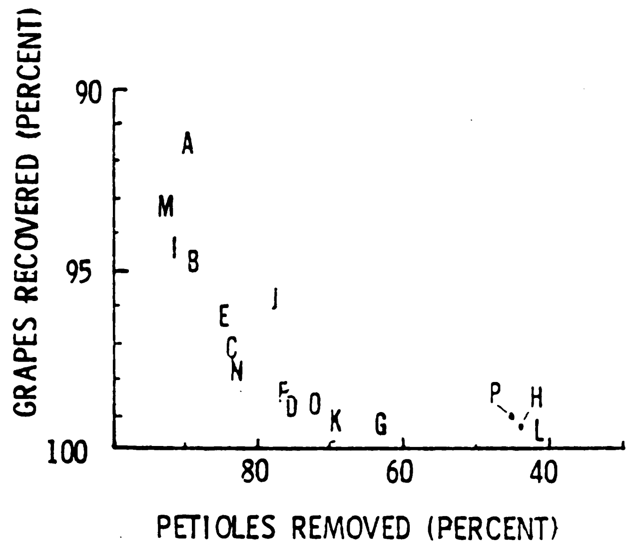

Figure 23. Effect of Vibration Amplitude and Vibration Frequency on Grapes Recovered and Petioles Removed - 1975.

Table 5. Effect of vibration amplitude and vibration frequency on grapes recovered and petioles removed - 1975

POINT	VIBRATION AMPLITUDE (mm)	VIBRATION FREQUENCY (Hz)	GRAPES RECOVERED (Percent)	PETIOLES REMOVED (Percent)
A	3	3.0	93.6	89.4
B	3	4.1	94.9	88.6
C	3	5.4	97.1	83.3
D	3	6.7	98.8	75.7
E	16	2.1	96.4	84.5
F	16	3.0	98.4	76.4
G	16	4.1	99.4	63.6
H	16	5.4	99.4	43.2
I	29	2.1	94.5	91.4
J	29	3.0	95.6	87.6
K	29	4.1	99.3	69.8
L	29	5.4	99.5	41.5
M	41	2.1	93.4	92.4
N	41	3.0	97.9	82.3
O	41	4.1	98.8	72.3
P	41	5.4	99.2	44.9

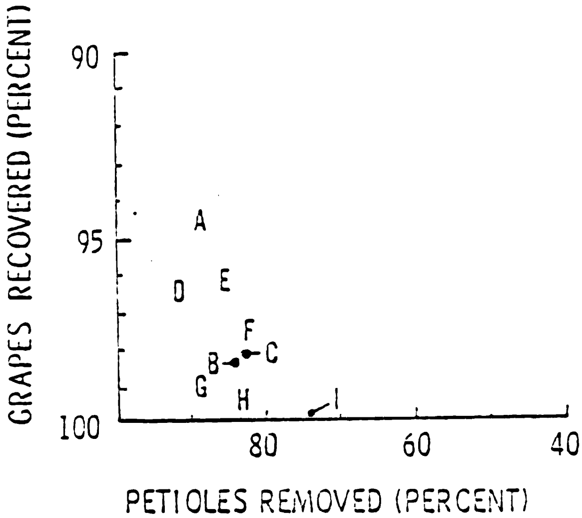

Figure 24. Effect of Vibration Amplitude and Vibration Frequency on Grapes Recovered and Petioles Removed - 1976.

Table 6. Effect of vibration amplitude and vibration frequency on grapes recovered and petioles removed - 1976.

POINT	VIBRATION AMPLITUDE (mm)	VIBRATION FREQUENCY (Hz)	GRAPES RECOVERED (Percent)	PETIOLES REMOVED (Percent)
A	3	2.0	94.6	89.0
B	3	2.5	98.4	85.0
C	3	3.0	98.2	83.7
D	13	2.0	96.5	92.0
E	13	2.5	96.1	85.7
F	13	3.0	97.6	83.4
G	25	2.0	99.1	89.7
H	25	2.5	99.4	83.6
I	25	3.0	99.8	74.6

optimum setting for petioles removed (89.7 percent) and grapes recovered (99.01 percent) in 1976. During a year that a frost has occurred, the primary concern may be that more than 90 percent of the petioles be removed, point D, improving petiole removal (93.9 percent), but reducing grape recovery (96.6 percent).

