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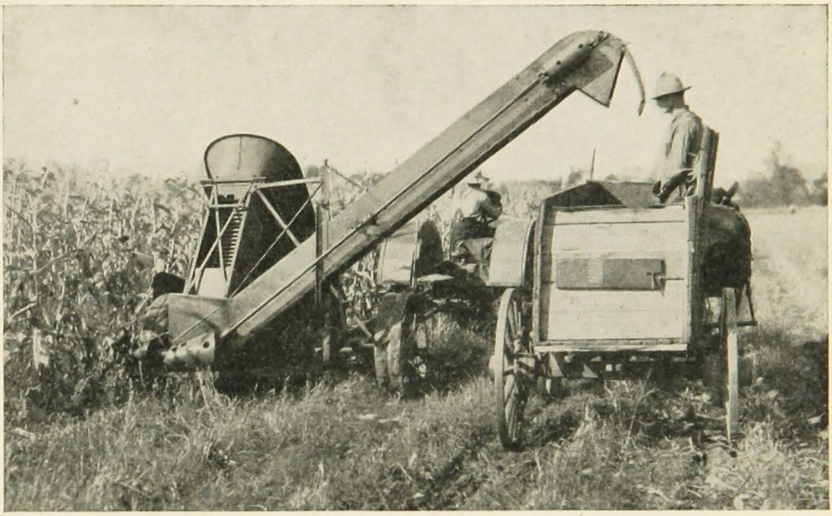
FIELD ENSILAGE HARVESTER



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FILLING SILOS WITH THE FIELD ENSILAGE HARVESTER

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INTRODUCTION

About a sixth of the corn crop grown annually in the dairy sections of Minnesota is put into the silo. In northern Minnesota, outside the corn belt, corn is grown mainly for silage. In some cases sunflowers and other crops, as well, are used for this purpose. Where corn will ripen, the acreage per farm usually exceeds the requirements for silage. Large acreages of corn are grown in sections of the state where dairying is not practiced. Only a small part of the corn crop in some of the southwestern counties is put into the silo.

In 1930, 12.0 per cent of the corn acreage in Minnesota was cut for silage; in 1935, 9.8 per cent.[2] Minnesota had 36,278 silos in 1927[3], which is about one silo for every five farms.

Equipment and Procedure

The field ensilage harvester is essentially a combination of corn binder and silo filler. The corn stalks are cut one row at a time near the ground, just as when a corn binder is used, and are then run through the cutter head, where they are cut into lengths suitable for silage. The cutter head on the field ensilage harvester is similar in design to the spiral or cylinder type used on stationary silo fillers. A wagon with a box of suitable size is drawn beside the machine. The ensilage is deposited into this box by means of a conveyor, which is part of the harvester.

The fundamental difference between this method of filling silos and the use of the standard-type silo filler is that the cutting of the corn into lengths suitable for silage is done in the field with the ensilage harvester and is done at the silo with the stationary silo filler. When the cutter is hauled around the field, additional power and more sturdy construction are needed.

The use of the field ensilage harvester saves much hard work. With this method it is necessary to handle the corn by hand during unloading only—the rear end gate is removed from the box and the ensilage drops into the hopper of the elevator. It eliminates the necessity of

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[1] The authors wish to acknowledge the co-operation of the farmers who were operating field ensilage harvesters and who supplied the data that made this report possible.

[2] Yearbook of Agriculture, U. S. Department of Agriculture.

[3] Kirk, Paul H. Minnesota State Farm Census, Bul. 61, p. 9. 1927.

loading the bundles on wagons in the field and unloading them into the silo filler. Both operations are strictly hand labor, and as green corn is heavy, this work is usually considered one of the hardest jobs on the farm.

Two power units are necessary with the field ensilage harvester as well as with the corn binder and the silo filler. The power unit in the field must be somewhat larger than is required to draw the corn binder, and that at the silo may be somewhat smaller than is necessary for operating a silo filler.

The equipment and power required for hauling the corn to the silo are very much the same in both cases except that a box is used for hauling with the ensilage harvester and a rack is used for hauling bundles.

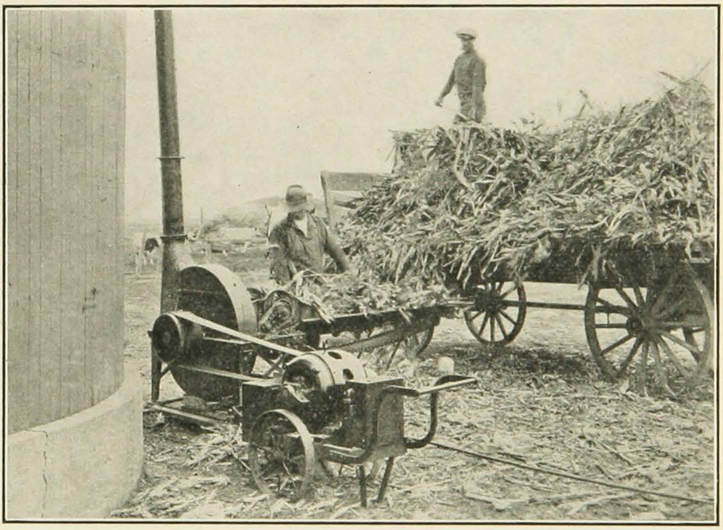

Fig. 1. Filling a Silo with the Stationary Silo Filler
Corn is hauled from the field in bundles and is unloaded into the silo filler.

History of Development

The field ensilage harvester is relatively new. Available information with regard to its development to the present stage shows that the first machine of its kind was built and operated by Adolph and Andrean Ronning, on a farm near Boyd, Minnesota, in 1913.[4] Considerable experimental work was done on the machine at that time, and the fol-

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[4] The history of the development of the field ensilage harvester was furnished by C. M. Hunt, Manager, Minneapolis Branch, International Harvester Company of America.

lowing year three machines of different types and designs were placed in the field for trial. In 1915 the Ronning Machinery Company was organized for the purpose of manufacturing the machine. It was then known as the Ronning Ensilage Harvester.

