CONSTRUCTION, EVALUATION AND EFFICIENCY STUDIES OF A MECHANICAL CUCUMBER HARVESTER

Thesis for the Degree of M. S.
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CONSTRUCTION, EVALUATION AND EFFICIENCY
STUDIES OF A MECHANICAL CUCUMBER HARVESTER

By

George William Bingley

AN ABSTRACT

Submitted to the College of Agriculture of Michigan
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1959

Approved Wesley F. Buchele

George William Bingley

Michigan growers receive over five million dollars annually from pickling cucumbers. Harvesting this crop by present methods costs the growers over two and one-half million dollars. The development of an efficient mechanical cucumber harvester would reduce the costs involved in harvesting and in labor procurement.

The first step toward mechanization of the cucumber harvesting operation was the introduction of a human carrier--designed to reduce the physical effort in hand harvesting. A project was set up in 1957 to develop a mechanical cucumber harvester at Michigan State University in cooperation with private industry and financed by the National Pickle Packers Association.

The present investigation was conducted to evaluate the efficiency of the pneumatic vine trainer and the mechanical cucumber harvester which was designed and constructed for this research endeavor.

Synthetic cucumber fruit and vines were developed to be used in testing various harvester components during the off season.

An experiment was conducted to confirm and extend the basic physical properties of the pickling cucumber fruit and vine.

The pneumatic vine trainer was 75 percent effective in positioning the vines in the desired direction for harvesting.

There was an undesirable effect resulting from the use of the trainer--the return per acre was reduced by 10 percent as compared to the return from an untrained row.

A complete harvesting unit was designed and constructed to mount underneath the tractor. Mounting in this manner provided good visibility and complete control over the operation of the harvesting unit. The machine was designed to harvest cucumbers from trained rows.

A tapered roll pickup with retracting fingers was designed and developed to position the vines onto the separating bed prior to the separating process.

To measure the forces exerted on the vine during the harvesting process, a transducer was developed to be used with strain gage recording equipment. During the time the vine was on the separating bed, it was established that from seven to twelve percent of the foliage (by weight) was removed.

Harvesting by machine resulted in a return of only 21 to 27 percent of the value received by hand harvesting. A study was conducted on the effect of return by supplementing machine harvesting with hand gleaning operations. By using two hand gleaning operations during the first two machine harvests, it was found that the return was increased to 48 percent of the value received by a grower using hand harvesting methods.

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INTRODUCTION

The annual value of pickling cucumbers received by growers in the United States is more than 19 million dollars. Michigan, with a production of 4.2 million bushels, receives about 5 million dollars for the crop each year. This is 26.2 percent of the United States value. Michigan grew 28,200 acres in 1958-23.7 percent of the national acreage. While the acreage of cucumbers has decreased 28.3 percent in the last two years, the yield has risen from 74 bu/acre to 148 bu/acre.

The importance of the cucumber industry to the future of Michigan can be seen from the following economic trends: The value received by the Michigan growers during the two year period, 1956 - 1958, increased by 20 percent while the national value increased only 10 percent during the same period; The production in Michigan increased by 43 percent as compared to a 27 percent increase in the production for the United States; The Michigan yield increased 100 percent while the national average yield increased only 40 percent.

The development of a mechanical cucumber harvester has created considerable interest throughout the cucumber industry during the past several years. Financial support was provided by members of the National Pickle Packers Association and other producers in the United States and Canada.

Private companies and individuals have worked on the development of a mechanical cucumber harvester for over ten years. The Agricultural Experiment Station project calling for the design and development of a mechanical cucumber harvester was initiated in the Spring of 1957.

The two factors mainly responsible for the increased interest in the development of a mechanical harvester are as follows: the increase in harvesting costs, and the procurement of hand labor.

At the present time, the cucumber grower receives one-half of the gross value of the harvested crop. From this the grower must pay the insurance and transportation costs of the pickers and cucumbers. Thus, annual harvesting costs to Michigan growers totals over 2-1/2 million dollars.

The problem of procuring laborers, usually Mexican Nationals, arises from the expenses involved in recruiting, importing and housing of laborers. This expense totals over one million dollars each year.

Dailey (1958) reported that hand harvesting of cucumbers is expected to give way soon to the advances in efficiency of the mechanical cucumber harvester.

The importance of the development of a mechanical harvester can be seen, not only in eliminating the problems involved in hand picking, but also from the standpoint of increased acreage and greater capital investments.

The purpose of this thesis is (1) to invent, design, and fabricate a cucumber harvester, (2) to develop a synthetic cucumber fruit and vine, (3) to measure the forces exerted on the vine by the picking action of the flights, (4) to evaluate the effectiveness of the separating bed, (5) to evaluate the effectiveness of the pneumatic vine trainer and (6) to confirm and extend the basic relationships concerning the physical properties of the cucumber fruit and vine established by Leonard (1958).

REVIEW OF LITERATURE

The review of literature by Leonard (1958) revealed some of the physical characteristics of the cucumber fruit and vine which must be considered in the design and development of a mechanical cucumber harvester. A brief history of cucumber harvesting mechanization was traced to the beginning of the investigation. In a book published by the National Pickle Packers Association, Banadyga (1949) compiled and summarized all available literature related to the cucumber pickling industry. The present review of literature will complete the above reviews as well as review the recent investigations and developments in the mechanical harvesting of cucumbers.

The first step toward mechanization of the cucumber industry was the introduction of the human carrier -- designed to reduce the physical effort involved in hand harvesting. George (1955) developed a human carrier which reduced harvesting time by 15 percent. An article that appeared in the New York Times (Sept. 7, 1955, pp 33) described a prone position carrier, devised by Henry Schwenck, a farmer in Bridgehampton, New York. The carrier was twenty feet wide and carried six pickers. The estimated capacity of the carrier was four to five acres per day.

The first concentrated effort on the development of a mechanical cucumber harvester was started at Michigan State University, East Lansing, Michigan, in 1957. In a progress report concerning the development of a mechanical cucumber harvester, Stout and Ries (1959) described the harvesters that had been tested and evaluated since the start of the project. The overall efficiency during the 1957 testing season of the Grew Belt machine was 33.5 percent. The value was calculated by comparing the value of fruit harvested by machine to that harvested by hand. Based on the number of fruit harvested, the Chisholm Ryder machine, 1958, showed an average efficiency of 38 percent for three harvests. A test conducted later showed an individual harvest efficiency of 79 percent.

Stout (1958) reported on two problems concerning the harvesters under development. These were vine damage and the inability of the harvester to harvest the fruit set within six inches of the base of the plant.

In studies concerning the effect of applying gibberellin to vegetable crops, Wittwer and Bukovac (1957) observed that many of the first nodes, which normally would have produced flowers, remained sterile after early foliage sprays of 10 to 100 parts per million. This result may be significant in reducing or restricting early fruit set near the base of the plant and thus facilitating mechanical harvesting.

An experiment was conducted by Stout and Ries (1959) to evaluate the effectiveness of gibberellin in delaying early flowering. The results of one test indicated considerable success. The first flower appeared at an average distance of seven inches from the base of the plant, however, there was considerable variation in the results obtained from all the plots.

Hawkins (1951) indicated it was essential to remove the first few cucumbers set near the base of the plant. Failure to do so would delay the production of new blossoms.

Banadyga (1949) reported that the growing plant will mature not over 5 - 10 fruits in a season. If the fruits are removed before they attain a considerable size, the plant may produce between 35 - 50 fruits.

The importance of yields has become more pronounced with the introduction of the mechanical cucumber harvester. Miller (1957) stated that concentrated early yields are necessary to fulfill the requirements of the processor. They are also important from the standpoint of insect and disease problems which prevail during the later portion of the season.

Pickling cucumber salting station operators urge growers to harvest frequently, usually 2 or 3 day intervals, so that a large portion of the crop will be of the most desirable grades. In a report on the influence of the length of interval between pickings on yield and grade, Seaton (1935) observed that:

(1) Total number of fruits produced was inversely proportional to the length of interval between pickings.

(2) Total weight in pounds, was proportional to the interval between harvests.

(3) Lengthening the picking interval reduced the quantity of small grades and increased the quantity of larger size fruits.

(4) Returns were highest from vines picked on a four-day interval.

(5) Harvesting should be twice each week to produce the most profitable combination of small and large size cucumbers with a minimum of culls.

In a similar report on the effect of frequency of picking cucumbers on income, Woodworth (1956) reported that frequency of picking had a pronounced effect on the per acre hours of picking labor required and the value received per acre. Picking 1.4 times per week required 105 hours per acre and gave a return of 275 dollars per acre, while harvesting six times required 294 hours per acre and a return valued at 375 dollars per acre. With a preharvest fixed cost of 100 dollars per acre and a labor charge of 50 cents per hour, the most profitable output was 350 dollars per acre when harvesting three times per week. This corresponded to 167 hours of labor input.

Stout and Ries (1959) discussed the yields obtained from 40 - 60 - and 80-inch row widths with 6 - and 12-inch plant spacing. The highest yields were obtained from rows spaced 40-inches apart, regardless of in-the-row spacings. The yields for the 60 - and 80-inch rows were 70 to 56 percent respectively of the yields obtained from the 40-inch row.

INVESTIGATION

Cucumber Plots

Considerable time and money were expended in traveling to the fields during the investigations conducted in 1957 and 1958. The cucumber plots were located over 20 miles from the shop facilities. To eliminate the above expenditures, an arrangement was made with the Horticulture Department to provide a continuous supply of cucumber vines for testing. The plots were located on the Horticulture farm, only a short distance from the Agricultural Engineering Research Laboratory.

Three plots were provided for the development of the experimental harvester and the determination of forces exerted on the vine by the harvester.

The first planting was on May 22, in plot 1 (refer to Figure 1). These vines were used for initial harvester adjustments and in determining the force necessary to separate the fruit from the vine.

The plants in plot 2, were initially planted in the greenhouse on May 11th. They were transplanted in the field on May 29th. This plot was used for the efficiency studies of the experimental cucumber harvester. Additional studies were conducted on the effect of machine and hand training on yield. The yields obtained from the rows with the above treatments were compared to a hand-harvested check row.

Plot 3 was treated in the same manner as plot 2. The plot was planted 14 days later than plot 2.

Table 1 indicates the method of vine training and the type of harvest employed in plots 2 and 3.

TABLE 1.

METHOD OF VINE TRAINING AND TYPE OF HARVEST USED FOR PLOT 2 AND PLOT 3

Row #	Plot	Method of Training (1)	Type of Harvest (2)
11	2	MT	MH
12	2	MT	MH
14	2	MT	MH
15	2	MT	MH
16	2	HT	MH
17	2	HT	MH
18	2	MT	HH
19	2	NONE - CHECK ROW	HH
23	3	MT	MH
24	3	MT	MH
25	3	MT	HH
26	3	NONE- CHECK ROW	HH
27	3	HT	HH
28	3	HT	MH
29	3	MT	MH
30	3	MT	MH
31	3	MT	MH

(1) Hand training - HT
Machine training - MT

(2) Hand harvest - HH
Machine harvest - MH

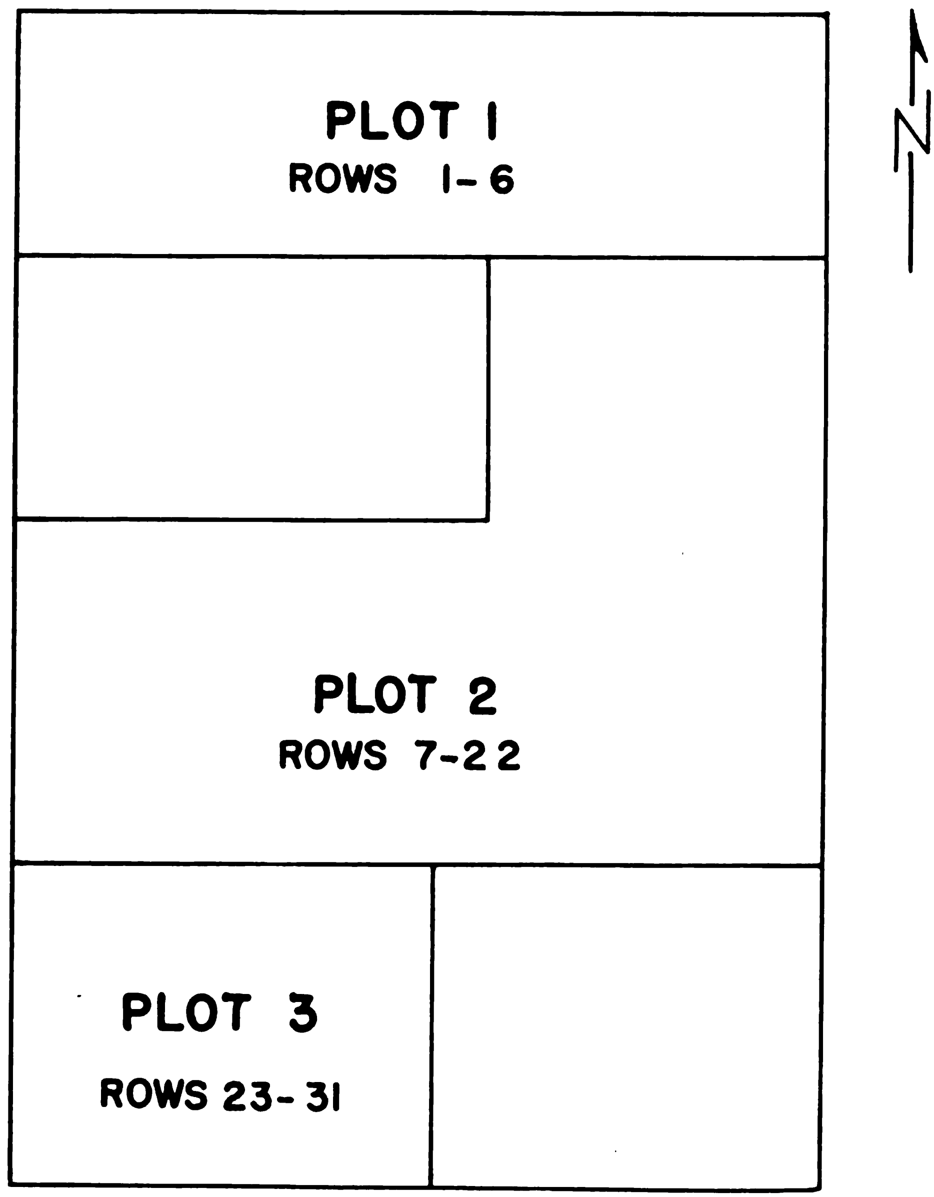

Figure 1. Map of the cucumber plots used in the evaluation and development of the experimental cucumber harvester.

Development of a Synthetic Cucumber Fruit and Vine

The importance of developing a mechanical cucumber harvester has been established from an economic standpoint. In general the rate of progress is proportional to the length of available growing season. A short season will not allow sufficient time for effectively developing and evaluating the machine since, as in all developmental work, continuous changes are taking place.

At least three alternatives were available to the research investigators for lengthening the growing season. The first and most expensive is to follow the growing season as it proceeds northward. This means that all plans must be formulated well in advance. The scheduling and planting of the various plots must be done accurately. Many problems can arise that may turn a fruitful research endeavor into a complete failure. Some of these are weather and soil conditions, variation in plant varieties, and mechanical failures.

The second alternative is to provide a plastic greenhouse large enough to accomodate a harvester for testing purposes. The greenhouse would be used in starting plants earlier in the season as well as providing later plantings for testing purposes. Such a system was constructed during the summer of 1959 on the Horticulture farm at Michigan State University and will be available for future testing.