The trade-off between petiole removal and grape recovery is shown in Figures 20 and 21, and Tables 5 and 6. Data for 1975 clearly demonstrates the trade-off because of the wide ranges of vibration frequency and vibration amplitude tested. Though the basic theory of operation of the 1975 and 1976 debris removal systems is the same, there are several factors that can affect the response of the system and for this reason, comparison of the 1975 and 1976 results is not advisable. The physical properties of the grape and vine debris may vary enough to prevent accurate comparison of specific responses from year to year.

The most apparent machine factor that could effect the response of the debris removal system from 1975 to 1976 is the width of the cluster breaker. The brushes on the 1976 model were two times wider than the 1975 model. Dispersion of the grape material out of the cluster breaker onto the chain belt was less than the full width of the belt [38.1 cm (15 in)]. Therefore, the load per unit width on the 1975 chain belt could have been as much as 1-1/2 times higher than the 1976 model employing a 45.72 cm (18 in) wide cluster breaker. This would result in a potentially higher grape loss requiring a more aggressive vibration which results in reduced petiole removal due to the trade-off mentioned above.

The grape industry has indicated that it would be desirable to maintain greater than 99 percent grape recovery, even if petiole removal is less than 100 percent. The stationary tests have shown that the 1976 debris removal system shows potential for approaching these requirements, possibly achieving close to 100 percent petiole removal.

C. Chain Belt Down-The-Row Test Results.

The preliminary trials down-the-row permitted "real world" testing that could not be accomplished in the stationary tests. Table 7 presents the data obtained.

The factors affecting the down-the-row tests were not concluded; many more factors were present in down-the-row testing (e.g. variation of vineyards and time of season). Therefore, the results discussed are not statistically representative of results obtained from more extensive testing. Some trends do exist, however.

The average control sample contained 0.142 percent petioles (by weight). The debris removal system removed an average of 51.6 percent of the petioles. In vineyard 5 (runs 7 and 8), a frost prior to harvest froze the upper 15 to 20 percent of the foliage. The petiole content was 0.31 percent, triple the average petiole content of 0.108 percent for the other ten runs shown. Over 75 percent of the petioles were removed in this partially frosted vineyard.

The average control sample contained 0.072 percent leaves (by weight). The debris removal system removed an average of 60.7 percent of the leaves. During some of the trial runs, the harvester operator turned the debris fans off and the leaves removed by the debris removal system more than tripled. The debris output of the removal system was not analyzed during these runs.

Rachae (grape stems) made up 1.039 percent of the mechanically harvested product. The debris removal system removed about 25 percent

Table 7. Results of down-the-row testing of experimental debris removal equipment in Michigan and Pennsylvania, 1976.

Run No.	Date	Yield est. metric t/ha	Vineyard No.	Vib. freq. (Hz)	Vib. amplitude (mm)	Debris In Control Sample (%) Petioles	Leaves	Stems	Miscellaneous Fine	Miscellaneous Coarse	Total fiber 2/	Efficiency of Debris Removal Equipment (%) Petioles	Leaves	Stems	Fine misc.	Total fiber	Grape & juice loss (%)	Juice depth increase (%)
1	9/24	1.10	1	4.2	3	.173	.105	NR 1/	.040	0	.266	48.6	67.6	NR	35.0 3/	50.3	.62	38.6
2	9/25	0.55	2	3.5	3	.093	.032	NR	.032	0	.141	-------	-------	NR	------	------	------	53.3
3	9/28	0.37	3	2.1	3	.076	.041	.810	0	.343	.131	29.0	22.4	32.1	4/	37.9	.27	NR
4	9/28	0.37	3	2.1	25	.076	.041	.810	NR	NR	.097	------	NR	------	5/	100	.26	NR
5	9/29	1.84	4	3.3	25	.111	.066	1.152	.022	0	.166	36.9	63.6	24.1	50.0	44.0	.24	44.0
6	9/29	1.84	4	2.9	25	.144	.050	.925	.027	0	.174	35.4	88.0	22.6	18.5	45.0	.13	29.9
7	9/29	0.73	5	2.5	25	.313	.048	1.166	.037	0	.374	79.2	54.2	32.3	6/	79.7	.24	57.6
8	9/30	0.73	5	1.5	25	.314	.052	1.259	.150	0	.490	74.2	55.8	22.7	6/	56.2	.24	NR
9	9/30	0.92	6	NR	25	.042	.041	.570	.015	.057	.078	-------	NR	------	7/	-----	NR	--------
10	10/5	1.84	7	3.8	13	.171	.166	1.364	.043	0	.297	25.2	33.7	18.7	NR	34.3	.39	19.2
11	10/5	1.84	7	3.8	25	.104	.147	1.297	.026	0	.204	-------	-------	NR	------	------	-------	57.6
12	10/13	1.46	8	3.3	25	.088	.074	NR	.009	0	.134	84.1	100	NR	NR	51.9	.44	NR
MEAN						.142	.072	1.039	.040	.033	.213	51.6	60.7	25.4	34.5	56.6	.31	42.9