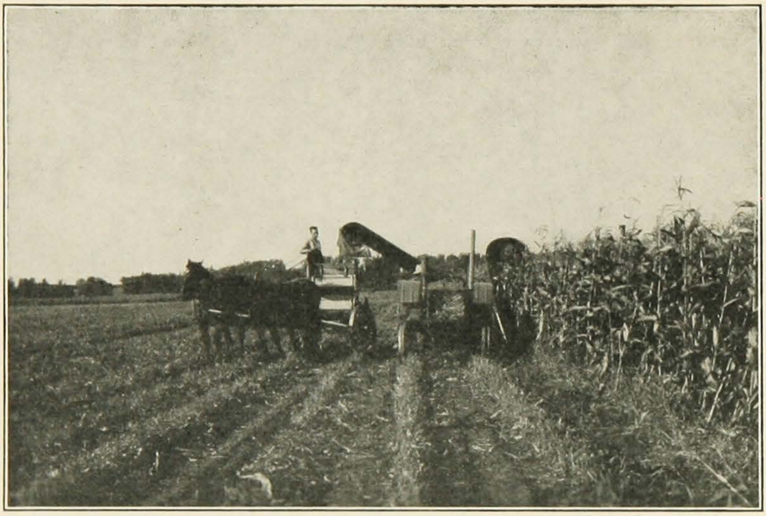

FIG. 2. FRONT VIEW OF THE FIELD ENSILAGE HARVESTER IN OPERATION

One row at a time is harvested. The corn is cut into lengths suitable for silage and by means of a conveyor is deposited into a box which is carried beside the harvester on a wagon or truck.

All the machines built before that time were horse drawn. Power to operate the cutting mechanism was obtained through a bull wheel similiar to that on a grain or corn binder. In that year a model was designed especially for tractor operation. It was to be drawn with the tractor, and, by means of special equipment, power to operate the cutting mechanism of the harvester was taken directly from the tractor engine. This model was exhibited at the Minnesota State Fair in the fall of 1915. Three years later the American Harvester Company was organized by business men of Minneapolis for the purpose of manufacturing and selling the Ronning Ensilage Harvester.

The machine was constantly improved. The inventors brought out a new and improved model almost every year. In 1921 the manufacture and sale of the harvester was taken over by the Morgan Harvester Company, and in 1925 the International Harvester Company of America was granted a license to manufacture and sell the machine. At present, at least two farm equipment manufacturers are making a field ensilage harvester.

Machines made at present are designed only for tractor operation. They are equipped with standard power take-off so that power to operate the cutting mechanism may be taken from the engine of the tractor that is used to draw the machine through the field. The harvester may be operated with a two-plow tractor when conditions are favorable. For most satisfactory results, however, a three-plow tractor is desirable.

Method and Extent of Study

The study reported in this bulletin was conducted by making a survey of 35 farms on which field ensilage harvesters were used. Usually a machine of this type is used on more farms than one. Fourteen machines were in use on the 35 farms. The farms surveyed were located in southern Minnesota, with the highest concentration in the southeast.

SILO FILLING ON THE FARMS STUDIED

Silo filling is no more important on the farms using field ensilage harvesters than on an average dairy farm. This is shown by the following facts concerning the farms studied: The average size is 221 acres, and the average number of acres in silage corn annually is between 13 and 14, which is slightly over six per cent of the total acreage.

Number and Capacity of Silos

The number and capacity of silos are shown in Table 1. Some of the farms had three silos, and there was at least one silo on every farm. The capacity of a silo was calculated from the dimensions as obtained from the owners. The weight of silage per unit volume of silo was obtained from Missouri Bulletin 164.[5] There is a wide range in the capacity of the silos. The average was 119.55 tons, and the average total capacity per farm was 136.62 tons. The kind of silo was not recorded. All but three, however, were of the round upright type. Of these three, one was a pit silo, one a trench silo, and one a crib silo.

Table 1. Number of Silos and Capacity in Tons

	Maximum	Minimum	Average
Number of silos per farm	3.0	1.0	1.17
Capacity per silo, tons	195.8	57.8	119.55
Silage capacity per farm, tons	277.3	57.8	136.62

Annual Use of Machines

Fourteen machines cut the silage on 35 farms. Each machine was used on an average of 2½ farms for harvesting a total of 37.3 acres. The maximum number of farms on which one machine was used was

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[5] Eckles, C. H., Reed, O. E., and Fitch, J. B. Univ. of Missouri Agr. Expt. Sta. Bul. 164, Table 6, p. 16. 1919.

5, and the maximum acreage per year per machine was 67. Five of the machines were used on only one farm each.

The acreage of silage corn on the average farm is so low that it does not pay to own a set of equipment for use on one farm only. On the five farms, on which one machine was used exclusively on each farm, the average acreage of silage corn was 14.4, which is only slightly higher than the average of all farms studied. Most of the machines that were used on more farms than one were owned co-operatively and were used on the same farms year after year.

CUTTING

Size of Crew

On 28 of the 35 farms investigated one man handled the ensilage harvester and the tractor or team. On three farms one man handled the harvester, with another man operating the tractor. With one harvester that was used on four farms the extra man was used on the machine only when the corn was down or tangled badly. There seems to be little need for more than one man for the cutting operation.

Size of Power Unit and Rate of Travel

With one exception, the machines were tractor drawn and operated. The tractors used were either the two- or the three-plow size. Table 2 shows the effect of the size of the tractor on the average rate of travel, acres cut per hour, man hours per ton for cutting, and tractor hours per ton for cutting.

Table 2. Effect of Size of Tractor on Rate of Travel and Capacity of the Field Ensilage Harvester

Size of tractor	Rate of travel, miles per hour	Tons cut per hour	Man hours per ton for cutting	Tractor hours per ton for cutting
3-Plow	2.766	6.295	0.186	0.159
2-Plow	2.346	4.905	0.214	0.199

The figures indicate the advantage of the larger tractor. This advantage would be still more noticeable with heavier yields. Some of the operators with the smaller tractors stated that with very heavy corn it was necessary to stop the forward movement of the tractor occasionally to allow the machine to clear itself.

The effect of rate of travel on cutting capacity is shown in Table 3.

One machine was operated at just a trifle more than 1.5 miles per hour. Its performance shows clearly how the slower rate of travel affects the amount of work accomplished. This machine was one of the older type and was operated by a tractor that lacked the necessary power to drive the machine when traveling at a higher rate of speed. In studying this table it must be kept in mind that the tons per hour are influenced by the tons per acre quite as much as by the rate of travel. The man hours per ton are affected by at least three factors, namely, the number of men used in the cutting operation, the rate of travel, and the tons per acre.

Table 3. Effect of Rate of Travel on the Capacity of the Field Ensilage Harvester

Rate of travel, miles per hour	Number of farms	Acres per hour	Tons per acre	Tons per hour	Man hours per ton
1.58 to 1.99	1	0.48	7.84	3.76	0.265
2.0 to 2.49	13	0.72	7.52	5.56	0.181
2.5 to 2.99	3	0.82	8.05	6.62	0.151
3.0 and above	17	0.78	6.90	5.38	0.231
All farms	34	0.75	7.28	5.45	0.203

The figures in Table 3 indicate that 2.5 to 2.99 miles per hour was the optimum speed at which machines should travel. This speed was used on only three farms, on the same machine, and it appears that all the operations were carried on very efficiently. The man power was used to best advantage. There were enough teams to keep the ensilage harvester moving, and the yield was such that the efficiency of operation was better than on the other farms.

