THE ADAPTATION OF THE COMBINE TO THE HARVESTING OF NAVY BEANS

Thesis for the Degree of M. S.

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This is to certify that the

thesis entitled

"The Adaptation of the Combine to the Harvesting of Navy Beans"

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H. F. McColly
Major professor

Date November 27, 1951

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THE ADAPTATION OF THE COMBINE TO THE HARVESTING OF NAVY BEANS

A Thesis

Presented to

the Faculty of the School of Graduate Studies

Michigan State College

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Agricultural Engineering

by

Andrew J. Asher

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ABSTRACT

A previous survey indicated that the farmers of Michigan suffered large losses in the harvesting of navy beans because of adverse weather conditions. Two projects were undertaken by Michigan State College to alleviate this condition. One project is plant breeding, which is being conducted by the Farm Crops Department. The Agricultural Engineering Department is working on the mechanical aspects of the harvesting problem.

This thesis treats some of the mechanical difficulties involved in the cutter-bar mechanism. Several devices were tested to improve the hay intake into the combine.

The result of these tests indicated that the Hume reel and the flat type guard are the most advantageous from the operator's viewpoint of visibility, rock damage, and ease of operation.

November 27, 1951

H. F. McColly

Major Professor

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Professor H. F. McColly, under whose inspiration, constant supervision, and unfailing interest this investigation was undertaken and to whom the results are herewith dedicated.

He is also greatly indebted to Dr. E. E. Down for his kind guidance and valuable help insofar as the botany of navy beans is concerned.

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CHAPTER I

INTRODUCTION

A problem exists in Michigan of harvesting navy beans because weather conditions at harvest time may not be favorable. The harvest may begin in August and extend into the later part of October. The actual time of harvest depends on the weather. The navy bean in Michigan is one of the principal cash crops.

Moisture content of the air after the beans have matured is a very critical matter. Even if the relative humidity of the air is as low as 82 per cent, the conditions are such that mold formation of the newly matured beans is favored. Higher humidity will damage the crop to a point that harvesting will not be profitable. If the beans are not mature at the time this condition exists, they will not be affected. The resistance of the growing plant will thwart the molding. For this reason some plots are affected, and others are not. Even the soil type in a given field will vary enough to prevent even maturity and uneven damage will be the result. Since these were the prevailing conditions during the harvesting period of the year 1950, the amount of loss was a direct function of maturity.

The usual method of harvesting includes, in order, pulling, windrowing, and combining with the use of the pick-up attachment on the combine. These operations require the use of the tractor, a special bean puller, a hay windrower, or a special bean windrower, and a combine with the pick-up attachment. This type of equipment is used quite extensively on the average size farm.

Farmers who engage in farming on a larger scale may use the self-propelled bean thresher. This is a machine converted from a simple thresher to a unit which will operate in the field and will feed directly from the windrow. This machine has two cylinders for the threshing of the beans. The initial cylinder operates at a low speed (200 to 250 rpm) and the second cylinder operates at a higher speed (600 to 750 rpm). The second cylinder removes the beans which have escaped the initial threshing. This type of machine reduces cracking and splitting of the bean to a minimum. It has a very large capacity. The disadvantages are the weight and the high initial cost of the machine.

One other method which has been tried with a variable degree of success is the stacking method. This involves the use of the mechanical stacker. This method employs the stacker in the operation from the windrow. The straw and pods are picked up, molded into a cylindrical shape, and deposited upon the ground. They are left to cure.

Later they are threshed by a stationary thresher. This method requires a considerable amount of labor.

A more primitive variation of this method is the stacking by hand. This requires the most labor with respect to the total ways of harvesting. Sometimes the farmer may bring the stacks to the barn and then thresh in the winter. This method gives the most insurance for an adequate return from the crop, but is the most costly.

Tests on the feasibility of baling the hay and then threshing proved unsuccessful. The losses were high and the additional costs did not warrant the questionable advantage of handling ease. One problem encountered was securing bales of the desired weight. Light bales fell apart easily, while heavier bales were difficult to handle by one person.

CHAPTER II

PICK

Pick beans are beans which are unfit for human consumption for reasons of discoloration, weather damage, mold, or diseases. These beans are removed by means of the electric eye, a device which automatically rejects the beans defective in color. The cost of this operation is dependent upon the quality of beans which are removed. The current fee charged for the removal of pick beans is $0.15 per pound. When the price of beans is $7.00 per hundred pounds, the maximum pick which a farmer can afford to have before he starts paying the elevator to accept his crop is 46.6 per cent. Or, in other words, he must sell beans of such a quality that they contain no more than 46.6 pounds of pick in a hundred pounds of grain. However, he cannot afford to harvest a crop which has a pick of this amount. He must include the cost of harvesting in his calculations, and thereby arrive at a decision. In some cases he would save money by leaving the crop in the field.

CHAPTER III

TYPES OF BEANS GROWN IN MICHIGAN

Two general types of beans are grown in Michigan. One bush type, the Michelite, stands fairly well and produces runners. The vine type which existed earlier before the introduction of the bush type is called the Robust. It is one which grows rather profusely on the top of the soil, and it presents a very difficult problem in harvesting. Machines which gather close to the surface of the soil will pick up rocks and the damage to the machine can be very high. Parts susceptible to rock damage are the pick-up attachment, cylinder, and the concave. Low, ground clinging pods are subject to damage if not harvested early. Moist conditions which will not allow harvest is very conducive to bean discolorment.

Plant breeding work by Dr. E. E. Down indicates that a new variety may be available in the next few years. This variety was obtained by X-ray treatment of Michelite beans. The treated seed was grown and strains were selected. These strains were then crossed back to Michelite which was not treated. This crossing was for the purpose of giving hybrid vigor, early maturity, and high yielding quality. The strains were then selected again for the absence of runners, height of pod, and disease resistance.

Since all of these factors must be considered, the work of developing a new variety takes a long time.