The third alternative, and the least expensive is to develop a synthetic cucumber fruit and vine. The synthetic plant would be used in the evaluation of machine components of a harvester. The greatest advantage of this system is that the evaluation can be conducted in the laboratory during the off season. Once the characteristics of the vine have been related to the characteristics and properties of an actual vine, a component can be tested, reconstructed, and tested further to develop a component that is functional to the harvester as a whole.

Procedure for constructing the synthetic plant

A plaster of paris mold was used to reproduce the synthetic cucumber. The synthetic fruit was made with a plastic compound by mixing a resin, a hardener, and a coloring agent in definite proportions by weight.

To prevent the plastic from adhering to the mold, a thin layer of grease was applied to the cavity wall. The curing process required six to eight hours and took place at ordinary room temperatures. A small wooden dowel (complete with knob) was inserted between the molds to provide a means of attaching the synthetic cucumber, hereafter referred to as "synber," to the vine. An overall view of the materials used in the construction of the synthetic plants and the completed synbers is shown in Figure 2.

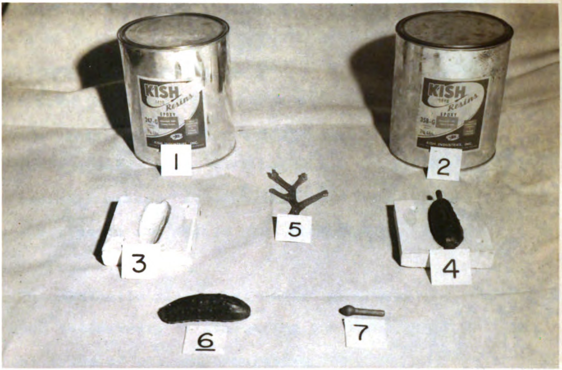

Figure 2. Materials used in molding the synthetic cucumber fruit and vine.

1. 247-G Resin.[1]
2. 358-G Hardener.
3. Plaster of paris mold.
4. Mold with synthetic cucumber in place.
5. Section of synthetic vine.
6. Completed synber.
7. Attachment device.

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(1) The plastic compounds were purchased from Kish Industries, Lansing, Michigan.

<u>Requirements for using the synthetic plants in the evaluation of a mechanical cucumber harvester.</u>

The synthetic plant must be durable and withstand the aggressive action of the harvester components throughout a series of tests. A second requirement is that the attachment must provide a variation in the force required to remove the fruit from the vine. This force will vary with different sizes of cucumbers; usually 2 - 4 pounds are required.

The synthetic plant must be held in a position similar to the ordinary plant. It must also have a provision for attaching the vine to the strain gage equipment described on page 41.

The synthetic plant that meets the above requirements could be used extensively in evaluating the effectiveness of different types of pickups, separating beds, and other components of an experimental cucumber harvester.

The synbers could also be used in improving the quality of pickling cucumbers received in the stations. Models could be made of rejects and undesirable fruit and placed on a stand near the sorting or grading machines. Machine operators would use the models as a guide in eliminating undesirable fruit. Synbers were molded by the author in cooperation with Libby, McNeill and Libby Company in 1959 and used in this manner.

The synbers could also be used in establishing the effectiveness of a grader, by grading a known quantity of synbers and checking the graded product.

Confirmation and Extension of the Basic Physical Properties of the Pickling Cucumber Fruit and Vine

Objectives

1. To confirm the relationships developed by Leonard (1958).
2. Introduce new relationships and design parameters for the development of a mechanical cucumber harvester.

Procedure

Picking force measurements

Three varieties of cucumbers were selected for the measurement of picking forces. The varieties were: SMR-15, SMR-18, and MSU 231.

A spring scale attached to the stem of the fruit, was used to measure the force required to separate the fruit from the vine. By holding the cucumber firmly against the ground and pulling in a direction perpendicular to the axis of the fruit, a maximum shearing force could be obtained. The variety SMR-15 was chosen to confirm the general weight-size relationship of the fruit.

Force to remove the cucumber plant from the ground

The experimental harvester pulled plants out of the ground during the harvesting process. To obtain design parameter data an experiment was conducted to determine the force required to remove plants from the ground.

The procedure in measuring this force was to attach the scale to the base of the plant and pull up in a vertical direction.

Results and discussion

Picking force measurements

To confirm the relationships developed in 1958, the data obtained for the three varieties was analyzed separately by using the regression method. The form of the general equation is as follows:

$$F = aW + b$$

Where

F = Picking force in grams.
W = Weight of fruit in grams.
a = Slope of the regression line.
b = F-intercept.

The picking force-weight relationship for the three varieties is shown graphically in Figure 3. The equations are listed below.

Variety MSU-231	$F = 1.21W + 1470$	(1)
Variety SMR-15	$F = 3.09W + 1641$	(2)
Variety SMR-18	$F = 12.1W + 826$	(3)

A distinct difference exists between the relationships developed for the three varieties. Table 2 illustrates the variation in force required to separate the fruit and vine for a given weight of fruit.

For the given variety of fruit (Table 2) the difference in picking force was 180 grams for MSU-231, 350 grams for SMR-12, 450 grams for SMR-18, and 1520 grams for SMR-15.

With the present harvesters the problem of removing the small fruit was greater than for larger fruit; because the small fruit did not hang down in a position for removal by the

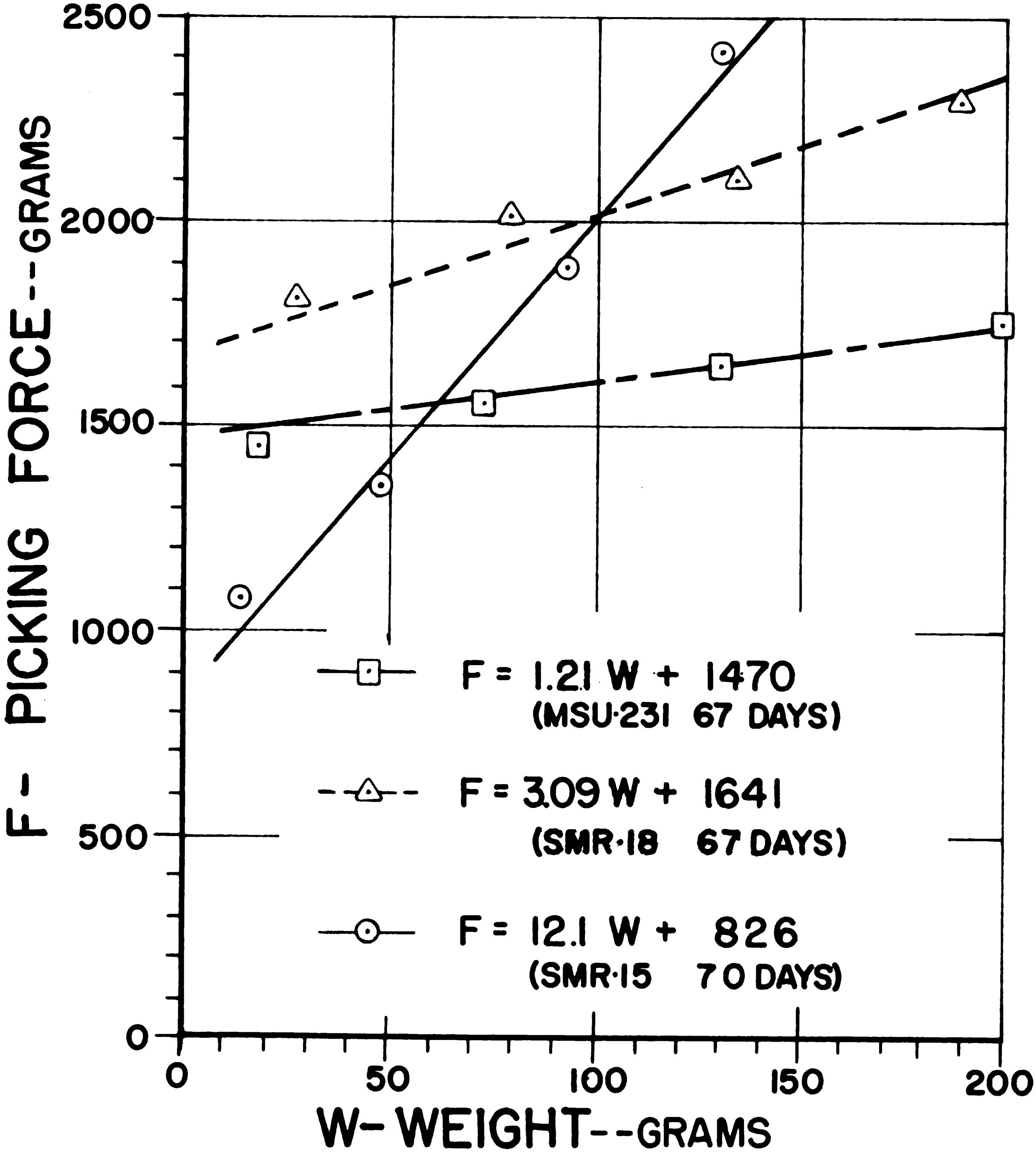

Figure 3. Picking force Vs weight relationships for three cucumber varieties.

harvester. Of the four varieties listed in Table 2, SMR-12 would seem best suited to mechanical harvesting.

TABLE 2.

VARIATION IN PICKING FORCE FOR A GIVEN SIZE CUCUMBER

WEIGHT gms.	MSU-231 gms.	SMR-18 gms.	VARIETY SMR-15 gms.	SMR-12 gms. (1)
20	1500	1740	1070	1060
80	1580	1950	1780	1220
150	1680	2190	2590	1410

The variety SMR-15, was used in determining the weight-size relationship. The equations were determined for an acceptable range in length/diameter ratio of 2.5 - 2.8.

Plotting the data on semi-log graph paper indicated there was a straight line relationship.

For diameter:

$$W = 3.8e^{1.96D} \text{ [2]} \quad \text{(Figure 4)} \qquad (4)$$

For length:

$$W = 2.2e^{0.89L} \text{ [3]} \quad \text{(Figure 5)} \qquad (5)$$

(1) Measured by Leonard (1958).

(2) Compares to $4.14e^{3.88D}$ developed by Leonard (1958).

(3) Compares to $2.44e^{0.82L}$ developed by Leonard (1958).

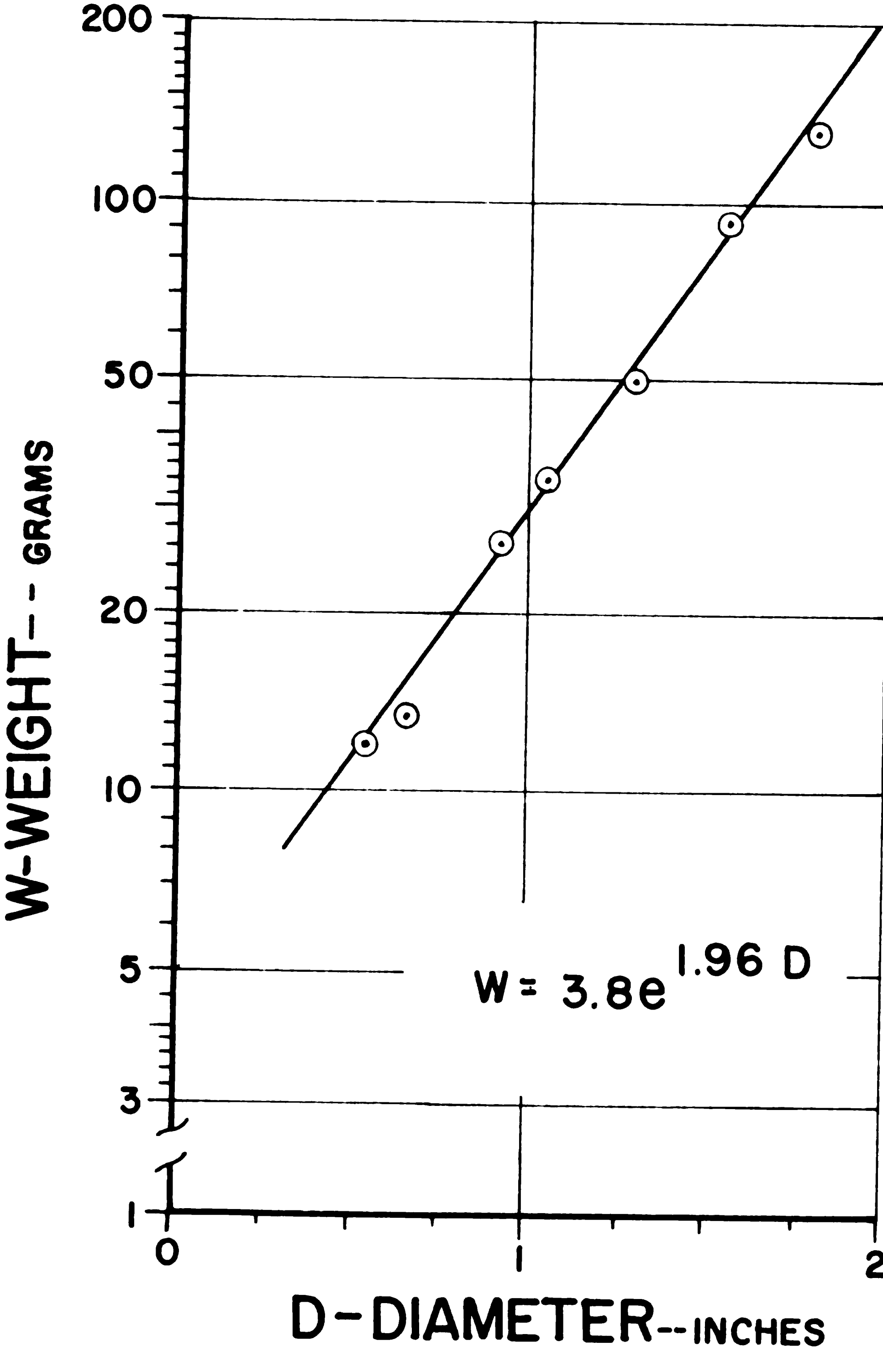

Figure 4. Weight-diameter relationship for SMR-15 variety for a length/diameter ratio of 2.5 to 2.8.