There are several reasons why the machines whose rate of travel was three miles per hour or more do not show better results. It was in this group that the extra man was used on the harvester, thus increasing the man hours per ton. In five instances they did not have as many teams hauling as were necessary for the most efficient operation, making it necessary to stop the harvester, thereby reducing the number of acres cut per hour.

Capacity

The data in Table 4 show what might be expected of a field ensilage harvester traveling at various rates of speed when the yield is kept constant. The data in this table were not obtained from the farms that were studied. They were computed on the basis of rates of travel as shown in the first column and on the basis of a yield of 7.3 tons per acre, which is the average of the farms that were studied. The rates of performance were computed by means of a formula that is commonly used for calculating acres covered per day by farm implements at various rates of travel.[6] This formula gives figures that are fairly accurate considering time lost for turning and stopping. It is assumed that one man handles both tractor and ensilage harvester.

[6] Width in feet x miles per hour = acres covered in a 10-hour day.

Table 4. Effect of Rate of Travel on the Capacity of the Field Ensilage Harvester and on the Utilization of Labor When the Yield Is Constant

Rate of travel, miles per hour	Acres per hour*	Tons per acre†	Tons per hour	Man hours per ton‡
1.5	0.525	7.3	3.83	0.26
2.0	0.70	7.3	5.11	0.20
2.5	0.875	7.3	6.39	0.16
3.0	1.05	7.3	7.66	0.13
3.5	1.23	7.3	8.98	0.11

* The following formula was used to compute the number of acres per hour:

$$\frac{\text{Working width in feet x rate of travel in miles per hour}}{10}$$

† The average yield on all of the farms studied was 7.3 tons per acre.

‡ It is assumed that one man operates the tractor and harvester, which was the case on 80 per cent of the farms studied.

Because a relatively wide range of rates of travel is possible with a tractor, the effect of speed on capacity, in the performance of any farm operation, becomes more important as the use of tractors increases. While the data in Table 3 show the capacity and rates of travel as they actually existed on the farms studied, other factors such as variation in yield and in size of crew influenced the capacity as well as did rate of travel. In Table 4 all other factors are kept constant and the effect of rate of travel alone on capacity is clearly shown.

HAULING

Size of Crew

The number of teams used in hauling the cut corn from the field to the silo is an important factor in the use of the field ensilage harvester. Because the capacity of the machine is limited by the amount that can be cut one row at a time, it is important that a sufficient number of teams are available to keep the harvester working continuously. On the other hand, more teams than can be used to advantage will increase the cost unnecessarily. Data obtained from 48 fields show that the number of teams per field varied from 1 to 6, the average being 3.6. In Table 5 is shown how the number of teams used for hauling varies on different fields.

Distance of Haul and Rate of Hauling

The distance from the corn field to the silo is an important factor influencing the cost and time required for filling the silo. The effect of the distance of haul on the time required for hauling and on the power and labor required for hauling is shown in Table 6.

Table 5. Actual Number of Teams Used for Hauling and the Number Considered by the Operator To Be Most Advantageous

Number of teams	Fields grouped on the basis of number of teams used		Fields grouped on the basis of the number of teams considered most advantageous	
	Number	Per cent	Number	Per cent
1	1	2.0	0	0.0
2	4	8.4	3	6.3
3	14	29.2	13	27.0
4	25	52.1	27	56.3
5	3	6.3	5	10.4
6	1	2.0	0	0.0

Because the hauling distance is an important factor, some of the men who were interviewed expressed the opinion that it would be advantageous to grow silage corn on land that is located as near to the silo as possible. Such practice might require repeating corn on the same field several years in succession, but the natural difficulties incident to such a practice might be obviated by a special system of crop rotation and soil fertilization.

Table 6. Effect of Distance of Haul on Number of Horses, Tons Hauled per Hour, Man Hours per Ton, Horse Hours per Ton, and Horse Hours per Ton Mile

Distance of haul	No. of fields	No. of horses per field	Tons hauled per hour	Man hours per ton	Horse hours per ton	Horse hours per ton mile
Less than ¼ mile	22	7.0	5.75	0.61	1.22	9.77
¼ and over but less than ½ mile	15	7.5	5.13	0.74	1.48	5.18
½ mile or more	11	8.2	5.06	0.74	1.48	2.57
All fields, 3/10 mile (Ave.)	48	7.45	5.36	0.68	1.36	4.94

In general, most operators consider four teams about right for average hauling distances. The effect of distance on the number of horses used is shown in the second column of Table 6. An average of only seven horses was used when the hauling distance was less than one-fourth mile, and 8.2 horses where the distance was one-half mile or more.

The average number of tons hauled per hour was 5.36. Table 6 shows that the tons hauled per hour decrease as the distance increases, in spite of the fact that the number of horses is increased with distance. Evidently the increased number of horses used for hauling long distances was not sufficient to maintain the same capacity that prevailed when the hauling distance was not so long.

The true effect of hauling distance on man labor and horse work requirements is shown in the man hours and horse hours per ton in Table 6. The largest relative advantage is obtained on short hauls.

When the haul is one-fourth mile or more, a short additional distance does not change the rate appreciably. The horse hours per ton mile decrease considerably as distance increases because of the smaller proportion of total time consumed in loading, unloading, and waiting.

Each operator was asked if in his estimation he was using the number of teams that would give him most efficient results. The answers to this question are shown in tabular form in Table 5. In no case was the most advantageous number of teams considered to be as low as one or as high as six. Over half of the operators stated that four teams were necessary; more than one-fourth of them said that three teams could be used to best advantage. In comparing the two columns in Table 5, it is noted that, in general, the farmers were not using as many teams as they considered best. The number of teams used on some of the farms was governed by conditions peculiar to those farms. Many, however, who had used the field ensilage harvester for several seasons had studied the problem and were operating on an economical basis.

UNLOADING AND ELEVATING

Equipment

The usual practice of unloading at the silo is to remove the rear end gate from the wagon box and move the corn from the wagon into the hopper of the blower or elevator. The hopper is usually so arranged that it may be raised off the ground to allow the load to be pulled into position and then lowered behind the wagon so that the corn drops from the rear end of the wagon box directly into the hopper.

Getting the load from the wagon to the receiving hopper of the blower or elevator is perhaps the hardest work connected with this method of silo filling. The corn is moved from the box by means of silage forks, shovels, or rakes. On only one farm the driver alone did the unloading. On all the other farms studied at least one man assisted the driver at unloading, and in several instances two men stayed at the silo for this purpose, making three men for this job.