CHAPTER IV

SURVEY OF LITERATURE

In Michigan the navy bean has been a crop which has received little attention by research men. Early work done in 1918 consisted of a report[1] urging farmers to make early selection of seed to insure adequate supplies of good seed. Ayleworth[2] published some results in 1933 pertaining to the economics of bean production. These results were summarized as follows:

a) Grow the beans only on soil and in areas suited to their production.
b) Rotate the crops so that a green manure crop can be plowed under.
c) Apply manure at a reasonable rate, covering as many acres as possible.
d) Use seed of the Robust variety.
e) Seed the beans the first part of June.
f) Make better use of labor by eliminating small fields and by the thorough preparation of the soil prior to seeding.

Of this summary (d) does not apply since today better varieties are being developed. Ten years later Brown[3] presented some data concerning the bean production and gross farm income. He stated that the yield was so low on some isolated farms and in some localities the farmers would have saved money if they had not grown the crop. He also noted that the major factor affecting gross income per acre was the yield. His analogy was:

"Farmers who have the greatest advantage in the production of beans find that crop more profitable than growing feed crops even under rather unfavorable bean prices."

Brown summarized the most important factors affecting the gross income per acre as being yield, time of marketing, quality of crop, and variety grown.

McDow[4] found in a study of defoliation that the two chemicals, dinitro-ortho-secondary-butyl and penta-chlorophenol, were satisfactory. On a field basis he found that drying of the stalk was accelerated when defoliating agents were used. Samples of the beans exposed to the chemicals were analyzed. The content of the bean defoliating chemicals absorbed by the beans through the pods was negligible and not harmful to human beings.

Bainer and Winters[5] conducted a series of tests with a combine using rubber rollers in California. They were able to thresh very fragile beans without damage. Since they use two rollers, the cost of the machine is higher. However, the use of rubber rollers or rubber bars in combines has not been accepted on a wide basis in Michigan.

Pettigrove[6] emphasized cultural practices which are essential to bean production. He cited the fact that early plowing under of a green manure crop increases yield. He noted that planting in the early part of June was essential for crop maturity. Adequate cultivation without root pruning

should secure weed control and improve plant growth. Poor drainage has an extensive effect upon the quality of bean production. Maturity and disease resistance are dependent upon the quality of drainage.

Kennedy[7] summarized the desired characteristics of the navy bean for the use of the plant breeder. They are as follows:

a) A bean that will produce a uniformly high yield.
b) A bean whiter and smoother in appearance than the present variety.
c) A bean that will mature evenly to facilitate mechanical harvesting.
d) A bean that will produce bush type bean vines to carry the pods off the ground to prevent water damage and facilitate mechanical harvesting.
e) A bean that will resist disease.
f) A bean that will mature earlier to allow planting a cover crop for winter protection.
g) A bean larger in size and more uniform in size and contour.
h) A bean that will cook easier and quicker.

CHAPTER V

PRELIMINARY ANALYSIS

Experimental Work 1950

Bush bean variety trials. Dr. E. E. Down and Dr. Axel Anderson of the Farm Crops Department had an experimental plot on the Walter Reinbold farm at Gera, Michigan. The Agricultural Engineering Department cooperated with Farm Crops in the harvesting process. Bader Brothers, John Deere dealers at Reese, Michigan, furnished a combine and an operator for this work. Universal Sales at Saginaw provided a Hume reel which was attached to the combine.

Initially, the plots were visited on August 28 and the plants were found to be defoliated and ready for harvest. The decision was made to combine directly with this equipment after Labor Day. However, on September 3 it started raining and the weather was too wet until September 15. Arrangements were made to combine the navy bean plots the following week.

On September 26 arrangements were completed and the harvest was started. Combining was started first on the bush type beans, using high lift guards, the Hume reel, and the John Deere pull type combine. In order to increase the effectiveness of the Hume reel, the high lift guards were removed and the reel was adjusted. This allowed the Hume

reel to be placed very close to the ground and the cutting sickle. The table was set as low as possible to harvest the low hanging pods. The stubble was found by measurement to be one inch in height. This meant, then, that the losses due to shattering of low formed pods was decreased. However, some threshing was noticed, which was caused by the reciprocating action of the sickle in shearing the stalk. It was believed that these losses were low, and would be comparable to losses sustained by the common method of pulling, windrowing, and combining from the windrow. As pointed out by the agronomists, the reason this method was good was because of the increased plant height and the standability of this variety. Weather losses due to pick, determined by taking random counts from the grain tank, were very small. This concluded work in the Saginaw area for 1950.

Michigan State College Agricultural Engineering Plots. The work on the combining of the experimental plots was delayed by extremely bad weather, including rain and non-drying overcast days, until October 6. Early predictions of a total loss delayed harvest until it was found that there was a possibility of realizing a little value from the crop. These early reports were based on general weather conditions and damage in the navy bean area of the Thumb. Since weather condition at maturity is the critical factor, these late maturing plots were not affected so adversely.

On October 4 a Gleaner combine was obtained on a lease arrangement between the Agricultural Engineering Department and the Farm Bureau Services, Lansing, Michigan. On October 6 some beans were pulled and windrowed. Before harvest could begin the weather changed adversely. These beans were then lost because of spoilage in the windrow. However, in these first attempts the spiral auger intake from the table sheared three bolts on the driving sprocket when a small rock lodged in the auger. This rock was kicked into the windrow by the windrowing process. This was repaired. During the next day pulling and windrowing was done. On October 20 the same three bolts sheared, and the overhauling operation was repeated. This is a definite weak spot in the Gleaner combine, since there was no appreciative clogging or heavy feeding at this time. Another day was lost due to these repairs.

In the week of October 22 rain prevented harvesting. Work was resumed on October 25 and completed the following day.

A total yield of 4630 pounds was placed in the Farmers Elevator Company, Lansing, Michigan. These beans which were harvested had a pick of approximately 30 per cent and were valued at $2.50 to $3.00 per hundred pounds. Later they were sampled at the elevator, and the pick was estimated at 40 per cent. The price at this rate of pick was given at $1.00 per hundred pounds.