1/ NR = NO RECORD

2/ TOTAL FIBER = PETIOLES + 1/2 LEAVES + FINE MISCELLANEOUS

3/ Debris removal system also removed: 14 pieces of wood (226 gm total) from approximately 1 metric ton of grapes.

4/ Debris removal system also removed: 2 pieces of concrete posts approximately 5 cm cube; 27 pieces of large wood (437 gm total) and 2 green immature clusters, from approximately 1 metric ton of grapes.

5/ Foliage was partially frozen, nearly tripling the petiole content. Debris removal system also removed: 15 pieces of wood (530 gm total); and 8 green immature clusters (115 gm total) from approximately 1 metric ton of grapes.

6/ Debris removal system also removed: 33 pieces of wood (1433 gm total) from approximately 1 metric ton of grapes.

of the rachae. Since rachae are not considered vine debris, this category was measured to determine how much the debris removal system would reduce the weight of the mechanically harvested product by removing 25 percent of the rachae. The result of this calculation is approximately 2.27 kg per metric ton (5 lb per ton).

The average control sample contained 0.040 percent fine miscellaneous debris (cane tips, shoots, and tendrils that were 5 mm, or smaller in diameter). The coarse miscellaneous debris from each pallet box (e.g. trunk or cordon wood and concrete post parts) was recorded and is footnoted in Table 7. Although the removal of coarse miscellaneous debris is extremely desirable, it is not included because of its variability. In some processing plants, coarse debris would be rejected by the destemmer. In others, in which pumps transport the product to the destemmer, this type of debris would present plugging problems.

Grape (and juice) loss was 0.31 percent compared to 1 percent in the stationary tests. The down-the-row settings were selected to maximize grape recovery for the grower. Therefore, the petiole removal was lower than desired. This illustrates the trade-off between grapes recovered and petioles removed.

The total fiber content of the control samples average 0.213 percent compared to 0.142 percent for petiole content. By considering total fiber content, the debris which is a potential problem for processing equipment is 1-1/2 times that of petiole content alone.

The average juice depth in a 0.9 metric ton control pallet box of grapes was 530 mm (20.9 in), whereas the average juice depth in a 0.9 metric ton pallet box of grapes handled by the debris removal system was 757.37 mm (29.8 in). The extra handling through the debris removal system increased the juice depth 42.9 percent.

Hand-sorting and evaluation of the material sorted by the debris removal system took 3 to 4 man-hours. Some of the rows in Table 7 show no record, which indicates that we did not have time to sort the sample.

The trade-off between petiole removal and grape recovery observed in the stationary and down-the-row tests is due to too aggressive operation of the vibratory unit. In general, a setting above a vibration frequency of 2 Hz, and vibration amplitude of 25 mm, the petioles were observed to rise off of the chain belt and slip end wise through the belt openings. This characteristic was most apparent directly over the vibratory unit where vibration was the most aggressive.

It was observed that well over 80 percent of the petioles fell through the belt in the second 76 cm (26 in) of belt length. On the other hand, close to 90 percent of the grapes fell through the belt openings within the first 76 cm of belt length.

In further development of the debris removal system, the margin between optimum petiole removal and optimum grape recovery must be increased. Vibration characteristics must still be aggressive enough to ensure maximum grape recovery, but the petioles must not be allowed to leave the belt surface.