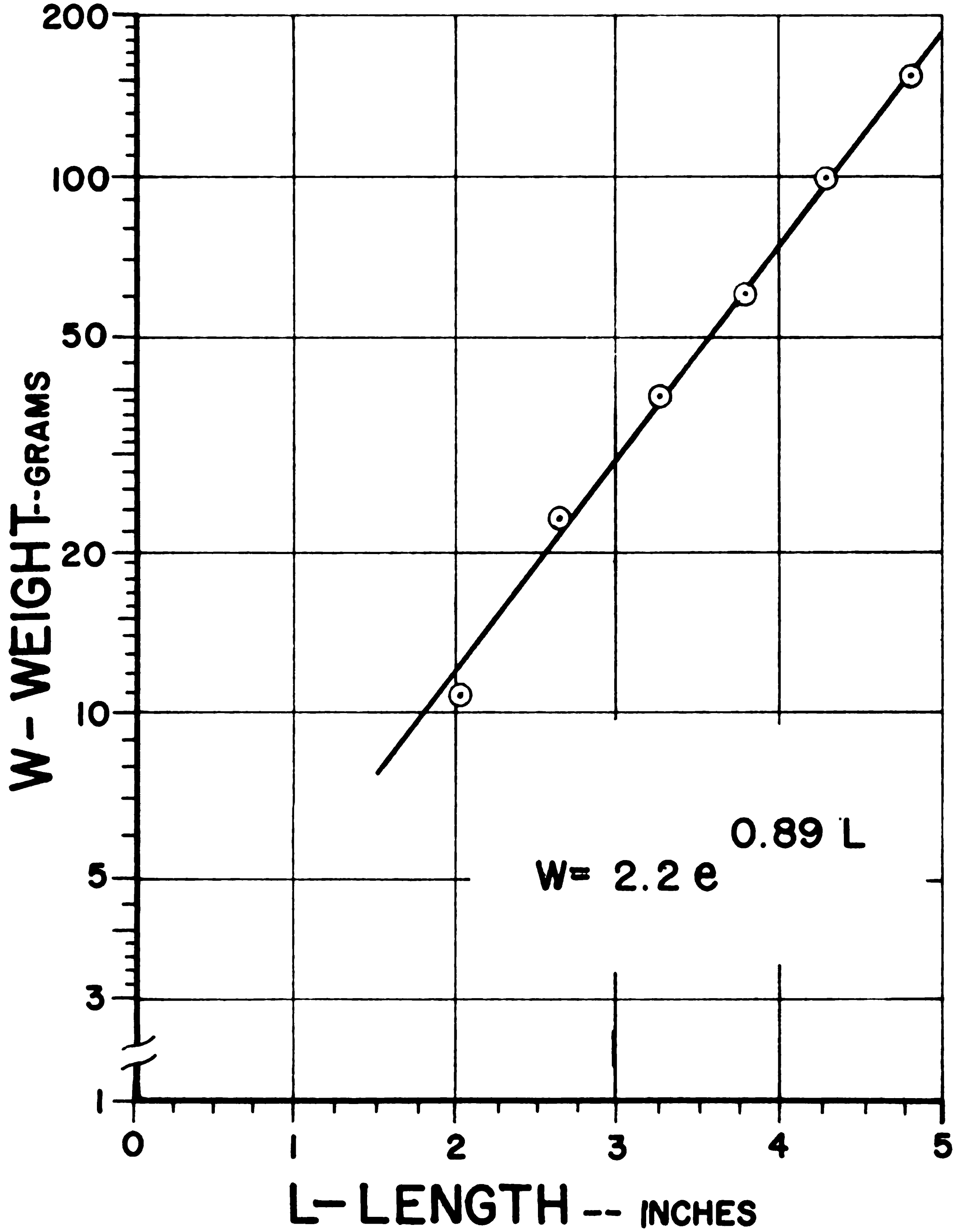

Figure 5. Weight-length relationship for SMR-15 variety for a length/diameter ratio of 2.5 to 2.8.

Where

W = Weight of fruit in grams.
D = Diameter of fruit in inches.
L = Length of fruit in inches.
e = Base of natural logarithms.

Force to remove cucumber plants from the ground

The general relationship between the force required to remove the plant from the ground and the weight of the plant is shown in Figure 6.

The force ranged from 10 to 25 pounds for plants grown in Hillsdale Sandy Loam soil. Additional information concerning the forces exerted on the cucumber vine by the separating bed is summarized on page 39.

Many factors, including soil and weather conditions, age of plants and variety of plants, will influence the ability of the plant to resist being pulled from the ground.

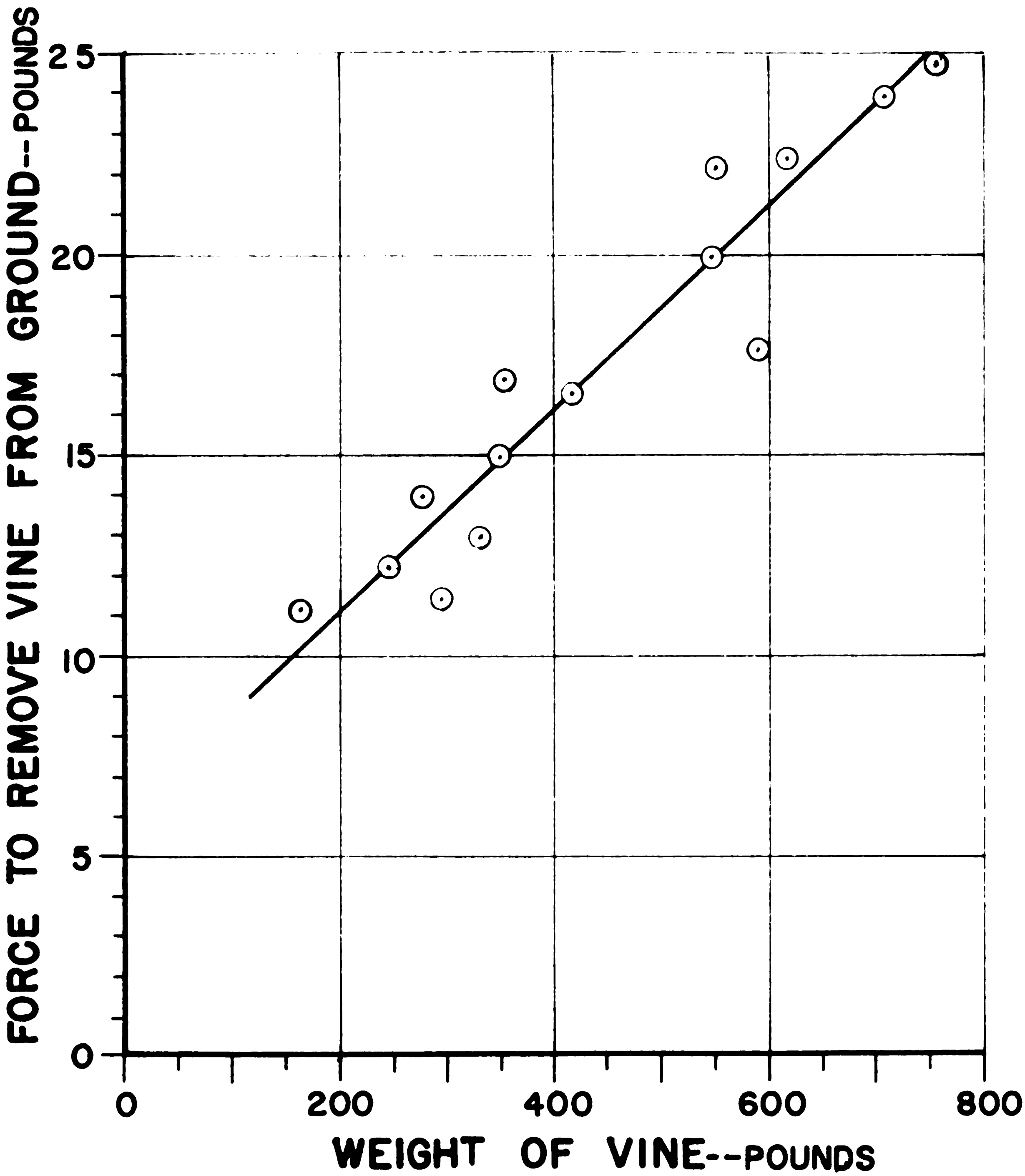

Figure 6. Force required to remove a MSU-231 cucumber vine from Hillsdale Sandy Loam soil.

Pneumatic Vine Trainer

The mechanical cucumber harvester developed for this investigation, as well as other harvesters which pick from one side of the row, require trained vines that extend from only one side of the row.

Vine training is an operation performed on the growing vines when they are 12 to 16 inches long. The vines are moved to one side of the row by means of an air stream directed perpendicular to the row.

Objectives

1. Improve the pneumatic vine trainer developed in 1958.
2. Evaluate the performance of the pneumatic vine trainer.

Procedure

The pneumatic vine trainer (Figure 7) was one of the most important developments of last year's work (Leonard 1958). Since the vine trainer was working well, only a few refinements were added to the machine to improve the efficiency and convenience of operation.

A new shovel-mounting frame was installed on the Allis Chalmers Model G tractor. The frame included the following parts: (1) lever system for lifting, (2) gage wheel for depth control, (3) small plow-type shovel, and (4) adjustments for spacing and mounting of the shovel (Figure 8).

The disc used on the 1958 trainer placed a small mound of soil on the base of the plants after the vines were trained.

Figure 7. Pneumatic vine trainer mounted on Allis Chalmers Model G tractor.

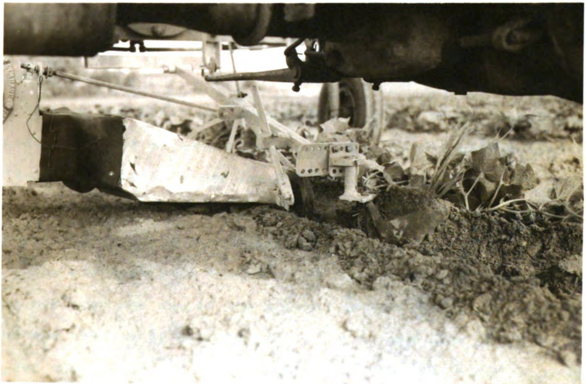

Figure 8. Pneumatic vine trainer. Note air distributor, gage wheel, and shovel.

Because the disc damaged the root system, a plow-type shovel was installed.

The performance of the pneumatic vine trainer was determined by evaluating the training operation on two rows during two training operations. The number of vines growing on either side of the row and the number of vines growing in the row were counted both before and after training. A vine was considered to be growing in the row if it laid within a 30° angle from either side of the center of the row.

Results and discussion

The vines in the second plot were trained on three different dates; June 30th, July 7th, and July 21st. Owing to the training effect of the picking bed, further pneumatic training was unnecessary. Vines having more or less growth than those used in this test may have to be trained on a different schedule.

During the first and second training operations the tractor speed was 1-1/2 miles per hour. In the third training operation, the tractor speed was 2-3/4 mph. Machine capacity at the respective forward speeds was, 1-1/3 and 2-1/2 acres per hour for an eight-foot row spacing.

The air flow rate necessary in the training operation depends upon the age of the plants, amount of foliage, and in-the-row spacing of plants. Initially an air flow rate of 3,000 cubic feet per minute was used. When the vines reached a later stage of maturity, less air was needed because most of the laterals were aligned in the direction of training.

When the period of time between training is too long, the vines will entangle and become a solid mat. At this stage it is impossible to train the vines.

During the first and second training operations the shovel was operated at a depth of two to three inches in the soil and six to eight inches away from the row. The shovel was removed completely during the third training operation. During the third operation the extension of the fan was removed to enable the tractor to operate without injuring the ends of the long vines.

The effect of placing soil on the plant during the training operation was compared between two rows in the third plot. One row was trained with the placement of soil on the base of the plant and compared with a check row without soil placement. By observation, there was little difference between the two rows from the standpoint of effectiveness of the vine training. This is insufficient evidence however, to conclude that the soil ridge is not needed. The effect of training against the prevailing wind or occurance of a violent wind storm may cause the soil ridge to play an important role in keeping the vines trained.

During the harvesting operation the mound of soil placed on the base of the plant tended to inhibit the effectiveness of the secondary flight in removing cucumbers set near the base of the plant. On the check row, the secondary flight was effective in removing cucumbers set near the base of the plant.

Results of the effectiveness of the first two training operations in the second plot, are summarized in Table 3. The general effect of each training was to reduce the number of vines and laterals growing in the row and in the opposite direction to the trained vines.

TABLE 3.

EFFECT OF PNEUMATIC VINE TRAINING ON TWO ROWS FOR TWO DIFFERENT TRAINING DATES

Row No.	Date	Before Training North %	Before Training South %	Before Training In Row %	After Training North %	After Training South %	After Training In Row %
14	June 30	19	31	50	1.5	81.3	17
14	July 7	2.7	14.8	82.5	.7	85.5	13.8
15	June 30	9.8	40.7	49.5	1.3	88.5	10.2
15	July 7	2.3	21.4	76.5	.5	75	24.5

The significant facts contained in Table 3, are listed below:

1. The effect of wind and natural growth on pneumatic vine training for row 14 can be observed by comparing the percentage of vines trained south on June 30th (81.3%) with the percentage of vines directed south before training on July 7th (14.8%). The difference can be attributed to wind action and natural growth.

2. A similar effect can be shown for row 15, with 88.5% trained south on June 30th as compared to 21.4% directed south before training on July 7th.

3. On each date the pneumatic vine trainer was 75% effective in positioning the vines in the direction required for mechanical harvesting.

Mechanical Cucumber Harvester

The importance of developing a harvester has been mentioned previously. Additional consideration must be placed on the type of harvester necessary from the standpoint of economy in initial cost and adaptability to various tractors.

The results obtained from the 1958 investigation indicated that a machine could be built to harvest cucumbers from one side of the row. The harvester used a mechanism designed to pick and elevate in one operation. Mounting was accomplished by attaching the picking bed and necessary components underneath the tractor.

This type of mounting provided good visibility as well as a convenient means for attaching the harvester to the tractor.

Objectives

1. To invent, design, and construct an efficient pickup.
2. Develop a mechanism to reduce the height of the separating bed.
3. Design, construct, and evaluate the separating bed.

Design and construction of the machine

The machine was designed from the requirements established during the 1958 investigation. Construction of the harvester, employing the flight-type picking principle, began on January 6, 1959. The harvester was completed and field tested for the first time on June 21, 1959. The harvesting unit was mounted on a model 340 International Harvester Tractor. An overall view of the complete machine is shown in Figure 9.

Tapered roll pickup with retracting fingers

During the later part of the investigation conducted in 1958, a sponge rubber roll, five inches in diameter and four feet long with one set of retracting fingers, was mounted on the leading edge of the separating bed.

The fingered roll assisted the vacuum pickup in lifting the vines onto the separating bed. By removing the vacuum pickup, it was found that the fingered roll alone would lift the vines. With this new principle in mind, a pickup was invented, designed, and constructed to lift the vines onto the separating bed.

The pickup had two distinguishing characteristics. It was designed in the shape of a frustum of a cone, and the pickup fingers were retractable.

The frustum of a cone was used to enable the pickup to remain close to the ground and still place the vines in the correct position on the inclined bed. The pickup cone was 36 inches long, 4 inches in diameter at the lower end, and 8 inches in diameter at the upper or drive end. Owing to the inclination of the separating bed, the vines must be raised a greater distance at the upper end of the pickup than at the lower end. The natural differential in peripheral speed at the ends of the cone enabled the pickup fo lift the vines onto the bed in a position parallel to the row.

Initially the tapered roll pickup was constructed to include three sets of retracting fingers with four fingers per

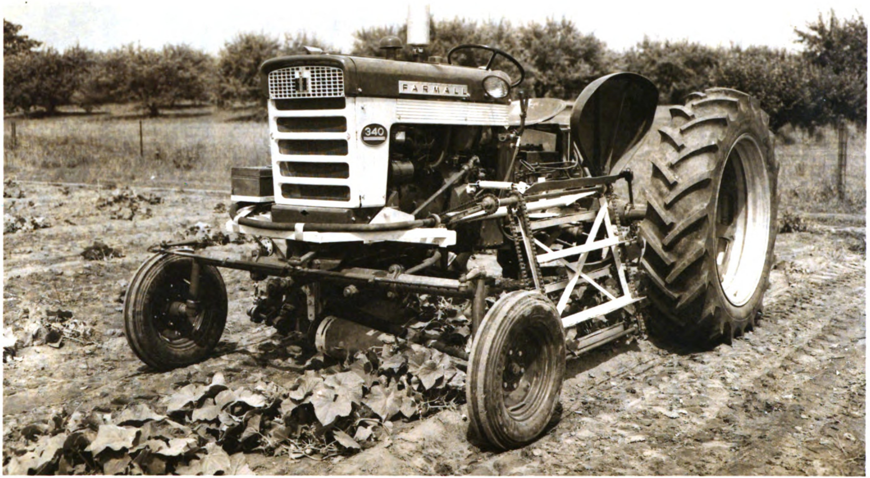

Figure 9. **Overall view of the mechanical cucumber harvester. Note tapered roll** pickup and secondary flight mounted on the left side of the tractor.

set (Figure 10). After initial field experiments showed the need for more fingers, an additional set was located midway between the lower two sets. To assist in lifting the exposed part of the tapered roll was covered with a sheet of polyester form, one-eighth inch thick.