About twenty bushels were turned over to Professor J. S. Boyd for drying experiments. The initial moisture content was fairly low, i.e. 15 per cent. The beans were then out of the critical moisture area. Samples of these beans were cooked by cooperators. Some of these beans were treated with ozone and checked against naturally dried beans. Since this project is still in progress, definite results cannot be given. However, information regarding this project can be obtained from Professor Boyd.

CHAPTER VI

SUMMARY OF OPERATING PROCEDURE 1951

Bush Bean Variety Trials

In view of the fact that the Gleaner combine used the preceding year did not have as many adjustments available as desired in this type of experimental work, it was decided that a different machine was needed. A study was made to determine the requirements of a machine which could be used in conjunction with other projects. The requirements were:

1. A self-propelled machine for work areas in which a tractor may not be easily procured.
2. A machine with many adjustments available independent of each other.
3. A machine which can be transported easily to different parts of the state.
4. A unit serviceable by well located dealers for parts, etc.
5. A machine capable of harvesting many small grain crops commonly grown on the farms of Michigan.

Considering the preceding requirements carefully, it was finally decided that a self-propelled Massey-Harris seven foot clipper combine would fulfill the need closely. Arrangements were then made with L. W. Garver, Product and Field Research Engineer, Racine, Wisconsin and R. R. Pascal,

District Manager, Jackson, Michigan to lease a combine on the ten per cent basis to the Department of Agricultural Engineering.

This combine arrived on August 22, 1951. The set-up was accomplished by assembling the table, reel attachment, and straw spreader. This preliminary work was completed during the first week of September.

Bean harvesting was pronounced ready in the Saginaw area by Dr. E. E. Down of Farm Crops Department. The combine was then loaded on a trailer and transported to the Henry Hetzner and Sons' farm at Saginaw, Michigan where the experimental plots were located. A Hume reel was placed on the combine in place of the standard reel which came as standard equipment with the machine.

The bush type navy beans in the experimental plots were very similar in appearance to the soy beans grown in the Middle Western States. The most notable difference is the lack of height, which is natural for a short season crop. The vine-type Michelite beans were also grown in these plots.

Harvesting was started on September 5 in the Saginaw area. The initial adjustment was to decrease the cylinder speed. This adjustment was needed because the beans were cracking excessively. After the cylinder speed adjustment was made cracking decreased somewhat. However, it was

decided that the combine had too many concave bars in the concave, and they were removed later. In order to continue operation on this day the speed of the entire combine was reduced by throttle adjustment. This decreased the speed of the straw rack and shakers, which caused some clogging on the part of the straw racks. With these measures taken, the combining preceded with Amir Khan taking efficiency tests and loss counts. The beans had good quality and very low pick.

The later part of the first week of September was unfavorable for harvest because of heavy rains. However, on September 12 the weather was again favorable and the harvesting of the test plots was completed by the once-over method. The beans and bean straw contained more moisture and it was noted that fewer losses occurred at this time at the cutter bar. The previous speed (450 rpm) for the cylinder was used and found to be satisfactory for efficient harvesting.

A comparison might be noted here. Using the once-over method for harvesting, one man was required to operate the combine for two hours. Another method of pulling, windrowing, hauling to the barn, etc. was in progress in a nearby field. Approximately the same acreage was harvested by combine as by the other method which employed seven men.

Michigan State College Experimental Plots

On October 3 the harvesting of the Michelite variety of navy beans on the experimental farms was begun. The primary purpose of these trials was to establish the best method of harvesting navy beans directly. Some difficulty was encountered in the harvest, since there was no weed seed eliminator on the combine. The content of weeds increased the moisture content to the point that it was necessary to clean the beans in order to insure safe storage. An A. T. Ferrell cleaner was used for this purpose on the following day.

One difficulty that was noticed in combining the plot was ridges. Ridges were evident in the plots due to seed bed preparation and cultivation practices. Ridges are bad because the uneven ground causes the table to tilt in such a manner that one row may be harvested and the second and third row are more or less missed because one must not allow the table to operate below the level of the ground. If this happens then there is damage to the combine due to the wearing effect of dirt. Also, the grain that is delivered to the grain tank is of poor quality because the combine is incapable of separating all the fine dirt from the grain.

Another difficulty which is generally encountered on Michigan farms is stones. In this method by raising the table, using the mechanical lift, stones may be avoided. With the use of the Hume reel they may be sighted quickly. Nevertheless, some of the crop is lost in raising the table. The best solution is using a field relatively free from stones.

In the operations, the general comments must include the discussion on pick and the number of cracks. Since the condition of the field was soft, due to recent rains, the straw was tough. The beans, being in standing position, were drier than the stalks and low clinging pods. The pick was low in the beans harvested, while the low formed pods were beginning to show damage from weathering effects. The cracks were few for the toughness in the stalks prevented easy threshing and shattering that comes with extremely dry beans.

On October 5 three rows were pulled by hand in order to compare direct harvesting with the pulling, windrowing, combining method. These were damaged considerably by rain befor harvest could be effected. This shows the effects of the unpredictable Michigan weather at harvest time.

The next week the weather turned favorable for harvesting. More beans were pulled, and the work was completed on October 11. The regular reel was used during these tests.

Canvas stripping was added to the regular reel to decrease the grain losses at the cutter bar. However, this gave the added difficulty of sweeping up the stones, as well as the shattered beans. Visibility was reduced very much. Stones clearly visible in using the Hume reel were not visible at all with the regular reel and canvas stripping. The difficulty of operating increased appreciably, for rocks will cause tremendous damage to the cylinder and concave.

Much the same conditions existed this week as was discussed under the report for the week of October 1. Perhaps a greater amount of pick in the lower formed pods occurred. This is not significant insofar as direct combining is concerned, and can be neglected. Other special equipment and tests are discussed in the analysis of data.

CHAPTER VII

OUTLINE OF TESTS PERFORMED

In order to evaluate the work on navy bean harvesting several tests were devised which would give an indication on recommended practices to be followed. It was thought that perhaps the material the farmer already might have on the farm could be used in improvising a good system on the forced feeding of the combine table. Hence the regular six bat reel was used. In conjunction with this reel canvas stripping was attached. This canvas stripping was used to see if better cleaning of the sickle bar could be obtained.