Wagon boxes.—The shape of the box in which the ensilage is hauled is an important factor in unloading. During the unloading all the corn must be moved to the rear end of the box. It is evident that the shorter the box the less labor will be involved in unloading a given amount of ensilage, for the amount of moving that is necessary is equivalent to moving all the material a distance equal to half the length of the box. If the box is made a little wider or a little higher, or both, and somewhat shorter, there will be a decided advantage in unloading. A box that is wider than the standard wagon box is desirable, also, because a man using a silage fork can work to much better advantage in a wide box.

Many of the operators interviewed appreciated the desirability of using wagon boxes somewhat wider than the standard, as shown by the fact that most of those who used the standard wagon boxes had them equipped with flare boards on the top. Most of the boxes used were not standard wagon boxes. Two were 5 × 14 feet; four were 5½ × 10 × 3½ feet; one was 6 × 16 × 1½ feet. Five farmers operating in one ring used what they termed "cabbage boxes." These were 7 × 12 or 14 feet with side boards from 1½ to 2 feet high. The largest box was 8 × 16 × 1½ feet high. This was altogether too long, and it was planned to cut the length to about 10 feet and make the sides higher. Some who were using boxes 14 feet long planned to reduce the length because of the distance necessary to move the front part of the load into the elevator.

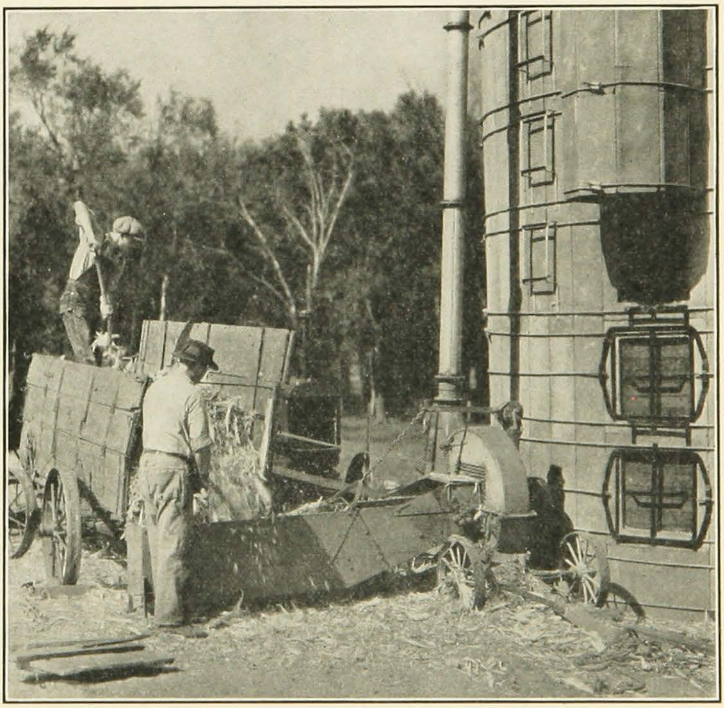

FIG. 3. UNLOADING ENSILAGE AT THE SILO

The ensilage is transferred from the wagon box to the hopper of the elevator. This is the most difficult labor job in connection with the field ensilage harvester method of filling silos. A box that is somewhat wider and shorter than the standard wagon box makes it possible to unload by moving the ensilage a shorter distance and makes work easier and more convenient for the man who is unloading.

Most of the boxes used had been on hand or could be arranged for easily. Some of the operators, however, found that boxes up to 7 feet wide and not more than 12 feet long with sides high enough to accommodate a reasonable load were fairly well suited to the work.

The data and curves in Figure 4 show the relation between length, width, and height of box and the tons of ensilage it will hold. By using these data it is possible to determine the necessary height for any given length and width combination and for any reasonable load. Likewise, the necessary length or width may be determined if one or more of the other factors are definitely predetermined. These data should serve as a useful guide to anyone who contemplates making or purchasing boxes for hauling cut ensilage.

Because the unloading is difficult and the job is steady, on several farms those who stayed at the silo to unload occasionally exchanged places with the teamsters. The inducements for adopting this method of filling silos would be much greater if there were some simple and practical way to facilitate unloading. When a normal crew is used it is easily possible to keep the work of unloading and elevating well ahead of the other operations. The capacity of the elevating equipment apparently is adequate, at least for all average conditions.

Elevators.—With two or three exceptions, the cut corn was elevated into the silo by means of a blower, part of the regular equipment of a field ensilage harvester. In general, the operation of the blower seemed entirely satisfactory. Some of the operators had used the type of blower that was sold with the older machines as well as the newer model and expressed themselves in favor of the older types as being less likely to clog.

The average speed of the blowers was 835 revolutions per minute. The manufacturers specify the speeds at which they should be operated—usually considerably lower than this average.

Two factors affect the speed. It is necessary to have a certain minimum speed at which the ensilage will be thrown to the top of the silo. Obviously this speed is greater for high silos than for lower ones. In general, the ensilage would be thrown to the top of the silo with much less speed than was used on these blowers or on most stationary silo fillers.

It is true that higher speed makes possible greater capacity. The capacity of the elevator is not the limiting factor, however, when using the field ensilage harvester method of filling silos. It is easily possible, under ordinary conditions, for the crew at the blower to take care of the ensilage as fast as it is produced by the harvester and hauled to the silo.

Width in Feet

Length in Feet

3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
					18.0	16.5	15.0	14.0
				19.0	17.0	16.0	14.5	13.5
			20.0	18.0	16.5	15.0	14.0	13.0
		21.0	19.0	17.0	15.5	14.0	13.0	12.0
	23.0	20.0	17.5	16.0	14.5	13.5	12.5	11.0
25.0	21.5	18.5	16.5	15.0	13.5	12.5	11.5	10.5
23.0	20.0	17.5	15.5	14.0	12.5	11.5	11.0	10.0
22.0	18.5	16.0	14.5	13.0	12.0	11.0	10.0	9.0
20.0	17.0	15.0	13.5	12.0	11.0	10.0	9.0	8.5
18.0	15.5	13.5	12.0	11.0	10.0	9.0	8.5	8.0
16.5	14.0	12.5	11.0	10.0	9.0	8.0	7.5	7.0
15.0	13.0	11.0	10.0	9.0	8.0	7.5	7.0	6.5
13.5	11.5	10.0	9.0	8.0	7.0	7.0	6.0	5.5
11.5	10.0	9.0	7.5	7.0	6.5	6.0	5.0	
10.0	8.5	7.5	6.5	6.0	5.5	5.0		
8.5	7.0	6.0	6.0	5.0	4.5			