To reduce the drag on the vines, caused by the forward motion of the harvester, the retracting fingers were designed to give a fast initial lift on the leading edge of the roll. In theory, this action would lift the vines upward before a dragging force could be exerted on the vines.

The retracting fingers were individually mounted on the rotating tapered shell (Figure 10). They were actuated by means of cams mounted on a stationary shaft. The cams were designed to engage the fingers after the pickup rotated past bottom center. The fingers remain engaged for a travel of 160°, at which time they were released and dropped back in the tapered pickup shell.

After the vines had passed the point where the fingers retracted, a tapered rubber stripper roll transferred the vines from the pickup to the separating bed.

Separating bed

The process of separating the fruit from the vines was accomplished on the separating bed. The bed was positioned to allow the vines to extend over the top of and toward the upper end of the bed. The ends of the flights were attached to No. 60 roller chain. They moved around the bed, underneath the vine and removed the fruit.

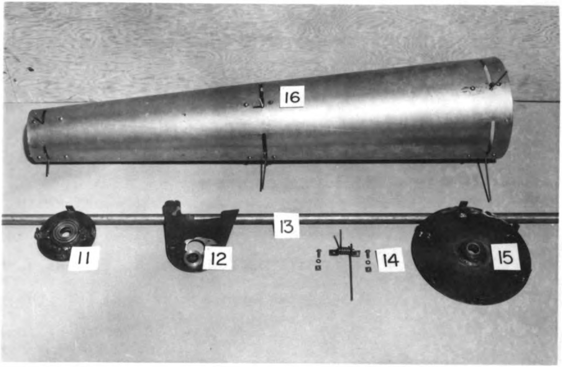

Figure 10. Disassembled view of the tapered roll pickup with retracting fingers.

11. Lower end plate.
12. Lower end mounting bracket.
13. Stationary mounting shaft for cams.
14. Retracting fingers.
15. Upper drive end plate.
16. Tapered pickup shell with three sets of retracting fingers.

The nine flights were fabricated from 3/4 x 3/4 x 1/8 x 41 inch angle iron. Canvas belting was used as a facing on the flights.

To reduce the depth of the separating bed at the lower end, a camming device was employed (Figure 11). As the flight starts forward, it engages the cam, causing the flight to pivot and extend out in its natural picking position. This feature also provided additional picking action on fruit set near the base of the plant.

During the forward movement of the flight it is held upright by two small arms located on the back and on either end of the flight (Figure 12). As the flight leaves the upper end, the arms are removed from the slide causing the flight to pivot and fold down for the return trip.

To keep the proper tension on the chain, two tighteners were located on the main drive shaft of the separating bed (Figure 12).

Once the fruit has been removed, it is conveyed toward the upper end by the canvas flights. The harvested fruit is then deposited on a six inch cross-conveyor, which carried the fruit to a container.

The retainer bar, a 1/4 x 1 inch strap iron, was placed on the lower end of the separating bed to counteract the forces on the vine during the harvesting process (Figure 13). The retainer bar was necessary when the flights were fabricated from the 4-ply canvas fabric material.

An attachment was provided that would enable the bed to pivot at a central point. This balanced the bed and facilitated

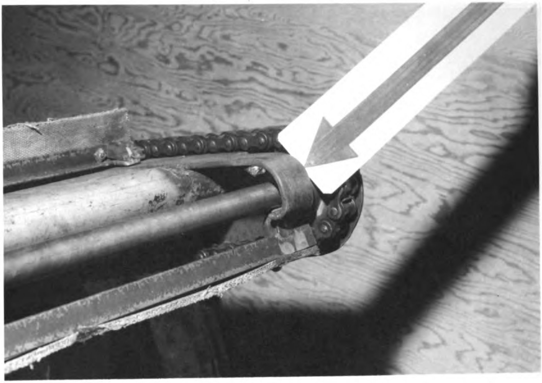

Figure 11. Lower camming device on separating bed.

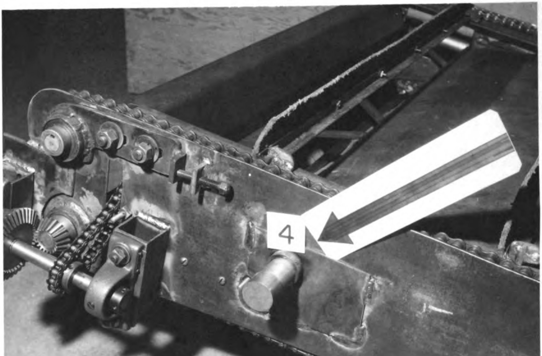

Figure 12. Separating bed showing the position of the supporting frame lugs.

ease of lifting (Figure 12).

Two hydraulic cylinders were mounted on the frame to lift the bed. To aid in lifting and to release the excess weight on the lower shoe, two helper springs were installed on the upper end of the bed. Their downward action assisted in providing a free floating system, enabling the bed to ride over any obstacles.

Secondary flights

The purpose of the secondary flight was to assist in the removal of fruit set near the base of the plant. Training vines that had moved out of position was another purpose served by the secondary flight.

As the plant matures, the fruits are set farther away from the base of the plant. This greater distance permitted the secondary flight to be removed after the fourth harvest.

The flight system was mounted in a vertical position (Figure 14). To provide a means for lifting the secondary flight at the same time the bed was lifted, a system of linkages and a cable were connected to the upper end of the bed.

Power was transmitted to the secondary flight through a flexible shaft which was connected to the main drive shaft on the right side of the tractor. The speed of the secondary flight was slower than the flights on the separating bed.

Cleaning fan

To assist in removing leaves and trash from the harvested fruit, a fan was mounted directly above the cross-conveyor of

Figure 13. Retainer bar located on the lower end of the separating bed.

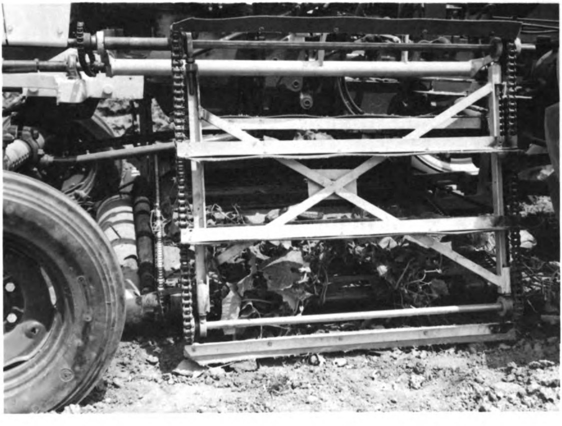

Figure 14. Secondary flight system used in removing fruit set near the base of the cucumber plant.

the separating bed (Figure 15). The air stream was directed toward the end of the belt.

Drive mechanism

A double "B" section V-belt sheave was mounted on the tractor PTO. Two belts connected the drive to the main drive shaft that was mounted along the right side of the tractor. The main drive shaft was used to provide power for the separating bed, cleaning fan, and the secondary flight. A complete schematic diagram of the drive mechanism is given in the appendix.

Safety features of the harvester

To provide complete protection all exposed drives on the main drive shaft were covered with suitable shields (Figure 16). The shielding not only provided a measure of safety, but at the same time improved the overall appearance of the harvester.

A spring tension belt tightner was installed on the main double V-belt drive. The device acted as a slip clutch if an obstacle became entangled in the machine.

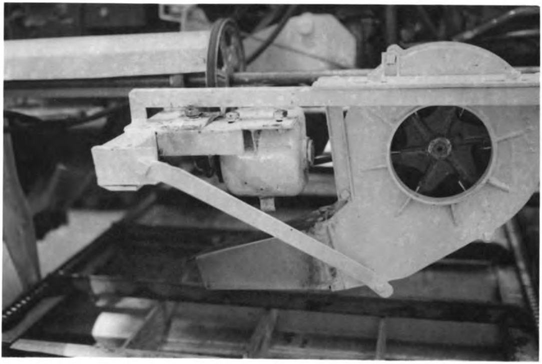

Figure 15. Fan used in removing leaves from harvested fruit. Note dividers located below the fan.

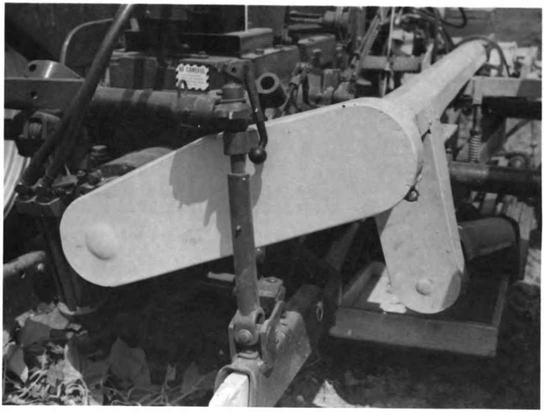

Figure 16. Safety shielding provided for main drive shaft and main drive.

Test procedure

Measurement of the power requirements of the mechanical cucumber harvester

The power requirements of the harvester were determined in the laboratory with a hydrostatic torque meter(1) mounted directly to the tractor PTO shaft (Figure 17).

A pressure gage was used as an indicating device. The pressure reading, pounds per square inch, was converted to torque, foot-pounds, by using a conversion factor of 1.309 ft-lb/psi.

To obtain a relationship of the power required to operate the three components of the harvester (separating bed, secondary flight, and cleaning fan), data were obtained in the laboratory for the range of operating speeds.

After the power requirements of the harvester were determined in the laboratory, field experiments were conducted to determine the power consumed during the cucumber harvesting operation (Figure 18).

Measurement of forces exerted on the vines by the action of the pickup and the separating bed

In order to establish a system for evaluating the various types of picking flights, a force measuring transducer was constructed that could be used in measuring the forces exerted on

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(1) The torque meter--model 31, range 0-260 ft-lb--is manufactured and distributed by the Frederick Products Company, P.O. Box 4827, Detroit 19, Michigan.

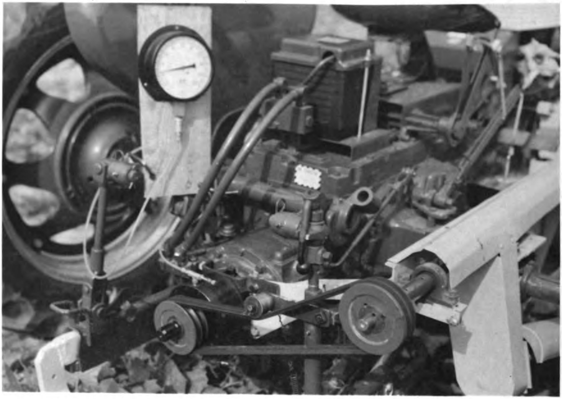

Figure 17. Torque meter used in determining the power requirements of the harvester.

Figure 18. The author and Dr. Buchele observing the operation of the torque meter under field conditions.

the vine. The transducer was a cantilever beam mounted with four SR-4 (type A-5) strain gages. The beam was attached to a two-inch channel iron base plate. A one-quarter inch eye-bolt was fixed to the free end of the beam. The bolt provided a means for attaching and holding the vine during the measuring process (Figure 19).

The strain gages were mounted on the beam to provide maximum sensitivity and complete temperature compensation. A Brush amplifier and oscillograph were used to record the dynamic forces. The measuring system was calibrated with a standard set of weights. The internal calibration circuit in the amplifier was used before each measuring period to eliminate the process of manual calibration. A schematic diagram showing the cantilever beam, location of the strain gages, and a calibration curve is presented in the appendix.

The equipment was used in the laboratory (Figure 20) to determine the amount of foliage removed from the vine by the separating bed. The vine was weighed before and after the experiment (all fruit were removed from the vine prior to weighings). The time of exposure was obtained from the oscillograph recording. The experiment was conducted with two-inch flights by measuring the forces parallel to the separating bed, and with three-inch flights by measuring the vertical forces with the retainer bar in place.

Using the weight of plant previously recorded, a relationship was established between this and the maximum and average forces exerted on the vine. This relationship was determined for flights of two- and three-inches in height.

The recording system was operated in the field to determine the actual forces exerted on the vine during the harvesting process. A small gasoline powered generator supplied the electrical power to operate the recording instruments. The transducer was placed in a trench and a wooden plank placed over the trench so that the harvester could be operated in the usual manner without damaging the transducer.

Size distribution of harvested fruit on the separating bed

Three partitions were installed on the separating bed above the cross-conveyor, dividing the upper portion of the bed into four equal compartments. The wooden dividers were located below the fan as shown in Figure 15. Each compartment served as a collecting point for the fruit harvested in that particular section of the bed.

The harvested fruit was removed from the four compartments and graded to size.(1) The weights of the three grades--Grade 1, Grade 2, and Grade 3--were collected from each compartment and recorded. To determine the value of the size distribution of harvested fruit in each compartment, the weight of each size was transformed into a monetary value.

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(1) The size of acceptable fruit received by the H.W. Madison Company in 1959 were as follows:

Grade 1--ranging in size up to 1 1/16" in diameter.

Grade 2--ranging in size from 1 1/16" to 1 1/2" in diameter.

Grade 3--ranging in size from 1 1/2" to 2" in diameter.

Figure 19. Strain gage transducer used in measuring the forces on the vine by the separating bed.

Figure 20. The author observing the strain gage transducer and recording equipment.

The price of cucumbers in 1959 were as follows: five cents per pound for grade 1; two cents for grade 2; and one cent for grade 3. The data from each experiment are presented in Figure 27.

The above procedure was followed in evaluating the effectiveness of the following type of flights:

1. Straight two-inch flight.
2. Two- to three-inch tapered flights.

Effect of machine training and harvesting on gross return per acre

The procedure followed throughout the experiment on yield studies was standardized. Each row was first machine harvested and then gleaned by two separate hand operations.

1. All the fruit removed from the vine by machine but dropped on the ground was gleaned by hand.

2. The remaining fruit in a six-inch zone extending away from the base of the plant was picked by hand.

The fruit was graded and a record made of the yield from each row. The value of the harvested crop was determined in a similar manner as described above. A sample data sheet for recording the weight of harvested fruit is presented in the appendix.

The hand harvested rows were harvested each time the machine rows were harvested. Each plot was harvested two times per week.

Two rows in each plot were used to determine the effect of machine training on yield.

Results and discussion

Measurements of the power requirements of the mechanical cucumber harvester

Torque requirements for the bed alone and, similarly, for the bed and secondary flight remained relatively constant as the speed was increased. The horsepower requirements of the complete harvester increased exponentially with speed (Figure 21), as the power requirement of a fan is proportional to the cube of the speed.

At the normal operating speed of 350 revolutions per minute (PTO shaft speed), the maximum horsepower required to operate the harvester was three horsepower (Figure 21).

Under normal picking conditions, the torque requirement of the separating bed and secondary flight ranged between 20 and 25 ft-lb, depending upon the size and weight of the vine. Since the operating torque was 18 ft-lb, (Figure 22) the resulting difference 2-7 ft-lb was the power consumed in the harvesting process. The average increase in horsepower for picking was 0.27 horsepower. The value is insignificant when compared to the horsepower required to operate the harvester alone. Thus, the torque meter could not be used in obtaining a relationship for the variation in picking forces.