The Hume reel was also used as an attachment which could be purchased, replacing the regular reel. This special reel had a mechanism which gave a lifting action to the crop.

To secure lifting action spring steel tines, which are pivoted on the extremities of the reel, are used. The accentuating mechanism acts on the cam principle, giving a lifting action when the tines are in contact with the plants. When the tines have passed the sickle, and are above the table, the cam action allows the plants to drop to the canvas intake of the combine.

To alleviate the problem of excess threshing at the cutter bar, several guards were ground down so that the top portion with respect to the sickle was removed. This type of guard has been used in the harvest of cow peas and lima beans. They have been used on these crops and are attached to the mowing machine. Checks were made, using these special guards, against the standard guards used on the combine for general grain crop harvesting.

CHAPTER VIII

PICTURE SECTION

Picture No. 1

Professor H. F. McColly Demonstrating the Method of Pick Determination to George French and Dr. W. M. Carleton.

Picture No. 2

A Large Converted Thresher with Pick-up Attachment.

Picture No. 3

The Bean Puller in Operation in Experimental Plots.

Picture No. 4

A Tractor-mounted Windrower.

Picture No. 5

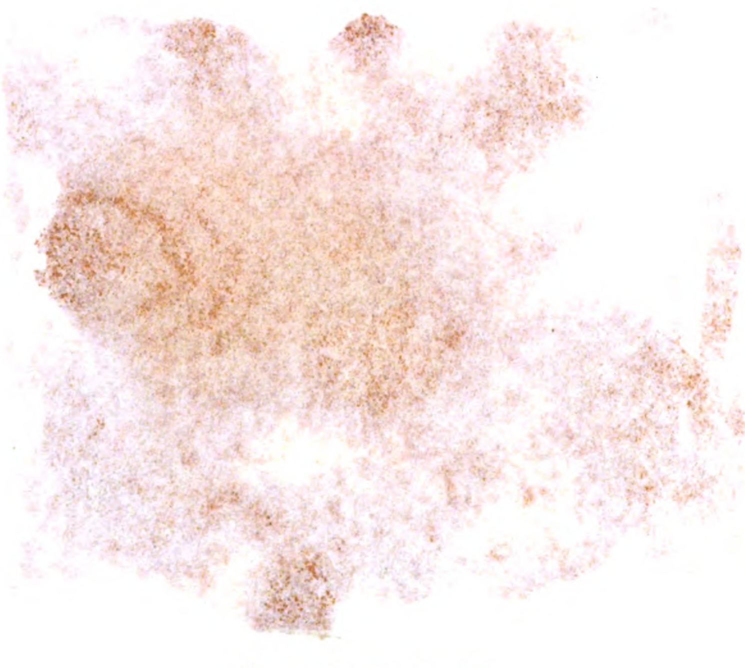
The Gleaner Combine with Pick-up Attachment.

Picture No. 6

Rear View of Gleaner Combine.

Picture No. 7

Massey-Harris Combine with Standard
Reel and Canvas Wipers.



CHAPTER IX

COLLECTED DATA AND FIGURES

TABLE I

PRODUCTION OF DRY BEANS IN MICHIGAN IN 1949

County	Acreage Harvested	Yield per Acre Bushels	Total Production Bushels
Tuscola	69,000	22.0	1,518,000
Huron	100,500	15.0	1,508,000
Saginaw	63,000	20.0	1,260,000
Sanilac	59,000	19.0	1,121,000
Gratiot	31,400	23.0	722,000
State	519,000	19.2	9,950,000

TABLE II

YIELD AND PRODUCTION OF DRY BEANS, NOVEMBER 1, 1950

	Average 1939---1948 cwt.	1949 cwt.	1950 cwt.
Yield per acre Michigan	8.22	11.50	8.00
Michigan total	4,405,000	5,968,000	3,696,000
U.S. total	17,367,000	21,554,000	16,419,000

TABLE III

BEAN COMBINING DATA
Michigan State College Experimental Plots
(Collected by Amir Khan)

1950 Gleaner Combine and Pick-up Attachment

Test	Length Feet	Yield from Combine	Threshing Loss	Shatter Loss	Total Loss	Per Cent Loss
1	108	11.85	1.90	0.37	2.27	16.0
2	85	8.66	1.34	0.33	1.67	16.1
3	88	3.72	.06	0.17	1.03	21.7

TABLE IV

DATA FOR MOISTURE DETERMINATION

Date		Gross Grams	Net Grams	Moisture Lost Grams	Moisture Content Per Cent
1951					
Sept. 25	Straw	62	40	4	10
	Beans	-	49	6	12.2
	Total		89	10	11,3
Sept. 28	Straw	53	31	6	19.3
	Beans	-	82	8	9.8
	Total		113	14	12,4
Oct. 5	Straw	90	68	8	11.7
	Beans	-	120	26	21.6
	Total		188	34	18.0
Oct. 9	Straw	74	52	6	11,5
	Beans	-	65	5	7.7
	Total		117	11	9.5
Oct. 11	Straw	56	34	5	14.7
	Beans		45	4	8.9
	Total		79	9	11.4

TABLE V

DATA FOR COMPARISON TESTS

Date	Method	Distance	Shatter Loss	Pick in Shatter Loss
Oct. 4, 1951	Hume Reel Flat Guards	8 Feet	18 Grams	42%
Oct. 4, 1951	Hume Reel Standard Guards	8 Feet	21 Grams	36%
Oct. 9, 1951	Hume Reel Flat Guards	8 Feet	25 Grams	7.7%
Oct. 9, 1951	Hume Reel Standard Guards	8 Feet	31 Grams	31%
Oct. 11, 1951	Standard Flat Guards Canvas Wipers	8 Feet	19 Grams	18%
Oct. 11, 1951	Standard Reel Standard Guards	8 Feet	30 Grams	10%

Figure 1.