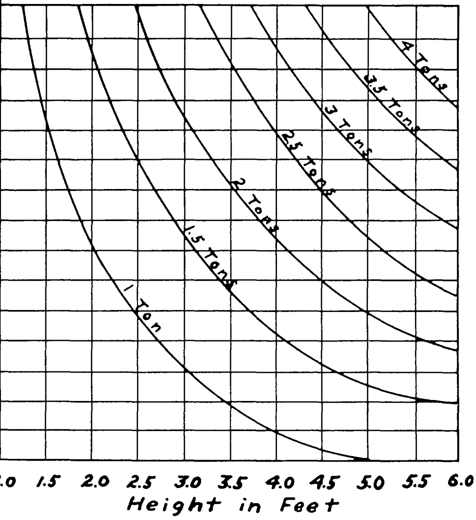

FIG. 4. RELATION BETWEEN LENGTH, WIDTH, AND HEIGHT OF BOX AND THE TONS OF ENSILAGE IT WILL HOLD

An illustration of how the table and the graph may be used: Suppose one wishes to make a box for hauling ensilage from the harvester to the silo; to have the box fairly wide so as to save labor at unloading, but for certain reasons to have it 6½ feet. The capacity of the box is to be about two tons. It is necessary to note the "2-ton" curve on the graph. From the figures at the bottom of the graph the minimum height for a 2-ton load is about 2½ feet and the maximum shown in the graph is 6 feet. Assume a height of 3½ feet. It is easy to find the point on the "2-ton" curve where the 3½-foot line crosses it. Now follow the line from that point directly across toward the left until the column of figures is reached under the number 6½. It will fall on about 11, indicating that the box would have to be about 11 feet long. If the height could be 4 feet instead of 3½, the length would need to be only about 9½ feet for 6½-foot width. A box 6 feet wide and 10 feet long carrying 1½ tons needs to be only slightly more than 3 feet high.

Excessive blower speed requires a great deal of power.[7] It has been found that about twice as much work is required to elevate a ton of silage a height of 30 feet when operating at about 700 revolutions per minute as is necessary when the blower is running at about 400 revolutions. Operating the blower then at speeds that are no greater than necessary to obtain proper elevation and the necessary capacity will mean savings in power costs, will in some instances make possible the utilization of a smaller power unit, and will save wear on machinery.

One of the farmers using the field ensilage harvester put his corn into a trench silo. This type of silo is particularly advantageous in filling with this method of harvesting. It is unnecessary to have any

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[7] Stewart, E. A., Larson, J. M., and Romness, J. The Red Wing Project on Utilization of Electricity in Agriculture. p. 85. Univ. of Minn. Agr. Expt. Sta.

equipment at the silo. Many trench silos are made so that it is possible to drive in at one end and out at the other. This practice not only facilitates unloading, but the corn is packed at the same time by the horses and wagons continuously going over it.

Another operator used the blower from an old stationary silo filler. The knives and the conveyor were removed and a hopper was built on the blower in such a way that the corn might be put into the receptacle, from which it would flow into the blower. A third man, who was not using the regular blower, used a regular slatted conveyor type of elevator driven with a fairly small gas engine. He used a crib silo 24 × 20 feet. A blower was available but he preferred this elevator.

Power units.—The power units used to operate the blowers and elevators were varied. Stationary engines were used in two instances, one operator used an electric motor, and two others used power plants built with multi-cylinder engines. With one other exception, the other operators used tractors of various makes and sizes. In the exceptional case a steam engine was used. This operator had a silo that was exceptionally tall and considerable power was required for elevating. The real reason for using the steam engine, however, instead of some other power unit was because he had a steam engine as part of his regular equipment.

The last statement explains why most farmers used the kind of power they did. Tractors were owned on practically all the farms visited, so the selection of the power units for the cutting and elevating was largely a matter of mutual agreement in the group. A tractor equipped with a power take-off was used on the cutter on all farms in the group and another available unit was used on the blower, evidently very little thought being given to the size of the power unit. This fact is evidenced by the replies to the question as to why certain power was used. The answer was almost invariably, "We had that power."

Size and Distribution of Crew

On about 30 per cent of the farms visited, a man worked in the silo all the time. In two instances a man went into the silo occasionally; in the majority of cases no one worked in the silo except for only a short time when the silo was nearly full. Some had tried different ways and finally decided the man inside was unnecessary.

In one instance, the driver did all the unloading. On all other farms, however, there was at least one man to assist the driver and on several farms two men. It has been stated that the hardest work in connection with this method of silo filling is the unloading. Because of this the men occasionally changed places, that is, the drivers took turns working at the blower. On some farms the teamsters were boys or girls or old men. They may be able to handle the team satisfactorily but can not be of much assistance in unloading. When such teamsters are used, it is more important to keep one or two good men at the silo for unloading.

SUMMARY OF PERFORMANCE RATES, COSTS, AND PRACTICES

Detailed descriptions and rates of performance of the various operations when filling a silo with the field ensilage harvester have already been given. The rate at which corn may be put into the silo is limited by the capacity of the harvester, which is designed to cut one row of corn at a time. The capacity of the harvester, or the output per unit of time, is determined by the number and duration of stops, the yield, and the rate of travel. Within certain limits all of these factors are within the control of the operator.

The number and duration of stops are important. There may be several reasons for stops, but the efficient operator will try to keep his machine in such a state of repair and will have his crew organized in such a way that the necessary stops will be few and of short duration. The yield of silage per acre will vary on different fields and from year to year on the same field. Naturally high-yielding corn makes possible a relatively high machine capacity. The average yield for all farms included in this study was 7.3 tons per acre, as shown in Table 3. The effect of different rates of travel on the capacity of the harvester, when no other factors influence it, is shown in Table 4. The capacity shown in the table when traveling at the rate of 3 miles per hour with corn yielding 7.3 tons per acre is 7.66 tons, or slightly more than one acre per hour. This assumes only the necessary normal loss of time due to turning and a few necessary stops. A capacity of about 7.5 tons, or about one acre per hour, might reasonably be expected under normal conditions. If the rate of performance runs much below either of these figures the cause should be looked for and the remedy applied. Greater capacity would be possible under some circumstances.

Table 3 shows the average output of the machines studied to be 5.45 tons per hour and 0.746 acre per hour. Several reasons exist for these low averages. The average rate of travel of the harvester in the field was 2.51 miles per hour. In some instances there were delays due to breakage or other causes and frequently the harvester was delayed because of insufficient teams and wagons. If the maximum capacity of the harvester is to be utilized, enough teams must be available. This is more important when a silo is to be filled by this method than when using the corn binder and stationary filler. It is impossible to recover any time that has been lost with the field ensilage harvester because the maximum rate of cutting and loading is practically fixed under any particular conditions.