Measurement of forces exerted on the vines by the action of the pickup and the separating bed

The force exerted on the vine was related to the weight of the vine and the type of flight used on the separating bed. The maximum force on the vine was determined for the straight two-inch flight with a flight speed of 290 feet per minute

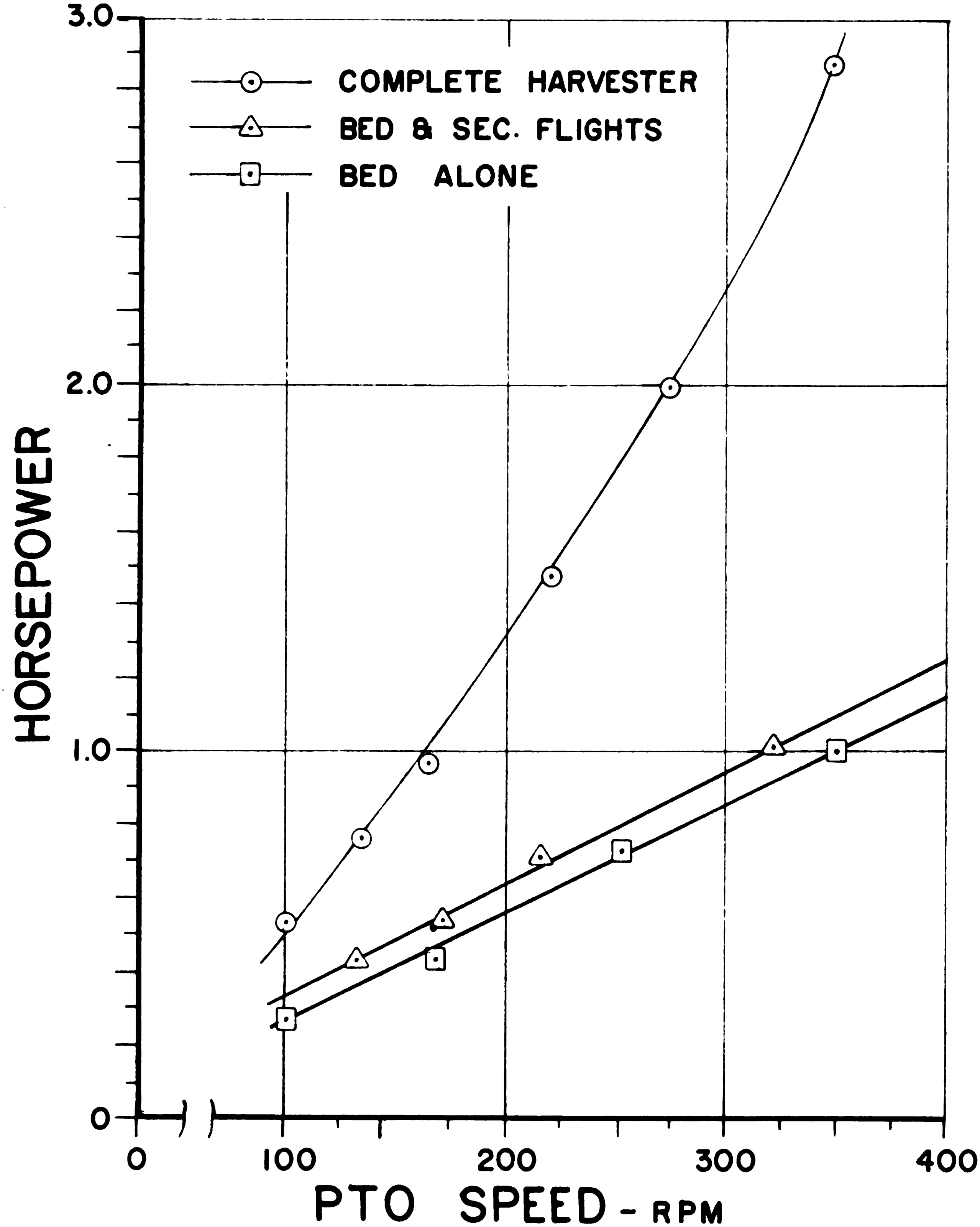

Figure 21. Horsepower requirements of the harvester vs PTO speed.

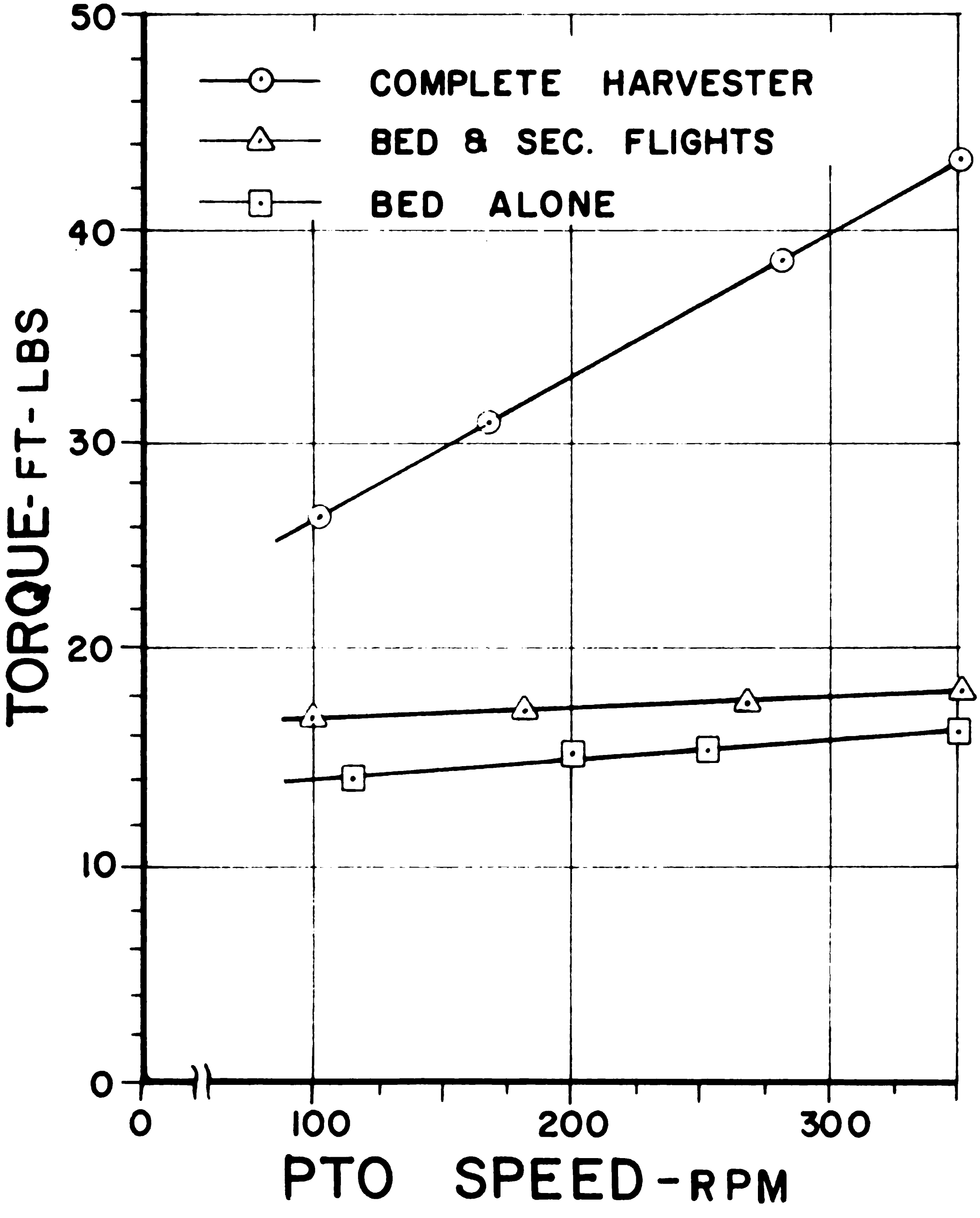

Figure 22. Torque requirements of the harvester vs PTO speed.

(Figure 23). Measurement of the force was made in a direction parallel to the direction of travel of the flights. Also shown on each graph, is the average force exerted on the vine as related to the weight of the vine. The three-inch flight, with retainer bar in place, exerted less force on a vine of a given weight than did the two-inch flight without the retainer bar (Figure 24).

A summary of the forces exerted on the vine by the two types of flights is given in Table 4.

TABLE 4

COMPARISON BETWEEN THE FORCES EXERTED ON THE CUCUMBER VINE BY TWO DIFFERENT TYPES OF FLIGHTS

	TYPE OF FLIGHT			
Weight of Vine	Straight 2-inch Without Retainer Bar		Straight 3-inch With Retainer Bar	
	Max.	Ave.	Max.	Ave.
lb	lb	lb	lb	lb
1	9.2	3.3	5.8	1.5
2	18.5	6.2	9.0	2.8
3	(1)	(1)	12.2	4.2
4			15.3	5.6

(1) Measurement did not include vines weighing more than three pounds.

A comparison of the force exerted on the vine (Table 4) with the force required to pull a vine from the ground

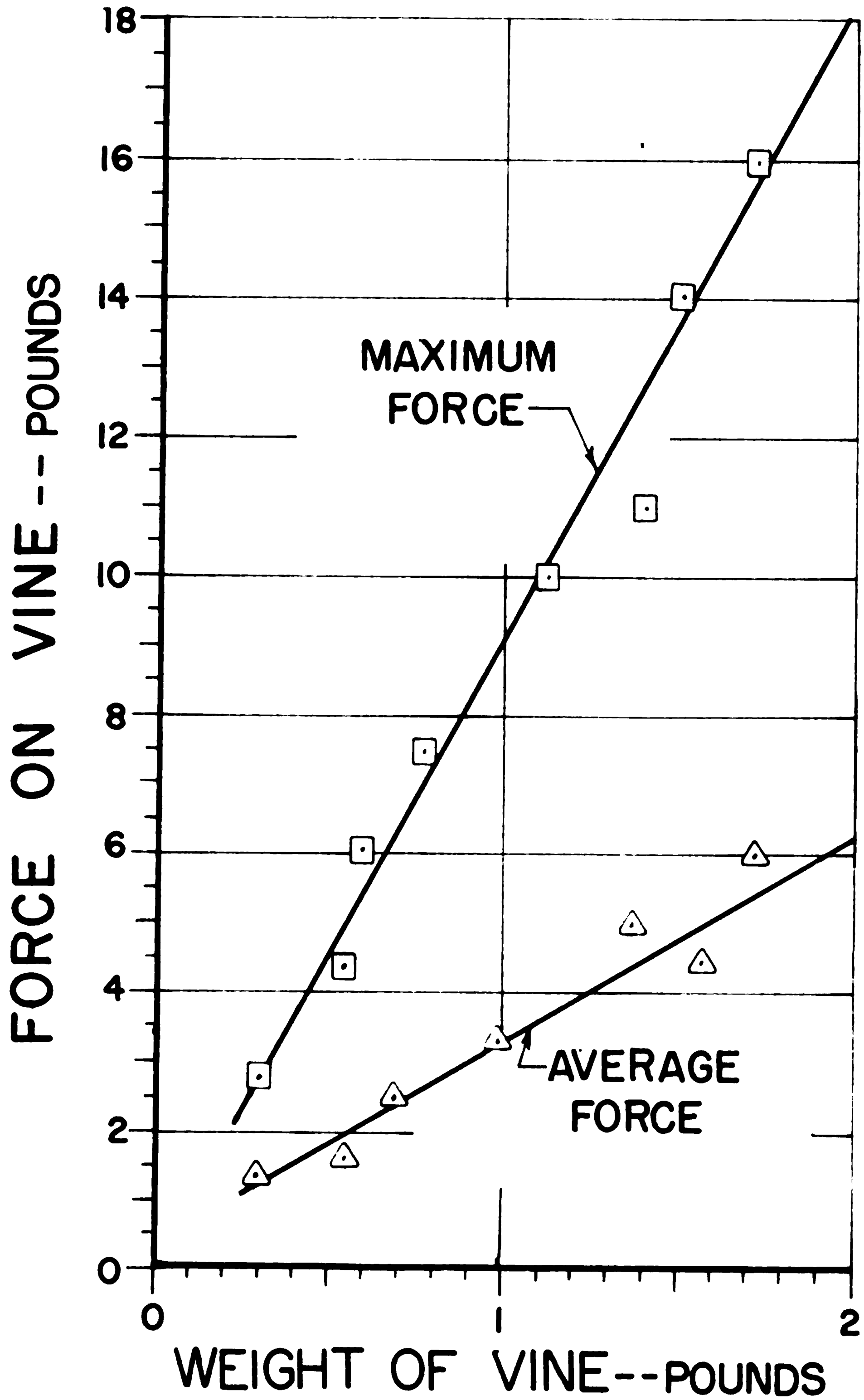

Figure 23. Force exerted on the vine vs weight of vine with straight two-inch flights.

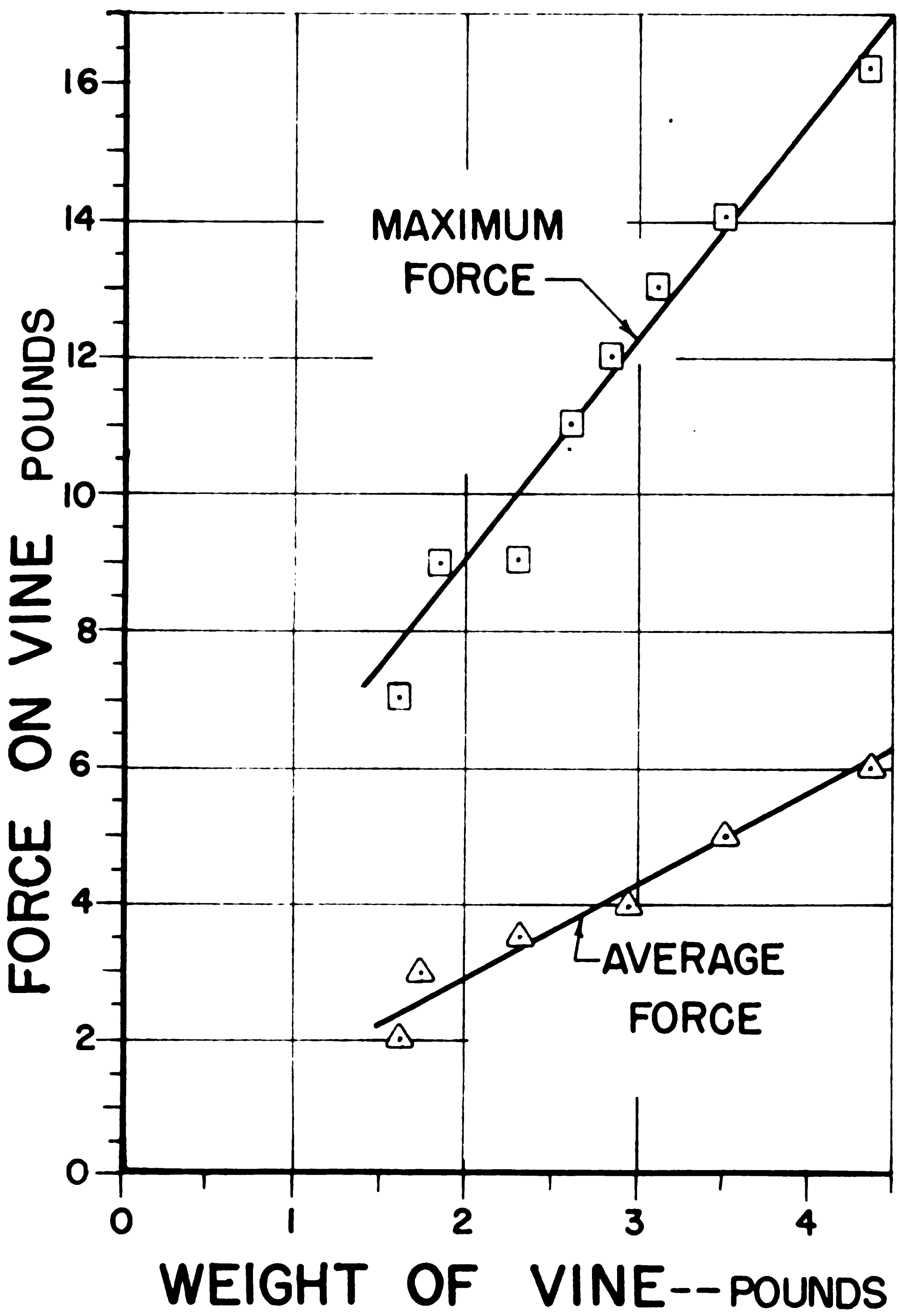

Figure 24. Force exerted on the vine vs weight of vine with straight three-inch flights and with the retainer bar in place.