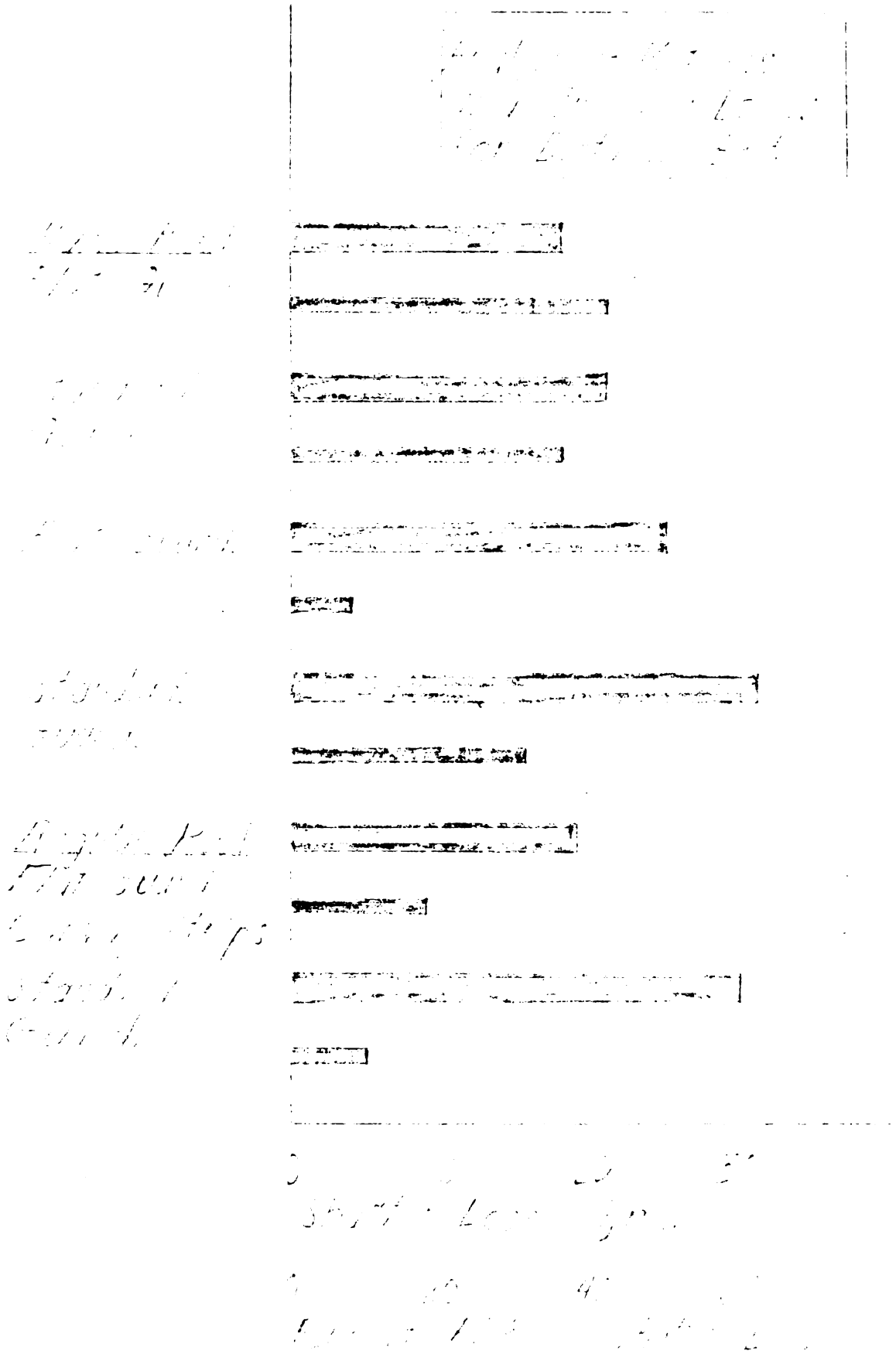


Figure 2.