VIII. CONCLUSIONS

The specific conclusions of the project were:

1) A mechanical self-cleaning method of separating vine debris from mechanically harvested grapes was successfully tested.
2) A cluster breaker was developed that maximized the separation of grapes from their clusters.
3) A trade-off was found between grape recovery and vine debris removal.
4) The cluster breaker removed 100 percent of the grapes from their clusters, the chain belt removed 90 percent of the petioles with more than 99 percent recovery of grapes, at feed rates up to 9.1 metric tons per hour (10 tons per hour).

IX. SUMMARY

Two years of testing demonstrated the efficiency of a concept utilizing a cluster breaker and vibrating chain belt for the removal of vine debris from mechanically harvested grapes. During stationary tests at feed rates of 4.5 and 9.1 metric tons per hour (5 and 10 tons per hour), the debris removal system removed approximately 90 percent of the petioles in the mechanically harvested product with grape losses of less than 1 percent. These results were achieved using a 25 mm (1 in) vibration amplitude and 2 Hz vibration frequency.

Down-the-row trials were not sufficiently extensive to conclude definite results. However, the limited down-the-row tests at feed rates of 1.8 to 9.1 metric tons per hour (2 to 10 tons/hr), the debris removal system operated satisfactorily. Down-the-row tests averaged 0.142 percent petiole content with 51.6 percent removal efficiency. Leaf content averaged 0.072 percent with 60.7 percent removal efficiency.

The observed efficiency of the debris removal system and field capacity warrant incorporation of the debris removal system into a commercial harvest system.

X. UNFINISHED WORK AND RECOMMENDATIONS

The down-the-row trials should be completed in more detail. A larger sample size will minimize irregularities in results and the data will become more reliable. The down-the-row tests will supply very useful results when completed to the degree the stationary tests were carried out in 1975 and 1976.

Tests conducted during February, 1977 integrating a barrier over the chain belt surface indicated that this concept should be tested further during the 1977 season. A plywood barrier was mounted at 2.54 cm (1 in) and 1.77 cm (0.5 in) heights above the chain belt to keep the petioles in a horizontal position when they leave the belt because of the higher levels of amplitude and/or vibration frequency. For the same reason, a plastic fabric was also draped over the belt. At various levels of vibration frequency ranging from 2 to 3 Hz, 20 petioles were fed onto the chain belt and percent petioles removed was calculated. Control tests using the unit without the barriers were run in order to compare the petiole removal efficiency to previous tests.

As the petioles rode along the chain belt and were subject to vibration, they would leave the belt, come in contact with the barrier and fall, maintaining their horizontal position. The results indicated that the closer the barrier is to the belt the more efficient the petiole removal, especially at higher vibration frequencies. The fabric drape yielded the best results, improving petiole removal by 20 percentage points at the highest vibration frequency. The plywood barrier improved petiole removal 15 percentage points at 1.77 cm and 10 percentage points at 2.54 cm above the belt at the highest vibration frequency (Figure 22).

Although these tests were conducted with only petioles, it may be assumed that the barrier would have little effect on grape recovery. The data indicated that the integration of a barrier would allow the use of higher vibration frequencies which would improve grape recovery. Detailed analysis of the acceleration characteristics of petioles are currently being conducted at Michigan State University to determine the best type of vibration for the vine debris removal system.

Limited tests have been conducted in Michigan in conjunction with Professor Vincent Petrucci, Fresno State University, Fresno, California. Thompson Seedless grapes were singulated with the cluster breaker and debris (dried canes and tips) were removed from on-the-vine dried raisins from California.

In order to reduce damage to the single grapes, two chain belt units could be used. The first chain belt would receive the raw product, separating single grapes from the clusters and debris. In turn, the clusters and debris would feed onto the cluster breaker and then singulated grapes would be separated from the debris on the second chain belt. This version of the debris removal system would reduce damage due to single grapes being handled by the cluster breaker.