The average size of crew on the farms studied was 6.8 men per farm. The average number of teams was 3.5. Assuming one driver for each team, an average of 3.3 men remained to run the harvester and take care of the work at the silo. The number of teams and the men required for hauling depend on the distance of haul. The effect of the distance of haul on the capacity of a man and a team is shown in Table 6. The average distance of haul for all fields was 0.3 mile and the average number of man hours and horse hours per ton for hauling this distance was 0.68 and 1.36, respectively.

Besides this number of men and teams, a tractor is needed to furnish power for the harvester and a power unit is needed to run the elevator at the silo. It has been shown previously that the rate at which the harvester travels in the field is one of the most important factors of the capacity of the outfit. A small tractor can haul the harvester at only a relatively low speed. The experience of the operators interviewed indicates that for best results a tractor that has a rating of at least 15 drawbar horse-power should be used. A tractor of such size is commonly designated as a three-plow tractor. It can easily handle the field ensilage harvester under average conditions at a speed of three miles per hour or slightly higher, which is about the intermediate speed in most of the recent tractor models. A tractor having a drawbar rating of about 10 horse-power may travel at intermediate speed with the harvester under ideal conditions, but normally only low speed can be expected of it.

The power unit at the silo may be a tractor, but as only belt power is necessary a stationary gasoline engine or an electric motor may be used. On most of the farms visited a tractor was available for this purpose because more than one farmer in a particular silo-filling ring usually owned a tractor. The power unit used at the silo should be capable of developing at least 5 horse-power.

Costs

The time required and average costs of the various operations on the farms studied are summarized in Tables 7 and 8. Table 7 gives the data on the acre basis, and in Table 8 the costs and the time required are shown per ton of silage. The total cost per acre of silage is $7.83, and the cost per ton is $1.07. These data are based on a yield of 7.3 tons per acre, which was the average of all fields included in this study.

Table 7. Time Required and Costs per Acre of Filling Silos with the Field Ensilage Harvester

Operation	Power		Labor		Machinery		Total cost
	Hours	Cost	Hours	Cost	Hours	Cost	
Cutting	1.31	$1.10	1.46	$0.44	1.31	$1.46	$3.00
Hauling	9.5	1.18	4.60	1.38	....	0.15	2.71
Unloading and elevating	1.31	1.02	2.48	0.74	1.31	0.36	2.12
Total	....	$3.30	8.54	$2.56	....	$1.97	$7.83

Table 8. Time Required and Costs per Ton of Filling Silos with the Field Ensilage Harvester

Operation	Power		Labor		Machinery		Total cost
	Hours	Cost	Hours	Cost	Hours	Cost	
Cutting	0.18	$0.15	0.20	$0.06	0.18	$0.20	$0.41
Hauling	1.3	0.16	0.63	0.19	....	0.02	0.37
Unloading and elevating	0.18	0.14	0.34	0.10	0.18	0.05	0.29
Total	....	$0.45	1.17	$0.35	....	$0.27	$1.07

Power.—In arriving at power costs, the cost per hour of a two-plow tractor was assumed to be 74 cents and that of a three-plow tractor 96 cents.[8] The cost of horse work was arbitrarily set at 12½ cents per hour. Tractors were used as the source of power for cutting, horses for hauling in all cases, but the elevating was done with several forms of power, including tractors, stationary gasoline engines, and electric motors. Tractors were charged at the rates shown above, regardless of whether they were used for field work or for belt work. Electric power was charged at the rate of 8 cents per horse-power hour and that furnished by stationary gasoline engines at 5 cents.

Labor.—All labor was charged at the rate of 30 cents per hour. Many of the operators interviewed used relatively cheap labor for hauling. In some instances children or old men did most of the hauling. They could handle a team but could not take the place of a man where heavy work is required. While it may seem unfair to charge the operation with this labor at regular rates, nevertheless the services of a regular laborer would be required if this inexpensive help were not available. The figures in the tables do not show this advantage with regard to the possible economy in utilization of labor when the field ensilage harvester is used. Another advantage to labor that does not appear in the figures is the relative ease with which the work is done in comparison with that in the use of the binder and the stationary silo filler method. When the field ensilage harvester is used, all the hard work of loading and unloading the bundles is eliminated. The only place

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[8] Schwantes, A. J., and Pond, G. A. The Farm Tractor in Minnesota. Minn. Agr. Expt. Sta. Bull. 280. 1930.

where it is necessary for men to handle the corn is in unloading the silage from the wagon into the hopper of the elevator. With proper equipment and arrangements, the force of gravity is utilized to some extent in this operation.

Machinery.—Factors of machine cost are depreciation, interest, and repairs. As this type of harvester is relatively new, no data are available with regard to the length of life of the machine. Each farmer was asked to estimate the probable additional life of his machine. This figure was added to the present age to obtain an estimated total life. The average of these estimates for all machines studied was 10.8 years and forms the basis for the annual depreciation charge.

There seems to be little relation between the amount of use of a machine annually and the length of life in years. Some of the machines included in this study were covering many more acres per year than others. On the average, the owners estimated the life of those doing the most work to be just as long as those doing only a little each year.

This emphasizes an important point in costs of using farm machines. If the machine cost of doing farm work is to be kept as low as possible, it is necessary that machines be kept in use as much as possible each year. A machine will depreciate a certain amount each year whether or not it is used, and will be worn out after a certain time almost regardless of how little it has been used. Frequently the advantage of certain types of machine such as the field ensilage harvester may be enjoyed with profit by doing custom work or by co-operative ownership, so only a portion of the overhead costs of the machine will fall on any one farm. As has already been pointed out, only five of the machines included in this study were used on only one farm, and several of the machines were used annually on as many as five farms. The average number of farms for all machines was 2½, with an average of 37.3 acres.

The first cost of the machines varied little. There was a slight variation in different locations. The average cost of the harvesters included in the study was $441.

The blower is usually purchased with the harvester. Twenty years was the average estimated total life of the blower; and $191.50 was the average first cost. The depreciation was calculated on the basis of these figures. Interest was charged at the rate of 6 per cent on the average investment.[9] The average annual charge for repairs for all machines was found to be 80 cents. The total for each machine for the period during which it was in use divided by the number of years used gave

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[9] The formula used in obtaining the average investment is: $\dfrac{\text{First cost} + \dfrac{\text{first cost}}{\text{length of life}}}{2}$

the average annual cost for repairs. This figure may be somewhat low because it represents costs during the early part of the life of most machines. However, this type of harvester is relatively new. Until now it has been in the development stage. As has been pointed out previously, some changes were made almost every year. While a machine is in the stage of development, weaknesses are discovered and remedied. Such weaknesses in design or construction tend to bring the repair bill higher than it should be normally. Hauling equipment is charged at the rate of 5 cents per hour for a wagon and rack.