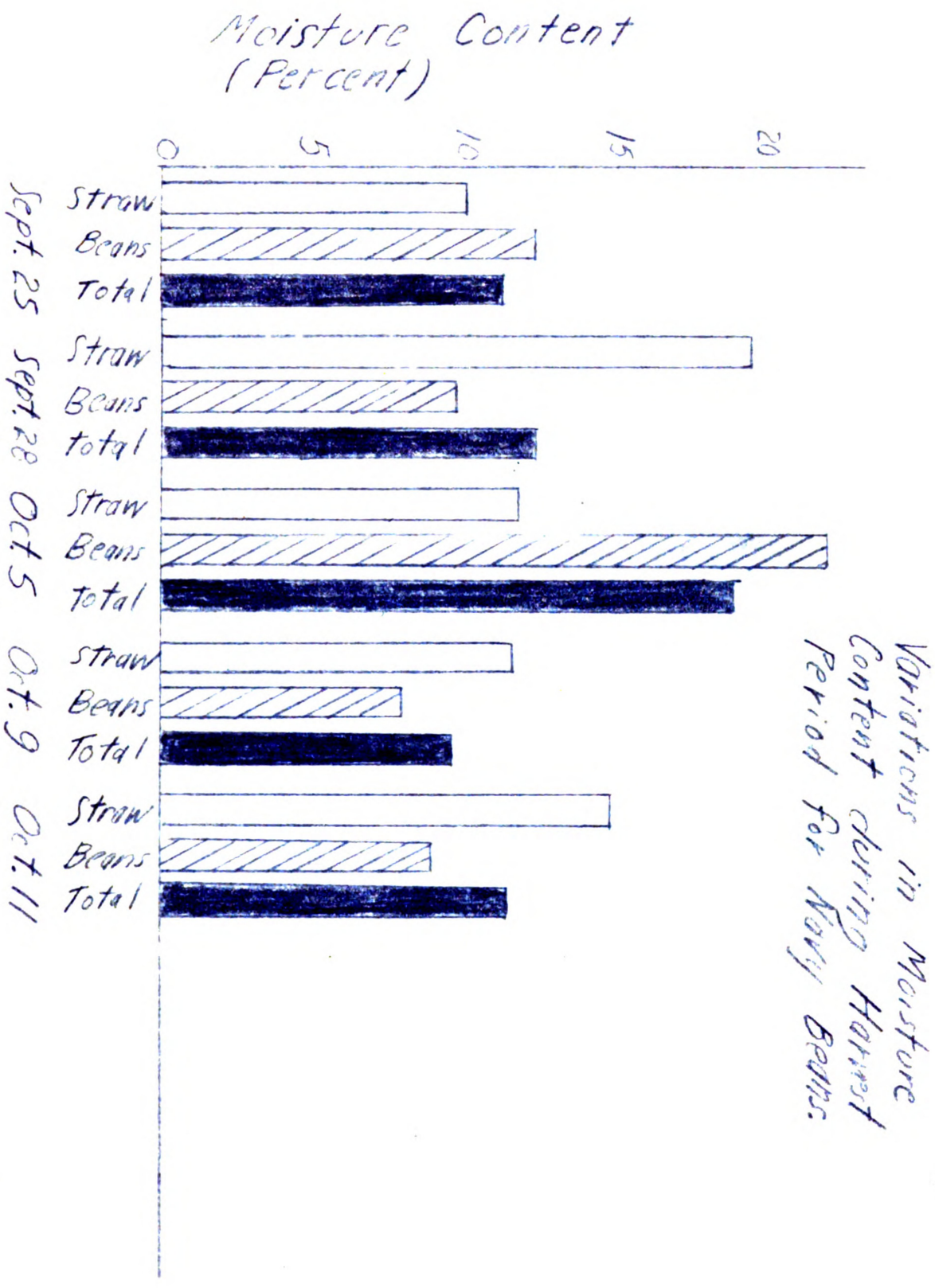
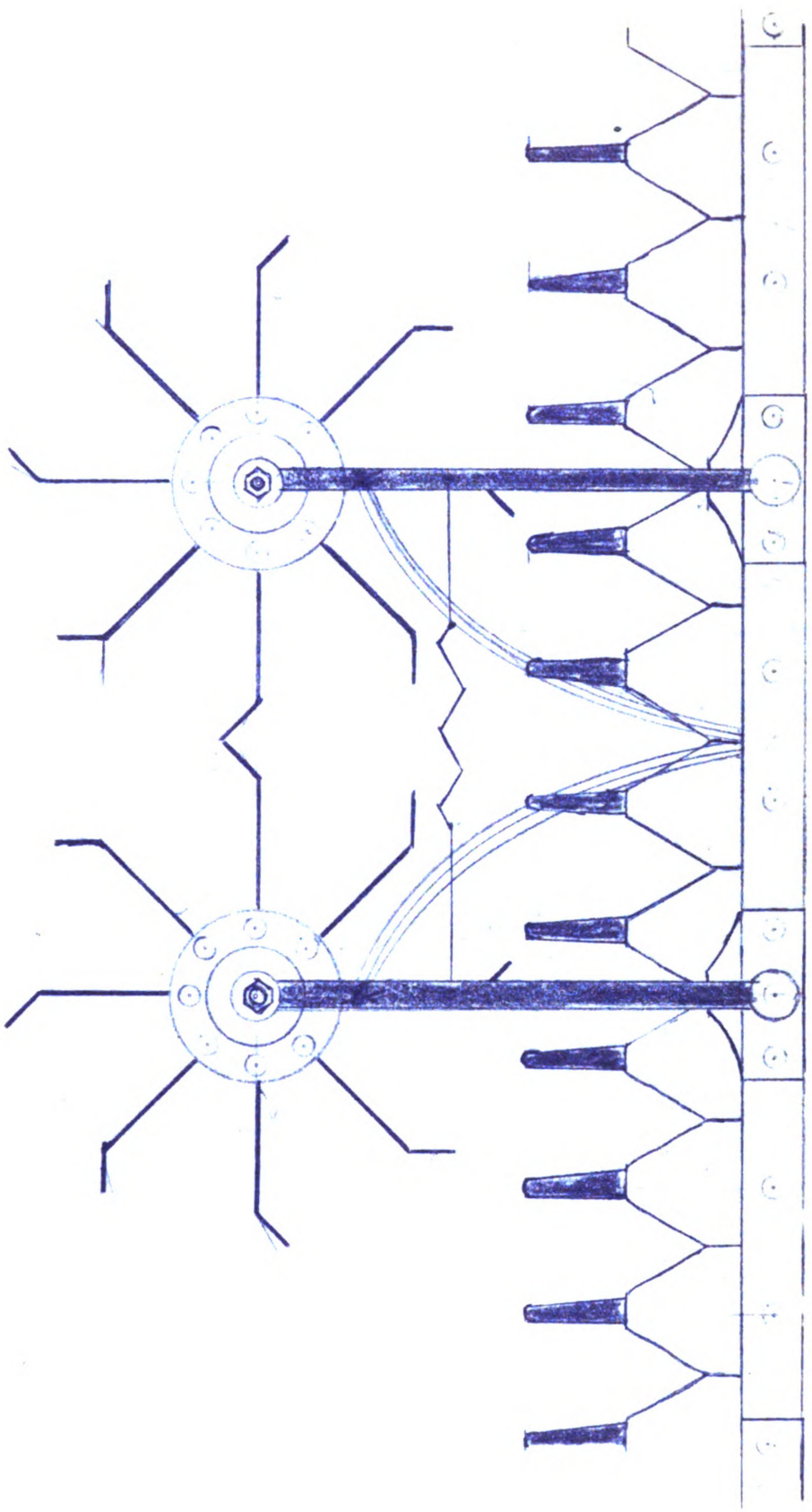
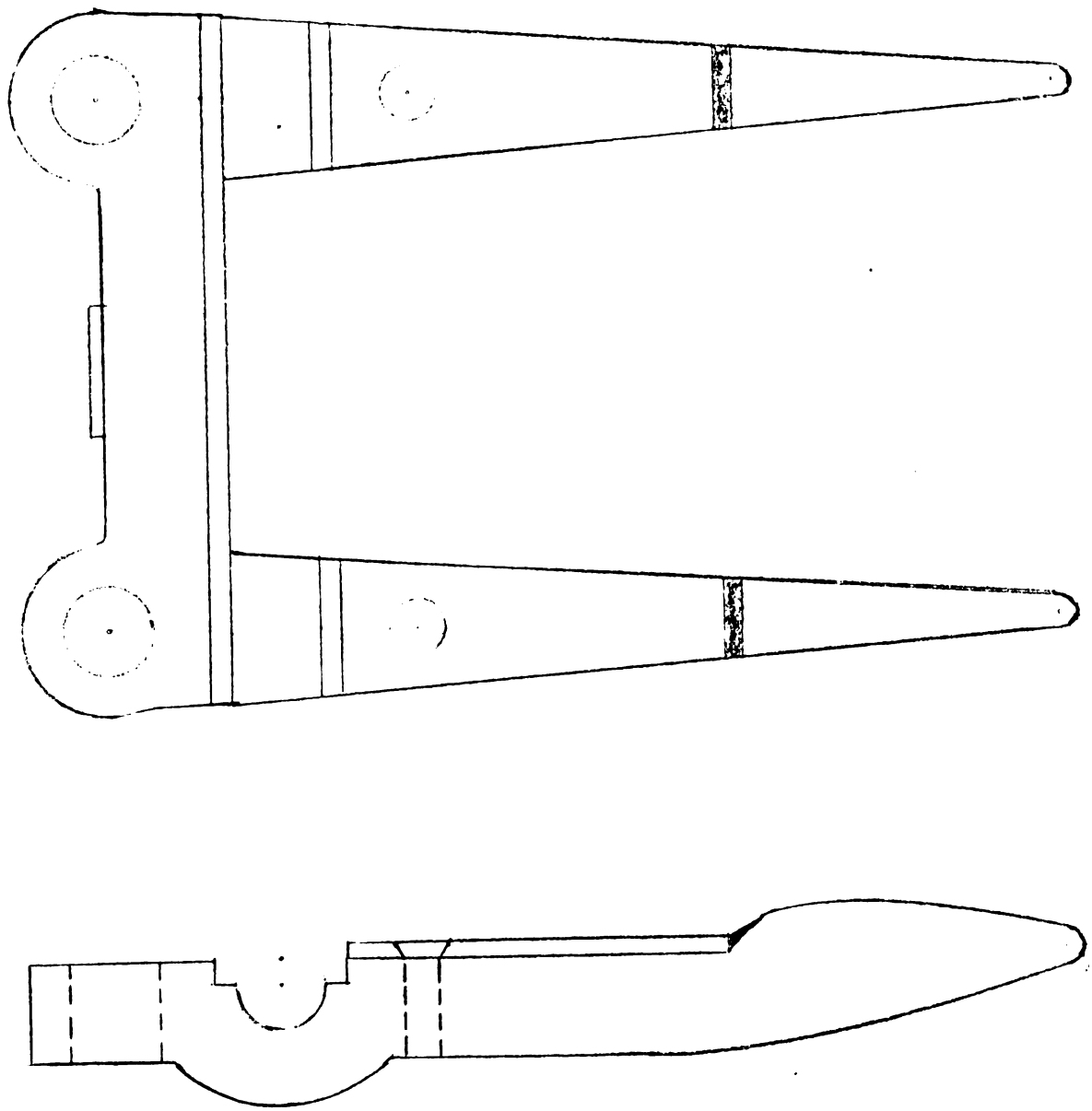