(Figure 6) will indicate the necessity of using the retainer bar with the fabric-flights.

The percent of foliage removed from the vine increased with the time (Figure 25). The normal time interval that the cucumber vine was exposed to the separating process was from three to four seconds. During this time the two-inch flight removed from seven to eight and one-half percent of the foliage by weight while the three-inch flight removed from nine to twelve percent.

Figure 26 shows the actual forces exerted on the vine during the harvesting process. The lower graph is a reproduction of the force recorded during the first pass of the vine over the separating bed and the upper graph is the recording obtained during the second pass. The graphs are typical of the recordings obtained by using the two- to three-inch tapered flights. Each graph is divided into four sections. The first section covers the time required to pick up the vine. Section two is the time the vine passes over the stripper roll. The separating process occurs during the third section. The fourth section covers the time the vine falls from the bed to the ground.

Roller flights were installed on the separating bed during the later part of the testing season (Figure 31). From the recordings of the tapered and the roller flights, a distinct difference was noted between the two types of flights. The tapered flights exerted a force over a longer period of time than the roller flights did. The roller flight, however,

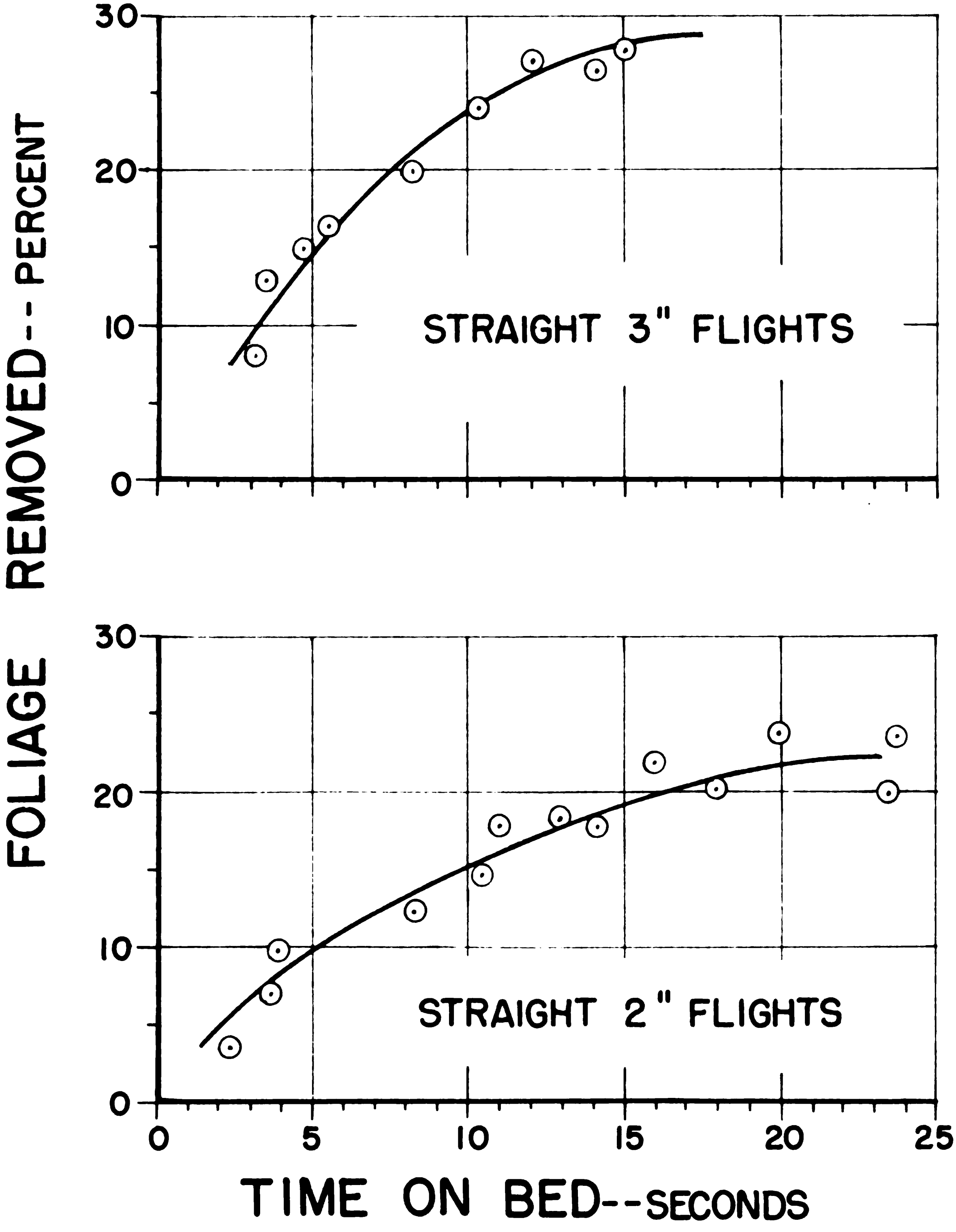

Figure 25. Percent of foliage removed from the vine by the action of the separating bed.

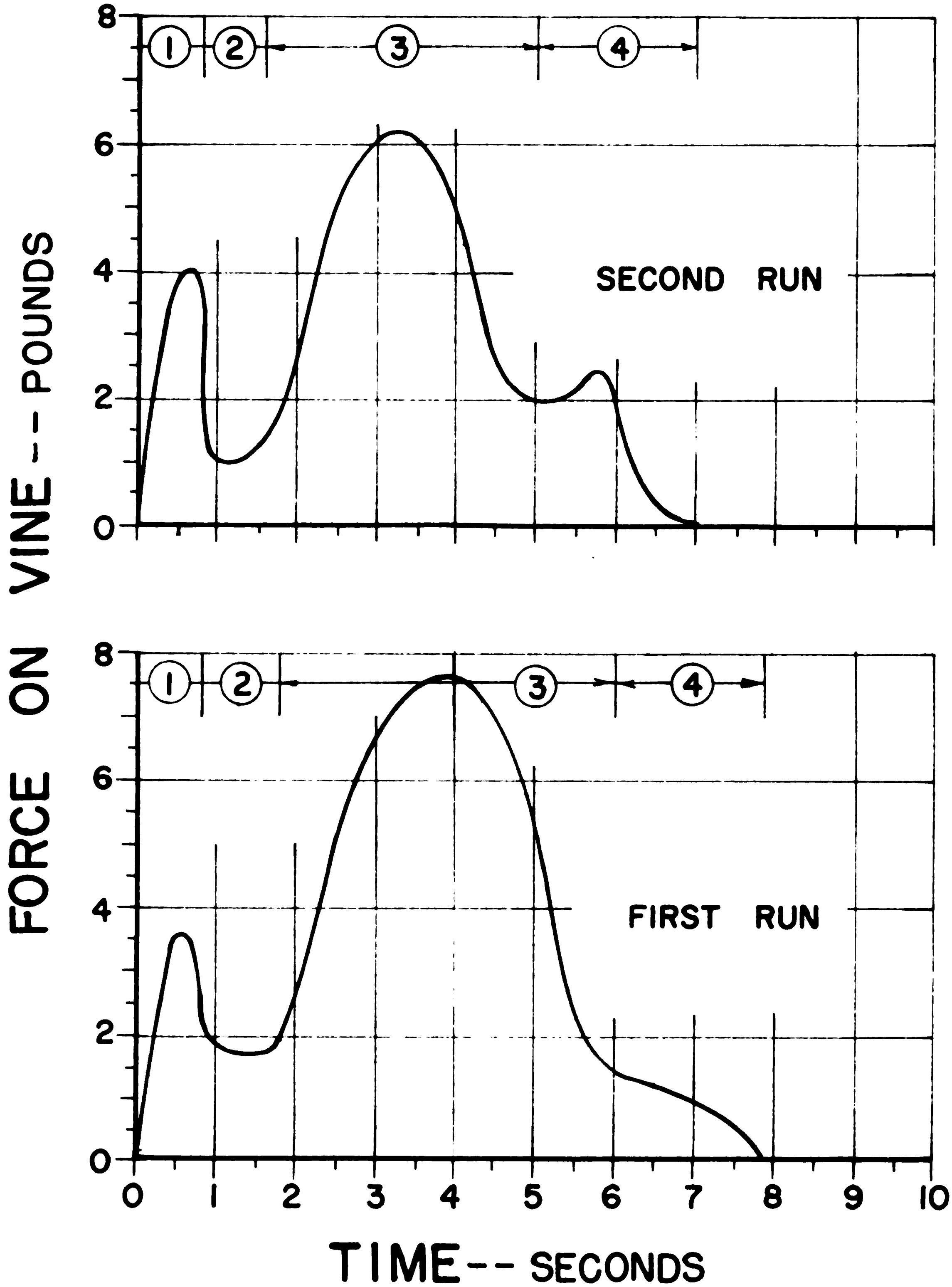

Figure 26. Actual force exerted on a cucumber vine during the harvesting process with a flight speed of 290 feet per minute.

reached a maximum value and remained there longer than the tapered flights.

Size distribution of harvested fruit on the separating bed

The results of the experiment conducted to determine the effectiveness of two types of picking flights are given in Tables 5 and 6. Figure 27 presents the breakdown of the percentage (by value) of each grade removed in each compartment for two different types of flights. The total percentage value of the crop collected in each compartment on the separating bed is also presented.

TABLE 5

PERCENTAGE VALUE OF HARVESTED FRUIT REMOVED IN EACH COMPARTMENT--2- TO 3-INCH TAPERED FLIGHTS

Compartment No.	Total Removed (By Value)	Grade 1	Grade 2	Grade 3	Rejects (By Weight)
	%	%	%	%	%
1	40.0	20.0	44.5	42.8	46.0
2	25.0	33.3	33.4	16.3	26.4
3	21.0	13.4	5.4	34.8	21.6
4	14.0	33.3	16.7	6.1	6.0
Totals	100.0	100.0	100.0	100.0	100.0

The tapered flights removed a greater percentage value of the fruit in the first compartment than did the

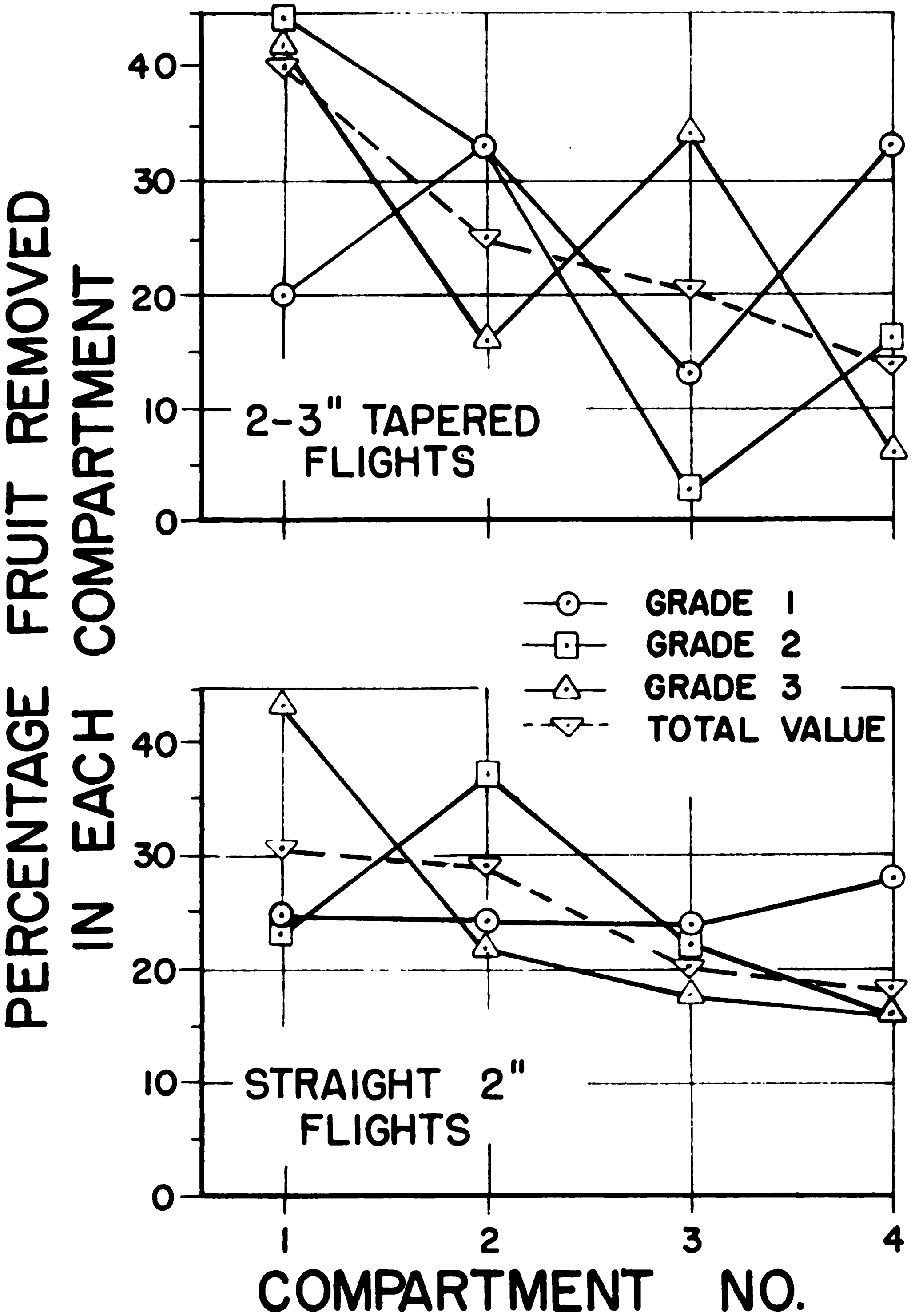

Figure 27. Percentage (by value) of the harvested fruit removed in each compartment by grade and total value.

straight flights. A larger amount of grade 2 was also collected. In each case the larger size fruit was removed first. The straight flights would seem best in that a decreasing trend is obtained in the percent of fruit harvested from compartment one to compartment four. The best type of flight would give a curve indicating a high percentage return in the first compartment and a lower percentage return in the fourth compartment.