From the data in Table 7 it is found that one-third of the total cost of filling silos with this method consists of labor and that the cost of power and machinery makes up the other two-thirds. The cost of power is greater than either of the other two items, being 42 per cent of the total. It is, therefore, important from the standpoint of economical operation to utilize power as efficiently as possible. There is no significant difference between the power cost of each of the three operations—cutting, hauling, and elevating. The cost of each is about one-third of the total. The machine cost is the smallest of the three factors, being 25.2 per cent of the total.

COMPARISON OF THE FIELD ENSILAGE HARVESTER METHOD WITH THE USE OF THE CORN BINDER AND STATIONARY SILO FILLER

Labor

The most important argument in favor of the use of the field ensilage harvester instead of the corn binder and the silo filler is that the former method requires less hard work. There appears also to be some difference in the total amount of labor required in favor of the field ensilage harvester. Table 8 shows that 1.17 was the average number of man hours per ton for all farms included in this study. The average number of man hours per ton where the corn binder and the silo filler were used was 1.60 in Rock and Nobles counties during the seasons of 1929 and 1930.[10]

The average number of man hours per acre for all farms included in the study of the field ensilage harvester was 8.54, compared with 9.9 for the study cited above. The Wisconsin Agricultural Experiment Station reports an average of 1.84 man hours per ton and 10.43 man hours per acre as a result of a three-year study on 17 farms in the dairy

[10] Sallee, G. A., Pond, G. A., and Loreaux, R. H. Mimeographed Report No. 54, Div. of Agr. Econ., Minnesota Agr. Expt. Sta.

section of the state.[11] There appears to be a slight advantage in favor of the field ensilage harvester as to efficiency in the use of labor.

The optimum size of crew is more definite when the field ensilage harvester is used than with the corn binder and the silo filler. With the necessary help to operate the ensilage harvester in the field and to unload at the silo, the only reason for a variation in the size of the crew would be the distance of haul. It becomes necessary, if labor and equipment are to be used economically, to adjust the number of teams to the distance. Four teams are the average for ordinary distances. In general, one man operates the equipment in the field. Usually two men are at the silo, altho in several instances only one man. This would bring the average crew up to seven men and four teams. For optimum capacity under various conditions, this might vary from six men and three teams to eight men and five teams. The latter crew is about as large as could be utilized economically under ordinary conditions with the field ensilage harvester.

With the corn binder and the silo filler, the rate at which the work may be done is more flexible. With a relatively large silo filler the crew may be increased up to 15 or 18 men and all of them profitably employed. Because the capacity of a corn binder is not equal to that of a large silo filler, the corn binder may be kept in operation longer than the silo filler, or corn cutting in the field may be started a day or two ahead of the actual filling. Frequently, more than one corn binder is used. This makes it possible to speed up silo filling if desired and if a sufficiently large crew is available. On the other hand, the crew may be cut down to the size that would be most economical for the field ensilage harvester method. With either method a small crew may be used if desired. Jones and Smith, of the Missouri Agricultural Experiment Station, found that the size of crew for filling silos in the regular way varied from 4 to 17 men.[12] Of all the farmers included in the study, 18.5 per cent used 10 men; 11.8 per cent, 11 men, and over 15 per cent, 12 men. It is apparent from these data that the tendency is for the average crew to be larger when the corn binder and the silo filler are used than when the field ensilage harvester is used.

Machinery

The initial investment in equipment is an important factor in a choice of two methods. For purposes of comparison it may be assumed that the cost of power units would be the same in either case, altho, as has

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[11] McNall, P. E., and Ellis, L. S. "Farm Costs and Practices." Wis. Agr. Expt. Sta. Research Bull. 83, p. 19. April, 1928.

[12] Jones, M. M., and Smith, Dwight D. Silo Filling Methods and Costs. Missouri Agr. Expt. Sta. Bull. 303. May, 1931.

already been pointed out, when the field ensilage harvester is used the power unit in the field must be larger and the one at the silo may be smaller than is required when using the corn binder and the stationary silo filler. It must also be kept in mind that a tractor is necessary to draw the field ensilage harvester; the corn binder may be drawn with horses, altho a tractor is often used.

The first cost of equipment varies, depending on the size and type purchased and on the locality. The field ensilage harvester equipment requires a cash outlay about 27 per cent higher than that for the corn binder and the silo filler. If, therefore, the machine costs per acre or per ton are not to be higher when the field ensilage harvester is used than when the other machines are used, the former must be used on a larger acreage or it must have a longer life. Table 8 shows that the average cost of all machines included in this study is 27 cents per ton of silage. This is based on an average estimated life of 10.8 years for the harvester and 20 years for the blower, and on an average yearly acreage of 37.3 per machine on 2½ farms.

Jones and Smith found that the machine cost for the corn binder and the stationary silo filler averaged 24 cents per ton of silage on 231 farms.[13] These figures are based on an average life for corn binders of 14.1 years and for silo fillers of 17.3 years, with 305 tons per year.

Power

In Table 9 is shown a comparison of power requirements and costs of the field ensilage harvester with the corn binder and the stationary silo filler. The data for the field ensilage harvester are taken from Tables 7 and 8. The data for Rock and Nobles counties are comparable to the figures for the field ensilage harvester because the same rates per hour were applied for horse and tractor work. The data from the Missouri studies are lower, comparatively, than the other figures because horse costs were computed at 11 cents per hour, whereas the rate of 12½ cents per hour was used for all Minnesota studies. There is little difference between the power costs of the two methods. The cost of power per acre when the field ensilage harvester is used is $3.30 and that in Table 9 for the corn binder and the stationary silo filler is $2.98. On the ton basis, the power for the field ensilage harvester costs 45 cents; the average for the other machines is 53 cents. The differences are due to differences in yield.

The power cost for cutting is considerably higher when the work is done with the field ensilage harvester than when the corn binder is

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[13] Jones, M. M., and Smith, Dwight D. Silo Filling Methods and Costs. Missouri Agr. Expt. Sta. Bull. 303. May, 1931.

used, because much more work is done with the harvester than with the corn binder. It is interesting to note that the cost of power for hauling the ensilage from the harvester is lower than that for bundles. The same tonnage must be transported in either case. The difference is doubtless due to the additional time required for loading and unloading the bundles. This requires additional horse time as well as man time. There seems to be little significant difference in the cost of power required at the silo.