Moisture Content
(Percent)
0
5
10
15
20
Straw
Beans
Total
Straw
Beans
total
Straw
Beans
Total
Straw
Beans
Total
Straw
Beans
Total
Sept 25
Sept 28
Oct 5
Oct 9
Oct 11
Variations in Moisture Content during Harvest Period for Navy Beans.

Figure 3



A Proposed Cutter Bar Attachment

Figure 4.



Flat Type Guard
Scale 1 in. = 1 in.

CHAPTER X

EVALUATION OF DATA

The use of the Hume reel proved to be very satisfactory under all conditions. The lifting action of the tines provided the necessary straightening and lifting of the plants before they were cut off and after they passed the cutter bar. Also, with the use of this type reel, visibility of the operator was not impaired. Rocks could be seen and avoided quite easily.

The standard reel without canvas wipers did not do the job. The beans were chipped and re-cut, so they were usually lost as the sickle continued to cut and thresh the pods. The standard reel with canvas wipers did a good job of forcing the crop into the machine. However, they also caused rocks to be easily pitched into the machine. Operator visibility was reduced. It was difficult to maintain cutting level and also avoid the rock hazard. The losses noted in the chart are not much different for the Hume reel than for the standard reel with canvas wipers. Although the conditions of the weather were similar, it must be said that the crop yield could affect these results, giving no significant difference.

Considering the use of the cut-off guards, one can say that they prevented some of the threshing at the cutter bar. The action of the sickle upon the plant can be compared to the spike tooth cylinder of the older threshing machine. This spike tooth system was used for threshing. Here it is evident, on a small scale, in the threshing of the pods. Removing the top portion of the guard allows the action to become pure shearing. The results indicated in the tests which were run note the decided difference in the cutter bar losses. It can be said that this is a definite result, and that the cut-off guard, or a guard of the cow pea type, can be used to a very good advantage in this type of harvest.

One more comparison was made in the field with the comparison of direct combining to that of the three stage method. It was found that although the losses incurred for direct harvesting were high under adverse conditions, the grain in the tank was low in pick content. The three stage method may run a larger amount of lower quality beans through the combine. With this lower quality product high pick will be incurred. Therefore the total crop value will be lower, since the cost of pick removed must be paid by the value of the good quality beans left after the picking operation is completed. This, then, justifies the use of direct harvesting during the course of adverse weather on the Michelite variety, the vine-type bean.

It is easily justified on the bush-type bean similar to soy beans since it is so like that crop in harvesting technique. Inasmuch as this mutated bean is not available for the general farmer, then this method cannot be used on as wide a scale at this time, except under adverse weather conditions.