TABLE 6

PERCENTAGE VALUE OF HARVESTED FRUIT REMOVED IN EACH COMPARTMENT--STRAIGHT 2-INCH FLIGHTS

Compartment No.	Total Removed (By Value)	Grade 1	Grade 2	Grade 3	Rejects (By Weight)
	%	%	%	%	%
1	31.2	24.0	23.5	43.2	47.5
2	29.7	24.0	37.4	22.4	23.0
3	20.6	24.0	22.6	18.0	20.5
4	18.5	28.0	16.5	16.4	9.0
Totals	100.0	100.0	100.0	100.0	100.0

Effect of machine training and harvesting on gross return per acre

The vines in plot 2 were harvested nine times. The number of harvests in plot 3 was reduced to seven because of disease problems. Table 7 gives a summary of the return per acre for both plots.

TABLE 7

VALUE OF THE CROP HARVESTED IN PLOTS 2 AND 3

Row	Type Of Training	Type of Harvest	Return Per Acre $	Return Per Acre Equal Plant Population Basis $
14	Machine	Machine	39	-
16	Hand	Machine	38	-
18	Machine	Hand	186	168
19	Check Row	Hand	187	187
24	Machine	Machine	47	-
25	Machine	Hand	175	163
26	Check Row	Hand	191	191
27	Hand	Hand	180	172
28	Hand	Machine	51	-
29	Machine	Machine	43	-
30	Machine	Machine	51	-

The effect of machine training and harvesting on yield as shown in Table 7 is very significant. The economic efficiency of the harvester was 21 percent in plot 2 and 27 percent in plot 3. The effect of the machine harvesting process was to reduce the average yield by 76 percent. The economic efficiency values were not obtained from a statistical analysis. They should only be regarded as trends resulting from the machine harvesting process.

One factor that tended to lower the economic efficiency was the initial injury to the vines. The injury does not show up immediately but will affect the final return per acre.

Table 7 also indicates there is an effect on the return per acre owing to the use of the pneumatic vine trainer. In both plots for an equal plant population basis, a reduction in return of over 10 percent was experienced. The decrease in returns may be a result of moving the vines in one direction and removal of some of the female flowers during the training process.

Individual harvest efficiencies increased during the season. The average increase for two rows in plot 2 and plot 3 is shown in Figure 28. As the plant matures, fruit is set farther out on the vine resulting in an increase in machine efficiencies. A decrease was also noted in the fruit remaining in the six-inch zone near the base of the plant and the fruit left on the ground.

Figure 29 shows the distribution of the three grades of fruit harvested by hand and machine methods. Harvesting by hand gave a larger percentage of grade 1 fruit than did machine harvesting. Since some fruit was left on the vine after each machine harvesting operation, the fruit harvested during the next operation would be larger in size.

The economic efficiency of the harvester described in this thesis averaged 24 percent. In an effort to improve the return received by the grower, a time and cost study was conducted using hand labor as a supplement to the harvesting

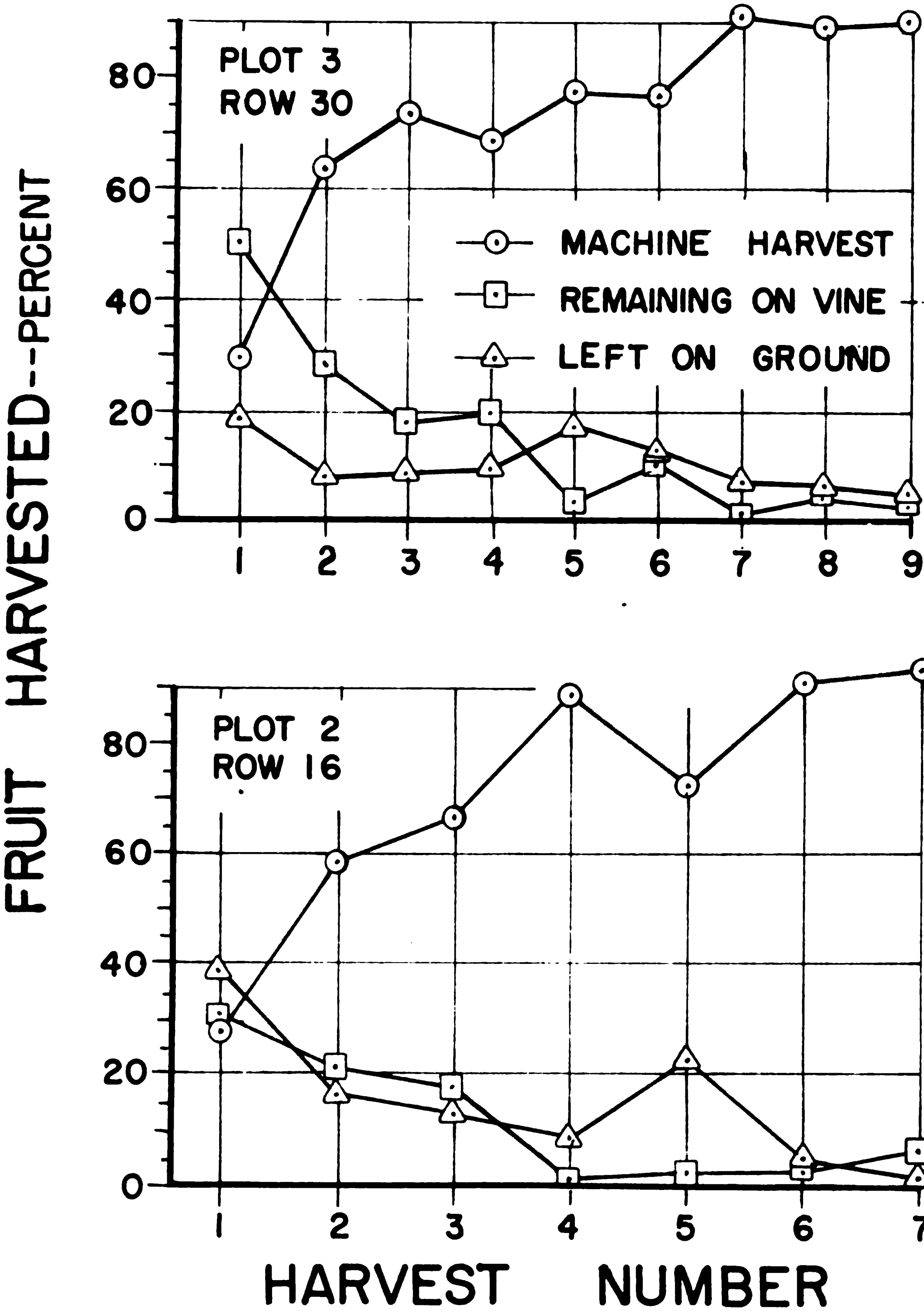

Figure 28. Percentage of fruit harvested during each individual harvest.

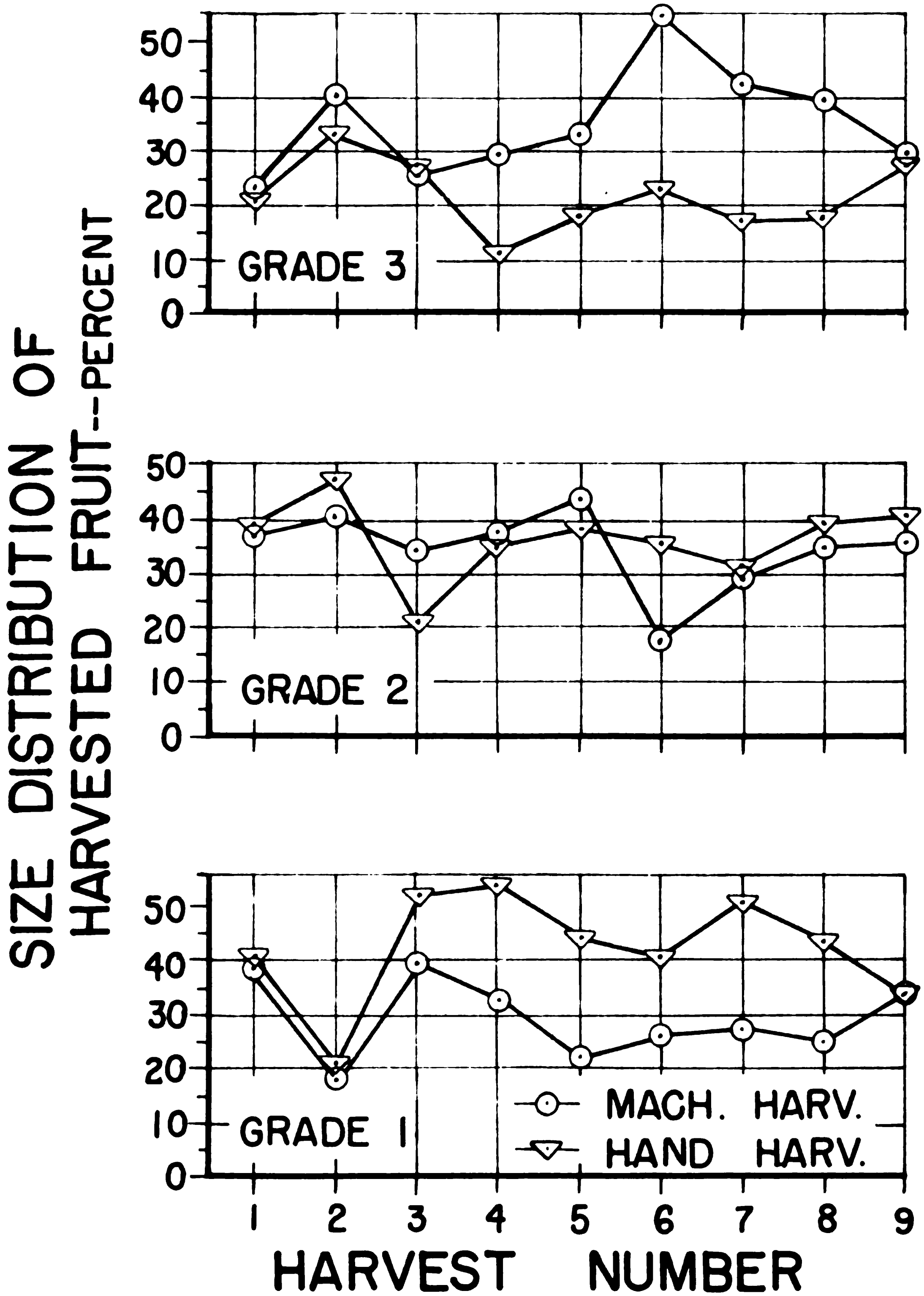

Figure 29. Distribution by grade of the fruit harvested by hand and by machine.

process. Hand labor was used to pick the fruit knocked on the ground and the fruit remaining near the base of the plant.

The labor requirement for the machine operator was 1 3/4 hours per acre. The gleaning operation required 3 hours per acre. The cost of labor was estimated to be $1.25 per hour. Tables 8 and 9 summarizes the return by using hand labor to glean the row after machine harvesting(Figure 30).

TABLE 8

RETURN PER ACRE BY SUPPLEMENTING MACHINE HARVESTING WITH HAND LABOR (PLOT 2--ROWS 16 AND 18)

Gleaning Operations	Gross Return Per Acre	Labor Cost	Semi-Net (1) Return Per Acre
	$	$	$
0	38.25	19.75	18.50
1	48.00	23.50	24.50
2	54.25	27.25	27.00
3	56.00	31.00	25.00
4	58.25	34.75	23.50
5	59.50	38.50	21.00
6	60.25	42.25	18.00
7	61.00	46.00	15.00
8	61.50	49.75	11.75
9	65.25	53.50	11.75

(1) Does not include expenses for repairs, fuel, and depreciation of harvester.

The gross return by machine harvesting alone was $38.25 per acre (Table 8). When the first machine harvest was supplemented with a gleaning operation the gross return increased to $48.00 per acre; which corresponded to a semi-net return of $24.50 per acre. The highest semi-net return--$27.00 per acre--was received when the first two machine harvests were supplemented with gleaning operations. Similarly, in plot 3 (Table 9) the highest semi-net return--$40.00 per acre--was realized when two gleaning operations were used.

TABLE 9

RETURN PER ACRE BY SUPPLEMENTING MACHINE HARVESTING WITH HAND LABOR (PLOT 3--ROWS 28 AND 29)

Gleaning Operations	Gross Return Per Acre	Labor Cost	Semi-Net (1) Return Per Acre
	$	$	$
0	51.00	15.00	36.00
1	58.00	18.75	39.25
2	62.50	27.50	40.00
3	65.50	26.25	39.25
4	67.50	30.00	37.50
5	70.25	33.75	36.50
6	71.00	37.50	33.50
7	72.50	41.25	31.25

(1) Does not include expenses for repairs, fuel, and depreciation of harvester.

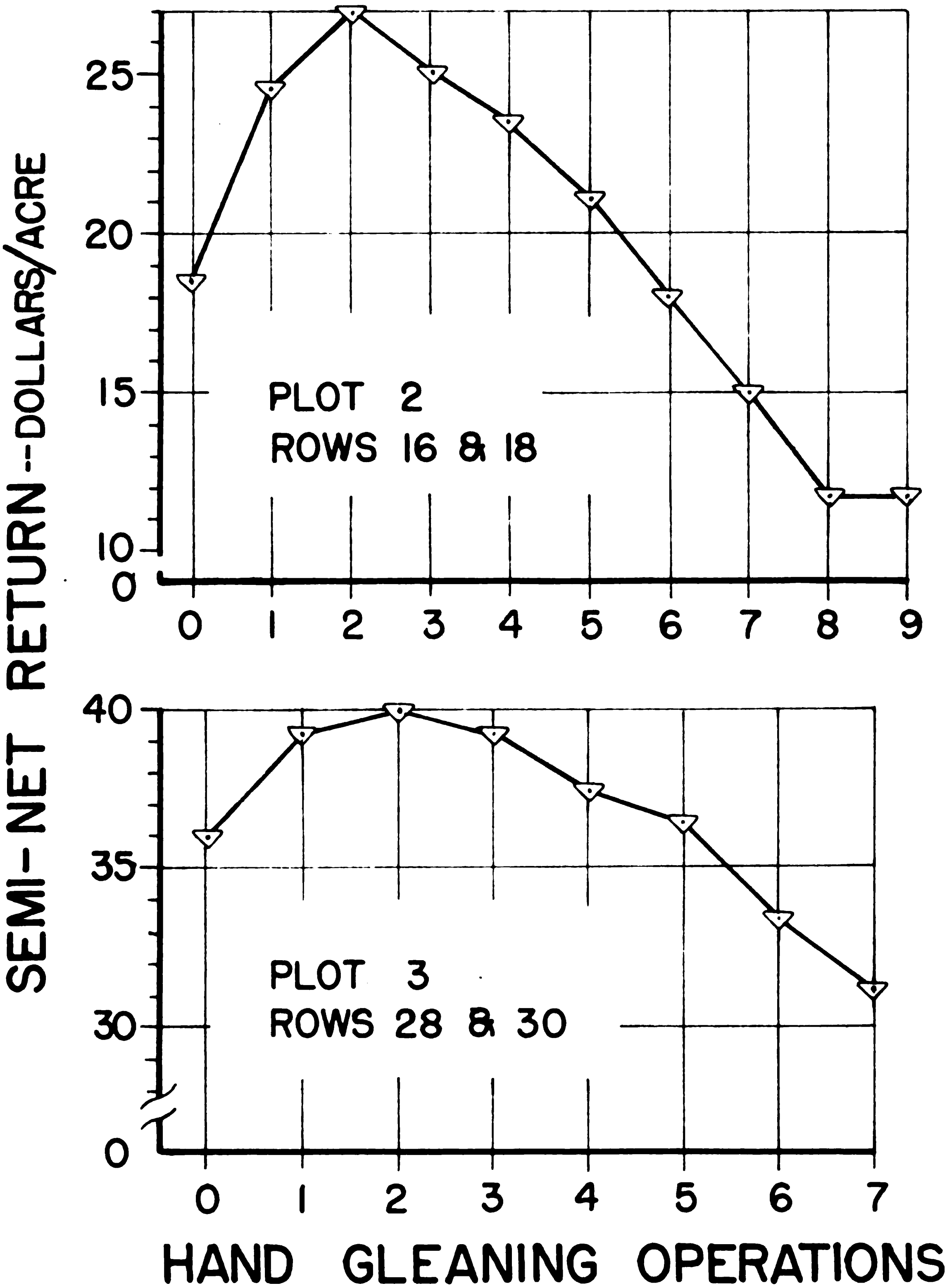

Figure 30. Semi-net return resulting from application of a variable amount of gleaning operations with machine harvesting.