Table 9. Power Costs for Filling Silos with the Field Ensilage Harvester and with the Corn Binder and the Silo Filler

Method	Location	Operation	Form of power	Hours		Cost	
				per acre	per ton	per acre	per ton
Field ensilage harvester	Southern Minnesota	Cutting	Tractor	1.31	0.18	$1.10	$0.15
		Hauling	Horses	....	....	1.18	0.16
		Elevating	Tractor or stationary engine	1.31	0.18	1.02	0.14
		All				$3.30	$0.45
Corn binder and stationary silo filler	Rock and Nobles counties,* Minnesota	Cutting	Horses	5.30	0.85	$0.66	$0.11
		Hauling	Horses	11.90	1.92	1.49	0.24
		Filling	Tractor	0.90	1.15	0.86	0.14
		All				$3.01	$0.49
Corn binder and stationary silo filler	Missouri†	Cutting	Tractor and horses	....	....	$0.54	$0.10
		Hauling	Horses	....	....	1.25	0.24
		Filling	Gas tractor and steam engine	....	....	1.15	0.22
		All				$2.94	$0.56

* Sallee, G. A., Pond, G. A., and Loreaux, R. H. Mimeographed Rept. No. 54, Div. of Agr. Econ., Minn. Agr. Expt. Sta.

† Jones, M. M., and Smith, Dwight D. Silo Filling Methods and Cost. Mo. Agr. Expt. Sta. Bull. 303. May, 1931.

Summary of Costs

In Table 10 is shown a summary of power, labor, and machinery costs for both methods of silo filling. Altho there is a slight difference in the cost per unit of time of some of the factors in the different studies, these differences are so slight in comparison with other variables such as yield per acre, distance of haul, size of cutter, and size of crew, that their effect on the final cost figures is insignificant. Because of these many variables it is impossible to make an exact comparison of the cost of the two methods, as is indicated in Table 10. If enough cases are studied, however, such a comparison will show in what direction the factors in one method will tend to vary from those in the other method. Thus, it is evident that there is no significant difference in the cost of power in the two methods.

The cost of machinery, likewise, is practically the same with both methods with the exception of perhaps a slight tendency toward lower machine costs when the corn binder and the stationary silo filler are used.

Table 10. Power, Labor, and Machinery Costs of Filling Silos with the Field Ensilage Harvester, and the Corn Binder and the Stationary Silo Filler

Method	Location	Power		Labor		Machinery		Total	
		per acre	per ton	per acre	per ton	per acre	per ton	per acre	per ton
Field ensilage harvester	Southern Minnesota	$3.30	$0.45	$2.56	$0.35	$1.97	$0.27	$7.83	$1.07
Corn binder and stationary silo filler	Rock and Nobles counties, Minnesota, 1929	3.01*	0.49*	2.97*	0.48*	1.85†	0.30†	7.83	1.27
Corn binder and stationary silo filler	Missouri‡	2.94	0.56	4.57	0.87	1.26	0.24	8.77	1.67

* Sallee, G. A., Pond, G. A., and Loreaux, R. H. Mimeographed Rept. No. 54, Div. of Agr. Econ., Minn. Agr. Expt. Sta.

† Computed on the basis of time per acre and per ton, as shown by the Minnesota studies, and the following rates per hour for machines: corn binder, 52 cents; silo filler, 82 cents; wagons and racks, 20 cents.

‡ Jones, M. M., and Smith, Dwight D. Silo Filling Methods and Costs. Missouri Agr. Expt. Sta. Bull. 303. May, 1931.

It is evident that there is a difference in labor costs, the labor item for the field ensilage harvester being significantly lower than that in the other two studies. It is evident that, in general, a saving might be expected in labor costs if the field ensilage harvester is used instead of the other machines, but the other factors of cost show no saving.

Table 11. Relative Importance of Power, Labor, and Machinery Costs in Two Methods of Filling Silos

Method	Percentage of the sum of the three factors		
	Power	Labor	Machinery
Field ensilage harvester	42.1	32.7	25.2
Corn binder and stationary silo filler	35.9	45.4	18.7

In Table 11 the relative importance of each of the three factors is shown for each method. When the field ensilage harvester is used the power and machinery costs are relatively higher than with the corn binder and the stationary silo filler. With the latter, labor constitutes a relatively larger part of the cost. Because of this it is necessary to pay more attention to the economical utilization of power and machinery when using the field ensilage harvester, if total costs are to be kept low.

SUMMARY

The field ensilage harvester is essentially a combination of corn binder and silo filler. The cornstalks are cut off near the ground and are than run through a cutter head, where they are cut into lengths suitable for ensilage.

The study reported here included 14 machines that were used on 35 farms. Most machines were owned co-operatively. Two and one-half farms and 37.3 acres was the average per machine. Five machines were used on only one farm each.

A capacity of about 7.5 tons, or about one acre per hour, might reasonably be expected under normal conditions. The capacity is determined by the number of stops, the yield, and the rate of travel. It is important to keep the outfit moving at a good rate of speed to obtain maximum capacity.

In most cases one man handled the ensilage harvester and the tractor or horses. An average of 3.6 men were employed hauling the ensilage from the field to the silo. On most farms one man remained at the silo to assist in unloading. In about one-third of the cases a man worked in the silo.

Boys or old men who are not able to take the place of a man at a labor job, can haul ensilage. When such help is used for hauling it is necessary for a man to remain at the silo to take charge of the unloading. Getting the load from the wagon to the receiving hopper of the elevator is the hardest work connected with this method of silo filling.

A box somewhat wider and shorter than the standard wagon box is desirable for hauling ensilage. Since the amount of moving that is necessary is equivalent to moving all the material a distance equal to half the length of the box, less labor will be required to unload a given quantity of ensilage from a short box than from a long one.

Four teams were used for hauling ensilage on one-half of the farms; on about one-third of the farms three teams were used.

The power unit for operating the blower may be smaller than that required to operate a stationary silo filler. In the field a three-plow tractor is needed to operate the field ensilage harvester. This is larger than necessary for the corn binder.

The average estimated life of the field ensilage harvester was 10.8 years; of the blower 20 years.

The total cost per acre of filling silos with the field ensilage harvester is $7.83 and the cost per ton is $1.07, based on a yield of 7.3 tons per acre and a charge of 30 cents per hour for man labor and 12.5 cents per hour for horse work. The cost of operating a two-plow tractor was assumed to be 74 cents per hour and that of a three-plow tractor 96 cents.

Labor costs are somewhat less with the field ensilage harvester method of filling silos than with the stationary silo filler method, but power and machinery costs tend to be about the same.

The field ensilage harvester equipment requires a cash layout about 27 per cent higher than that for the corn binder and silo filler.