CHAPTER XI

SUMMARY

The results of the development work on the methods for combining navy beans can be summarized as follows:

1. On bush-type beans the direct harvesting method is the best since it minimizes weather risk, reduces labor cost, and the losses at the cutter-bar are similar to losses incurred in pulling, windrowing, and combining.
2. On the vine-type bean the best method to be used under good weather conditions is the pulling, windrowing, and combining method.
3. Under adverse weather conditions the direct combining method may be used to an advantage on vine-type beans because the losses incurred are beans which would ordinarily be pick, since they are in contact with the soil and mold readily, or are subjected to weather damage. However, some losses occur; but this method will give a farmer some return on his investment.
4. The Hume reel was found to be the best attachment for the combine in forcing the feeding of the hay to the machine.

5. The use of the flat guards was found to be advantageous since the threshing losses at the cutter-bar were reduced.
6. The results indicate that grain losses were the least using the regular reel and the canvas wipers. However, considering the rock damage, operator visibility, and ease of operation, it must be concluded that this method involves a much greater risk to machine damage and crop loss than the method using the Hume reel.

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APPENDIX A

ANALYSIS OF THE OFFSET SLIDER CRANK MECHANISM

Insofar as farm machinery is concerned there are a number of examples of the slider crank mechanism as it is used for the transformation of rotary motion to reciprocating motion. The mowing machine is a classic illustration of this concept. The use of this type of mechanism may be found in some types of combines.

In the design of machinery it is well to have an idea of the velocity and acceleration at the different positions of the crank pin so that the calculations of the forces and the inherent stresses may be made. By using the Pythagorem theorem an expression may be obtained involving the displacement of the slider, the constants of the machine, and the angle of displacement of the crank pin with respect to the horizontal. By taking the first and second time derivatives of the displacement of the slider one can obtain expressions for the velocity and the acceleration respectively.

Terms used in this analysis are:

R - Crank pin radius.

L - Connecting rod length.

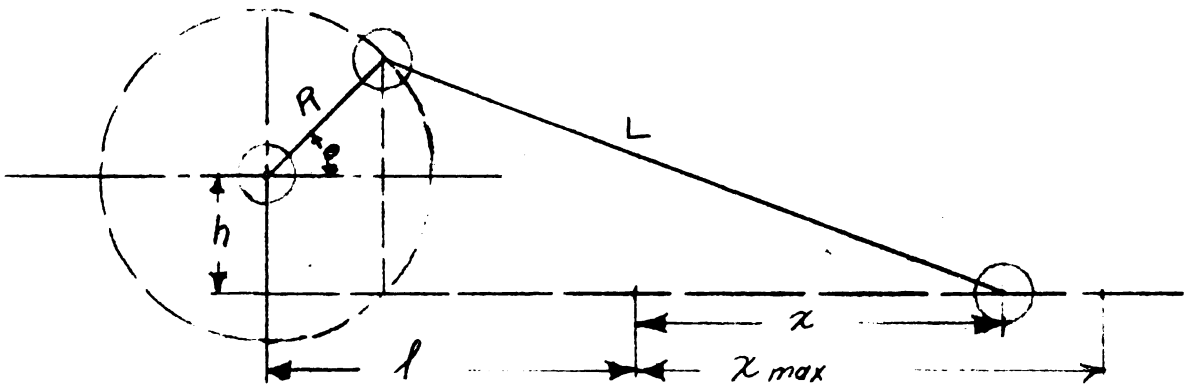
θ - Angle of displacement with respect to the horizontal.

h - Offset distance of the slider with respect to the crank.

l - Minimum distance of the slider with respect to the crank measured along the horizontal.

Note: In following through the mechanics of solution a consistent system of units should be used to get answers in the same units as desired.

Mathematics of an Off-set Slidercrank Mechanism



$$L^2 = [h + R\sin\theta]^2 + [l + x - R\cos\theta]^2$$

$$x^2 + [2l - 2R\cos\theta]x + 2hR\sin\theta - 2lR\cos\theta - K = 0$$

where $K = L^2 - h^2 - l^2 - R^2$

$$x = R\cos\theta - l + \sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}$$

$$v_x = \frac{dx}{dt} = \left[-R\sin\theta - \frac{2R^2\cos\theta\sin\theta - hR\sin\theta}{2\sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}}\right]\frac{d\theta}{dt}$$

$$a_x = \frac{d^2x}{dt^2} = \left[-R\sin\theta - \frac{2R^2\cos\theta\sin\theta - hR\sin\theta}{2\sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}}\right]\frac{d^2\theta}{dt^2} + \left(\frac{d\theta}{dt}\right)^2\left[R\cos\theta + \frac{(R^2\cos\theta\sin\theta + hR\cos\theta)^2}{(R^2\cos^2\theta - 2hR\sin\theta + K + l^2)^{3/2}}\right]$$

$$- \left(\frac{d\theta}{dt}\right)^2\left[\frac{2R^2\sin^2\theta - 2R^2\cos^2\theta - hR\cos\theta}{2\sqrt{R^2\cos^2\theta - 2hR\sin\theta + K + l^2}}\right]$$

APPENDIX B

RECOMMENDATIONS ON COMBINE ADJUSTMENT

Itemized below are some common troubles and suggested remedies in the combine harvesting of navy beans:

	Trouble	Suggested Remedy
A.	Loss of grain over the chaffer	1. Open the lips of the chaffer 2. Raise the chaffer extension 3. Reduce the air blast
B.	Excessive tailings	1. Reduce the openings in the chaffer and chaffer extension 2. Increase the air blast 3. Increase the concave clearance
C.	Cracking grain	1. Reduce the cylinder speed 2. Increase the concave clearance 3. Use smaller concave bars 4. The weed cleaner attachment should be removed 5. Increase ground speed to provide uniform intake of unthreshed grain
D.	Slugging of the cylinder	1. Do not operate when the vines are too high in moisture content 2. Reduce ground speed 3. Uneven windrows caused by bunching of the windrower. Reduce speed of windrower
E.	Loss of grain over the straw racks	1. Adjust the straw retarding flap or mechanism 2. Open the concave grates 3. Check levelness of the combine with respect to the hitch