Location of the debris removal system is subject to industry recommendations. Incorporation on a harvester would be an extensive project, requiring many alterations. In addition, the debris removal system must be smaller. The potential of the fabric drape may make this possible. If not, the debris removal system could be placed in the receiving line at the

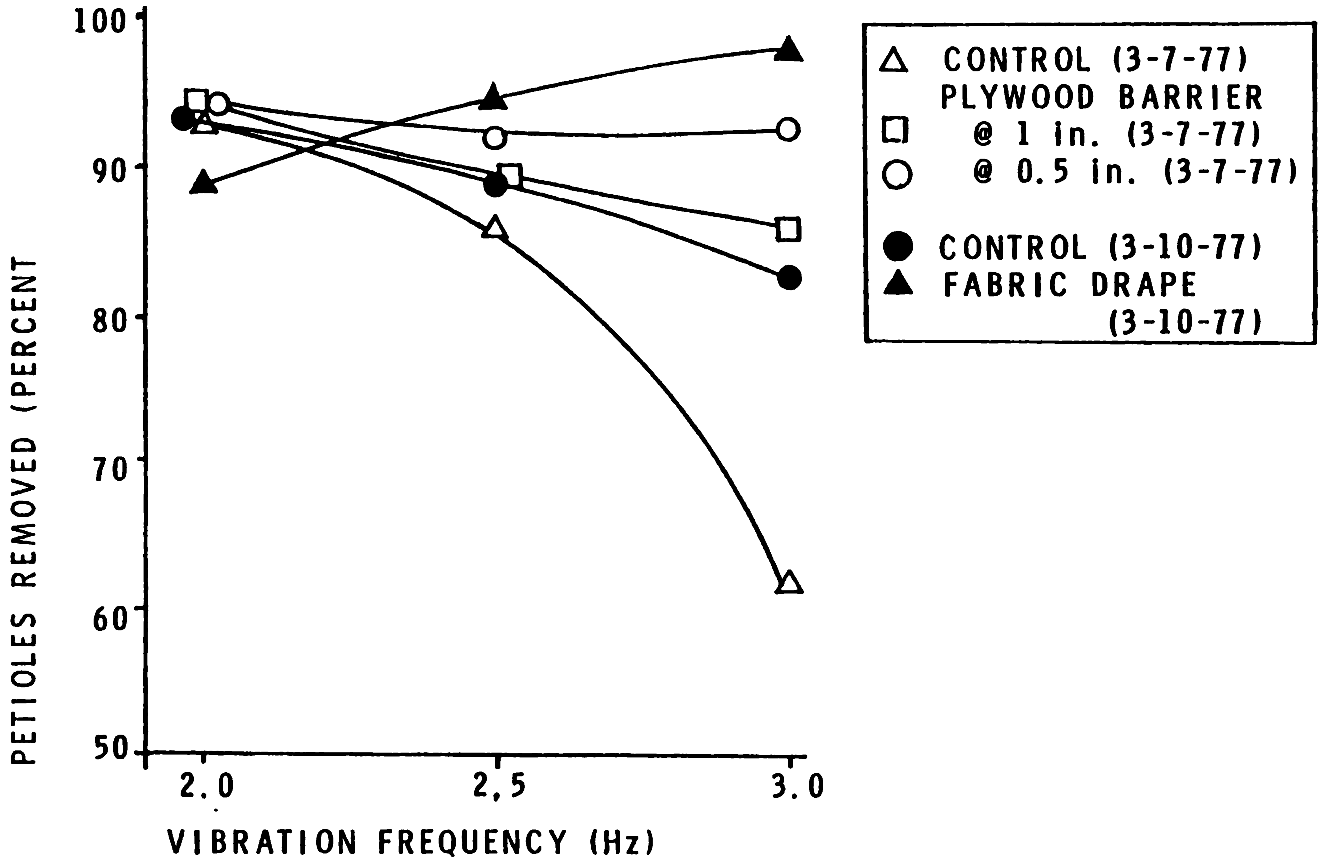

Figure 25. Preliminary Chain Belt Results Incorporating a Barrier and Fabric Drape to Improve Petiole Removed - 1977.

processing plant. Locating at the processing plant will leave the vine debris in contact with the grapes longer, but would require fewer, larger debris removal systems. This decision is ultimately up to the industry.