The results in Table 7 show a return for hand harvesting in plots 2 and 3 of 187 dollars and 191 dollars respectively. Since a grower would receive less than half of the amounts presented--95 dollars--the semi-net return per acre from each plot would be 28.4 and 42 percent of the net return received by the grower.

The gleaning operation can be performed with ease, since the vines are trained in one direction and the base of the plant is exposed to the gleaning operation.

Machine performance

The mechanical cucumber harvester developed for this research endeavor provided an effective means for obtaining data on machine efficiencies and the reduction in yield and income as a result of mechanical harvesting.

The capacity of the harvester ranged from 0.8 to 1.2 acres per hour based on a row width of eight feet. The row width is expected to decrease to a minimum of five feet for a machine designed to harvest trained rows.

The tapered pickup worked very well in every respect. Although three sets of retracting fingers were initially installed on the pickup, another set could have been added to assist in lifting the longer vines onto the separating bed.

The separating bed, using the fabric material for flights, worked effectively in elevating the harvested fruit to the conveyor. It did not function effectively in removing the fruit from the vine. The fabric flight would bend back as the flight moved underneath the vine. To improve the picking process a set of roller flights were installed (Figure 31). The roller flights exerted a greater force on the vines resulting in excessive foliage removed.

While the secondary flight provided assistance in removing the fruit set near the base of the plant, it also caused some damage to the main stem of the plant (Figure 34). Dirt and trash were often thrown onto the separating bed by the secondary flight system.

The vines dropped off the separating bed in a favorable position for the next harvest (Figure 32). As the season progressed and the vines grew to greater lengths, considerable dragging occured as the vine tips caught on the bed-mounting frame.

Figure 33 is a general view of plot 2 showing the condition of the vines after six harvesting operations. The weather was favorable throughout the growing season and provided excellent growing conditions. Another factor which contributed to the rapid growing of healthy vines was the installation and operation of an irrigation system at the beginning of the growing period.

Figure 31. Roller flights installed on the separating bed during the later part of the testing season.

Figure 32. Position of vines after leaving the separating bed.

Figure 33. Condition of the cucumber vines in plot 2 after six harvesting operations.

Figure 34. Main stem damage on the cucumber vine resulting from the action of the secondary flights.

CONCLUSIONS

The following conclusions are based on the observed performance of the mechanical cucumber harvester designed and constructed for this research endeavor and on the data obtained during this investigation.

1. The force required to pull a cucumber plant from the ground was related to the weight of the plant, the variety, type of soil, and to moisture conditions.

2. The pneumatic vine trainer placed 75 percent of the vines in the desired direction during the vine training operation.

3. The pneumatic vine trainer reduced the yield of the cucumber crop by 10 percent.

4. A positive tapered roll pickup with retracting fingers was designed, constructed and developed.

5. A means was developed to accurately measure the force exerted on the vine during the harvesting process.

6. A retainer bar was required on the separating bed to eliminate pulling the vines out of the ground.

7. The return per acre was reduced by 76 percent owing to the combined effects of the pneumatic vine trainer and the mechanical cucumber harvester.

8. The fabric picking flights removed from 7 to 12 percent of the foliage (by weight) during each picking.

9. The roller flights exerted a greater force on the vines with the retainer bar than did the fabric flights.

10. The lower camming device reduced the depth of the separating bed and assisted in removing the fruit set near the base of the plant.

11. The vines dropped off the bed in a position favorable for the next picking operation.

12. One plot of cucumbers was harvested nine times by the mechanical harvester.

13. Machine harvest capacities ranged from 0.8 to 1.2 acres per hour based on a row width of eight feet.

14. The capacity of vine trainer ranged from 1 1/2 to 2 1/2 acres per hour.

15. The semi-net return reached a maximum value when hand gleaning was supplemented with the first two machine harvests.

SUGGESTIONS FOR FURTHER STUDY

1. Study the effect of frequency of machine harvesting of cucumbers on yield and income.

2. Statistical analysis of yield from hand harvesting of cucumbers compared to machine harvesting.

3. Determine the effect of applying a flame to the base of the plant as a means of delaying early fruit set.

4. Use the synthetic plant in evaluating the effectiveness of harvesting mechanisms prior to the growing season.

5. Employ cultivation and pesticide techniques during the harvesting process.

6. Study the effect of compacting the soil near the base of the plant on yield and income.

7. Develop cultural practices that increase the efficiency of mechanical harvesting.

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APPENDIX

General Specifications of the Harvester

Overall length - - - - - - - - - - - - -	126 inches
Overall width - - - - - - - - - - - - -	92 inches
Row width - - - - - - - - - - - - - - -	8 feet
Separating bed length - - - - - - - - -	60 inches
Separating bed width - - - - - - - - -	42 inches
Upper bed depth- - - - - - - - - - - -	11 inches
Upper bed clearance- - - - - - - - - -	6 inches
Lower bed depth- - - - - - - - - - - -	6 inches
Flight spacing - - - - - - - - - - - -	14 inches
Flight speed	
Fabric flights- - - - - - - - - - -	290 ft/min
Roller flights- - - - - - - - - - -	230 ft/min

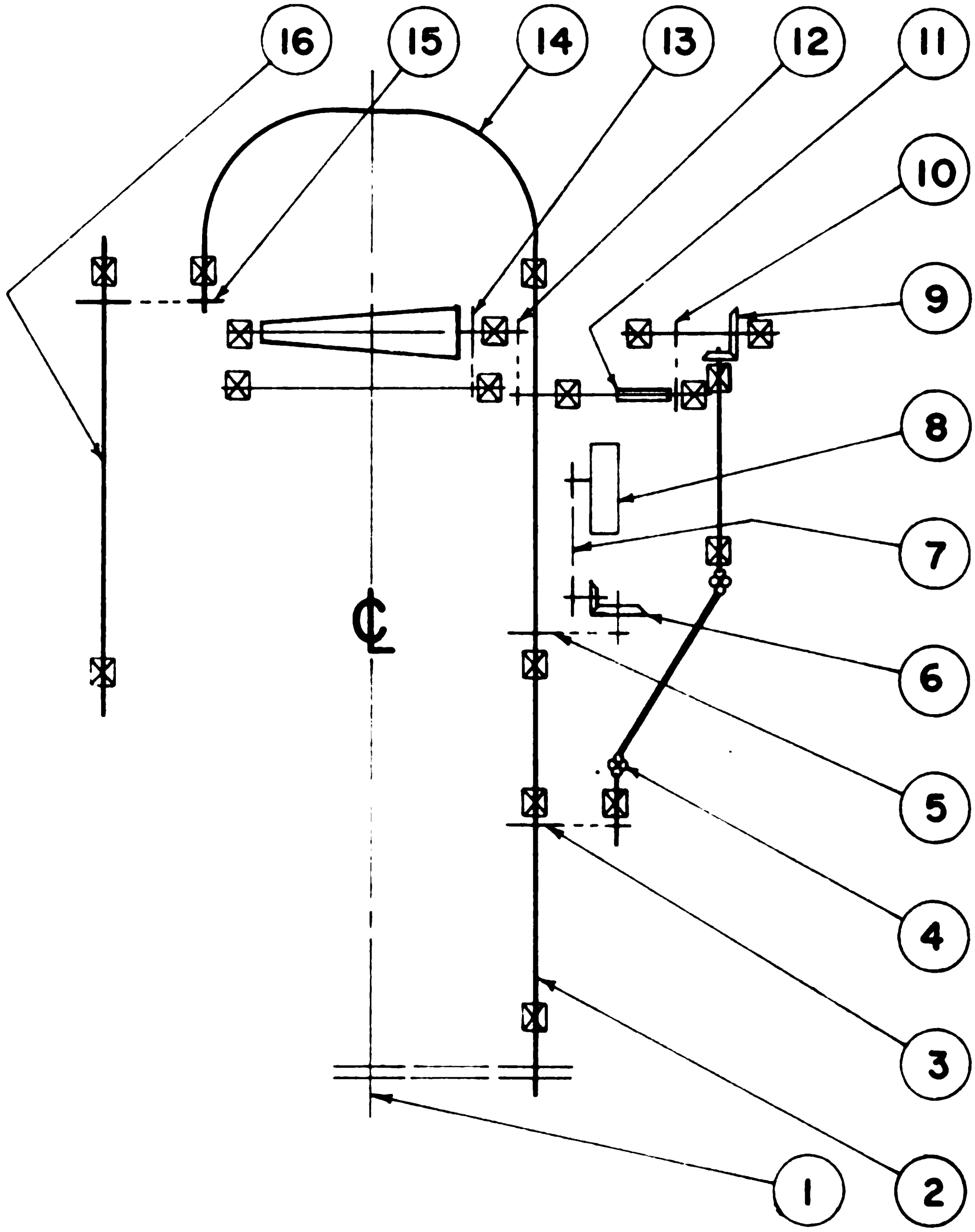


Figure 35. Schematic diagram of drive mechanisms.

Description of Drive Mechanisms

Number	Description
1	Main drive. Double V-belt "B" section sheaves 6-inch diameter drive to 5 1/2-inch diameter drives.
2	Main drive shaft.
3	Separating bed drive. No. 50 roller chain. Drive sprocket (16 teeth), driven sprocket (16 teeth).
4	Universal drive.
5	Gear box drive, V-belt "A" section sheaves. 8-inch diameter drive to 2 1/2-inch diameter driven.
6	Gear box--1:2.
7	Fan drive. V-belt "A" section sheaves. 6 1/2-inch diameter drive to 3 3/4-inch diameter driven.
8	Cleaning fan.
9	Bevel gear drive (2:1 reduction) for cross-conveyor, pickup, and stripper roll.
10	Cross-conveyor drive. No. 40 roller chain. Drive sprocket (16 teeth), driven sprocket (20 teeth).
11	Cross-conveyor drive roll.
12	Pickup drive. No. 40 roller chain. Drive sprocket (10 teeth), driven sprocket (20 teeth).
13	Stripper roll drive. V-belt "A" section sheaves. 8-inch diameter drive to 2-inch diameter driven.
14	Flexible shaft drive.
15	Secondary flight drive. No. 40 roller chain. Drive sprocket (12 teeth), driven sprocket (20 teeth).
16	Secondary flight.

HARVESTING RECORD -- DATA SHEET #2

Cucumber Harvester Project
G.S. 126

RECORDER ______________________

DATE ______________________

PLOT NUMBER ______________________

ROW NUMBER ______________________

TYPE OF HARVEST ______________________

PLANT POP BEFORE ______________________

PLANT POP AFTER ______________________

SPEED ______________________

CAPACITY ______________________

AGE OF PLANTS ______________________

REMARKS: ______________________

____

____

MACHINE HARVEST

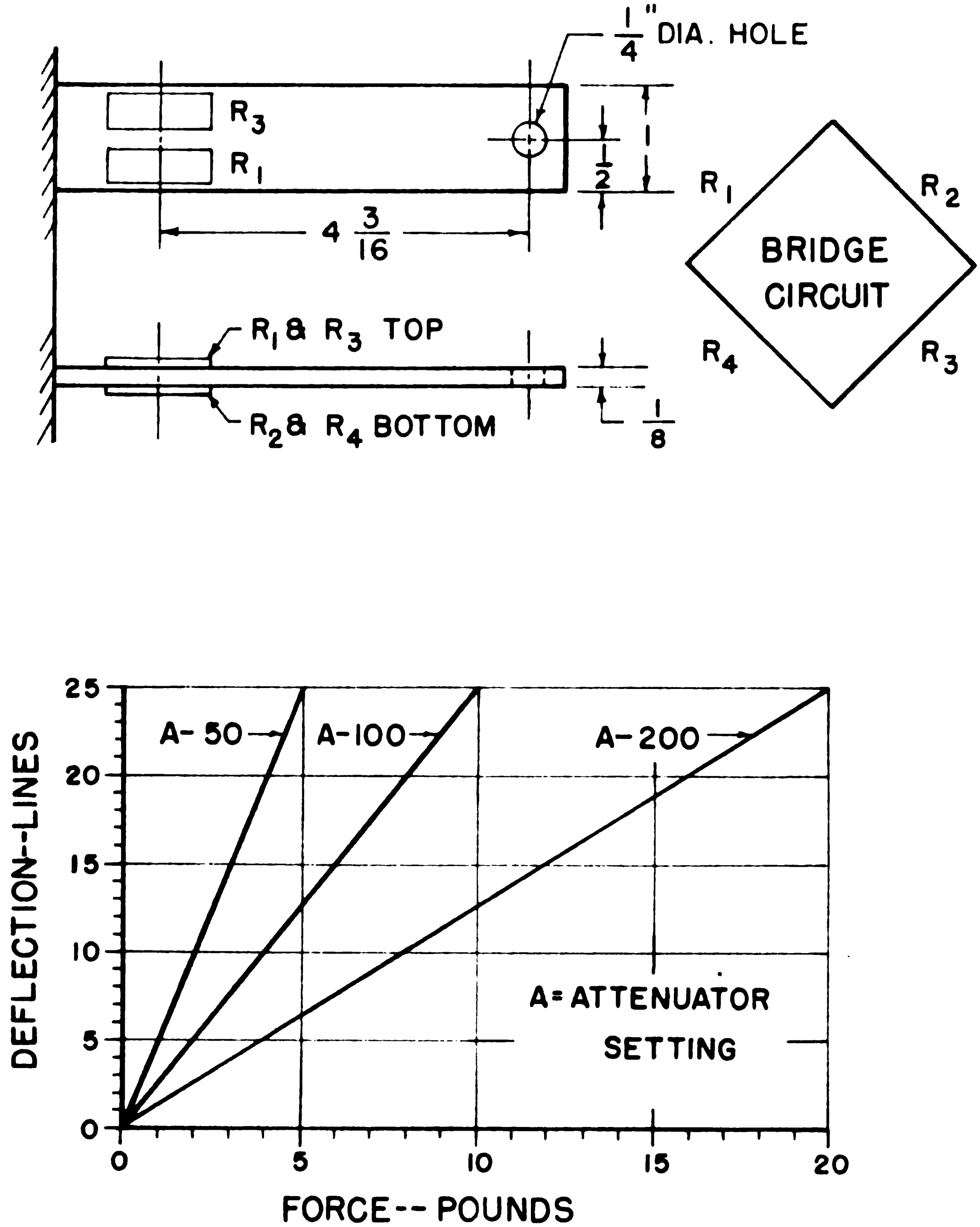
	#1	#2	#3	Rejects	Broken
Weights					
Total					
Percentages					

LEFT ON VINE

	#1	#2	#3	Rejects	Broken
Weights					
Total					
Percentages					

REMAINING ON GROUND

	#1	#2	#3	Rejects	Broken
Weights					
Total					
Percentages					



To obtain the above calibration, the internal circuit was adjusted to give 10 lines of pen deflecfion when the calibration button was depressed with an attenuator setting of 20.

Figure 36. Schematic diagram of transducer, and calibration curve.