XI. APPENDIX A

Forms used for Data Collection

DATE: / / LOCATION: ____________________

VARIETY: Niagara Delaware Concord GROWER: __________ HARVEST METHOD: Hand Mech

COMMENTS: ____________________

LIFT: ______ ____________________

VIBRATOR RPM

REP # ____			REP: ____			REP: ____			
____	____	____	____	____	____	____	____	____	BELT DRIVE RPM
									Wt Over
									Singles
									# Bunches
									# Petioles over
									# Petioles thru
									Wt Over
									Singles
									# Bunches
									# Petioles over
									# Petioles thru
									Wt Over
									Singles
									# Bunches
									# Petioles over
									# Petioles thru

"Chain Belt Data Sheet - 1975"

DATE: / /75

VARIETY: Niagara Delaware Concord GROWER:________ HARVEST METHOD: Hand Mech

AMPLITUDE OF CRANK:________

VIBRATOR RPM	BELT ANGLE:____			BELT ANGLE:____			BELT ANGLE:____			
	10	20	30	10	20	30	10	20	30	BELT DRIVE RPM
225										Wt Over
										# Singles
										# Bunches
										# Petioles over
										# Petioles thru
275										Wt Over
										# Singles
										# Bunches
										# Petioles over
										# Petioles thru
325										Wt Over
										# Singles
										# Bunches
										# Petioles over
										# Petioles thru

"Chain Belt Data Sheet - 1976"

RUN #______ DATE__________ CLUSTER BREAKER TEST

VARIETY: Concord Niagara Delaware Other_________

COMMENTS: ____

BRUSH TEXTURES: Slow__________ Fast___________

Brush Spd	Sgl Cltr Lst	Damage	%	Sgl Cltr Lst	Damage	%
SLOW FAST						

BRUSH TEXTURE: Slow___________ Fast_____________

SLOW FAST						

"Cluster Breaker Data Sheet - 1975"

Sample # ______ Variety: ______ Comments: ______

Date ______ Vineyard: ______ ______

Weather ______ Yield: ______ ______

______ SPEEDS: Chain ______ Crank ______ Cluster Breaker (S) ______ (F) ______ (Conv) ______

Catching Conveyor ______

	TOTAL	Petiole	Leaves	Rachis	Grapes Juice	Misc.	% Petiole	% Leaves	% Rachis	% Grapes	% Misc.
BULK BOX DEBRIS SAMPLE Pallet Box Wt. ______											

Comments:

	TOTAL	Petiole	Leaves	Rachis	Grapes Juice	Misc.	% Petiole	% Leaves	% Rachis	% Grapes	% Misc.
MECHANICAL HARVESTER SAMPLE 1)											
2)											
3)											

Comments:

"Down-the-Row Chain Belt Data Sheet - 1976"

XII. APPENDIX B

Letter from John Norton,
National Grape Cooperative

May 31, 1977

NATIONAL GRAPE COOPERATIVE

Producers of Welch's Quality Grapes

May 31, 1977

Carter D. Clary
Graduate Assistant
Dept. of Agricultural Engineering
Michigan State University
East Lansing, Michigan 48824

Dear Mr. Clary:

Your letter to Bill Grevelding Re: our views and comments on the need for trash removal was forwarded to me for reply.

We at National have felt since the advent of mechanical harvesting that there is a need for some kind of trash removal from mechanically harvested grapes prior to the time they are received at the plant. The bin attendant was our first effort in this area. However this activity is not the complete answer to the problem. At the present time the bin attendant is at best only doing a mediocre job of removing foreign material. As a matter of fact, some bin attendants do little or nothing. This is one reason we encouraged the work on a mechanical trash remover.

Because of the possible contaminating effect (whether it be flavor or filth) of the leaves, petioles, vine parts, foreign plants, post parts and other foreign material, it should be removed as soon as possible after harvesting. Apart from contaminating the product, the large vine parts or other large foreign material, if not removed, at times causes damage to the plant equipment. This more often results from grapes picked at night when it is more difficult for the bin attendant to see the objects, but it also happens during the daylight hours.

Further, late in the season (or after a frost) when excessive quantities of petioles are harvested with the grapes, the bin attendant cannot possibly remove enough of the petioles to prevent slowing down of the whole receiving process due to the clogging of the equipment. This of course increased the cost of processing not to mention the waiting time in the yard for the grower or his driver.

Therefore to achieve our goals of receiving the most debris free grapes possible and making the receiving operation

Carter D. Clary May 31, 1977

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as efficient as possible we have urged the development of the mechanical trash remover.

Hopefully the present model will result in a commercial model in the very near future. It cannot come too quickly for us.

We thank you for all your efforts in the development of the mechanical trash remover to date.

Very truly yours,

John E. Norton

John E. Norton
Coordinator - Member Service Projects

JEN/ds

cc: B. Grevelding

XIII. REFERENCES

XIII. REFERENCES CITED

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