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COST OF HARVESTING WHEAT BY DIFFERENT METHODS.

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CONTENTS.

DEVELOPMENT OF WHEAT-HARVESTING METHODS.

Within the memory of men now living, the entire wheat crop of this country was cut with cradles, bound by hand, and thrashed with flails, crude thrashing machines, or tramped out by animals drawing spiked rollers. The cost of harvesting and thrashing wheat by such means was naturally high, usually consuming one-fifth of the value of the crop.[1] But the time required to do the work when such methods were used was even more important than the expense involved, as it increased the danger of loss from storms to a great extent, and demanded a large number of hands to harvest even a limited acreage within the season available. It was necessary to start cutting at the earliest possible moment, selecting those parts of the field where the grain ripened first, in order to insure completing the harvest before heavy losses occurred from shattering the over-ripe grain. Two acres was considered a fair day's work for a man in cradling wheat, and another hand would be kept busy binding and shocking the wheat cut by one cradler. It is obvious that the acreage of wheat that could be raised per farm under such conditions was very limited because of the large amount of hand-labor involved.

[1] Tenth Census of the U. S. (1880), Vol. III, p. 529.

At the time these crude methods were used, wages for both man- and horse-labor were much lower than at present. To-day, with the unprecedented high wages for hired help for farm work, and its corresponding scarcity, together with the increased cost of maintaining horses, the necessity for using the most improved methods and machinery in order to reduce the amount of man-labor to a minimum is obvious.

During the last century there has been remarkable progress in the development of harvesting equipment. The mower, the reaper, the header, the binder, and the combined harvester have followed each other in rapid succession, substituting at first horse-labor for man-labor, and later introducing mechanical power in the form of steam and internal-combustion engines for horse-labor.

The cost of harvesting wheat at the present time varies widely in different sections of the country largely because of the different methods employed in these operations. In most cases the particular manner in which the crop is handled is influenced by climatic conditions and the requirements of the cropping system followed, as well as by the character of the wheat itself. The various methods followed throughout the country, therefore, generally are those which have been found to be well adapted to the particular conditions existing where they are used, although local custom has in some places operated to continue systems that are more expensive than others which would be entirely practicable.

The purpose of this bulletin is to point out, so far as possible, the comparative cost of the different methods employed in harvesting wheat and to outline the points which must be considered in calculating this cost in such a way that farmers readily may insert the figures which apply to their particular conditions, and thus be able to compare their present costs with those of others. By so doing, those who are not now doing the work in the most economical manner may be led to consider the adoption of some other practicable system which will result in a saving of time and money.

A careful study of the cost of harvesting wheat has shown that the greater items of expense are for man- and horse-labor and depreciation of machine, and in endeavoring to cut down harvesting expenses the farmer should give careful attention to the most important items. The large machines show the smallest cost per acre, and, other things being equal, the farmer therefore should use the largest machine practicable under his conditions in order to reduce the man- and horse-labor required. If he can make his machines last longer by a little inexpensive care, such as better housing, more careful overhauling during the winter months, etc., it may result in material savings in total harvesting expense. In the following pages are shown some figures which, though they may not be directly

applicable to many particular cases, should be of considerable value to farmers who are interested in cutting down their harvesting expenses, by showing them where the greatest expenses commonly are incurred.

THE BINDER.

By far the largest percentage of the wheat crop of the country is to-day harvested with the binder, the use of this machine being almost universal. Although headers are used in large numbers and over a wide area through the Middle West and West, binders also are used throughout the same area, it being quite common to find both machines on one farm. In some seasons only the binder will be used, in others only the header, while often both will be used, depending upon conditions which will be referred to later. The only wheat-growing sections where the binder is not used on the greater part of the crop are in the States of Washington, Oregon, and California, and parts of Idaho, Utah, Wyoming, and Montana, where much of the wheat is cut and thrashed with combined harvesters (see pp. 18 to 22), although even where these outfits are commonly used binders also are employed to some extent. (See Pl. I, fig. 1.)

The cost of harvesting may be somewhat greater where the binder is used than where the work is done with headers or combined harvesters. The binder, however, has a distinct advantage over these machines in that the work of harvesting may be begun from one to two weeks earlier with the binder than with either the header or combine, since wheat can be cut with a binder while in the early dough stage and placed in shocks to complete ripening; at the same time it is comparatively safe from destruction by storms. This feature is a very valuable one in many cases, not only for the reason just given but also because it permits the work of harvesting to be extended over a much longer period than with the other machines mentioned, thus requiring fewer horses and men to harvest a given acreage.

DUTY.

The cost of harvesting wheat with a binder varies considerably, being influenced by the several factors mentioned below. Data have been collected showing the daily duty of six-, seven-, and eight-foot binders, and the results of the tabulation of these data are shown in Table I. By this it will be seen that the six-foot binder is most commonly drawn by three horses, while on the seven-foot cut four horses are generally used. On the eight-foot binder, the use of four horses is practically universal. On the six-foot binder, the extra horse appears to make but a little over an acre's difference in the quantity of work done per day. The six-foot binder apparently does not overload three horses except where the yield is exceptionally heavy, or

where hilly or soft ground is encountered, and three horses, therefore, under most conditions, do a fair day's work for a machine of this size. The extra horse on a seven-foot binder adds slightly over 2½ acres per day to the work accomplished, which would seem to indicate that three horses are somewhat overloaded with such a machine.

TABLE I.—*Average acres cut by 6-, 7-, and 8-foot binders in a 10-hour day. (235 reports.)*

Width of cut and number of horses.	Acres cut.		
	Per binder.	Per horse.	Per foot of cutter bar.
6-foot, 3 horses	10.90	3.63	1.82
6-foot, 4 horses	12.10	3.03	2.02
7-foot, 3 horses	12.50	4.17	1.79
7-foot, 4 horses	15.10	3.78	2.16
8-foot, 4 horses	17.00	4.25	2.13

The larger binders are more efficient in the use of both horse- and man-labor than the smaller sizes. For example, on the six-foot binder each horse cuts approximately 3.6 acres per day, whereas on the eight-foot binder each horse cuts practically 4.25 acres per day, or accomplishes 17 per cent more work. This is probably accounted for by the fact that the weight of the eight-foot binder is only slightly more than that of the six-foot. Each horse on the six-foot binder drawn by three horses has to move more weight than on the eight-foot binder drawn by four horses, while the amount of work on the cutter-bar and other mechanism is in almost exactly the same proportion. It is not surprising, therefore, that more ground will be covered per horse by the larger binders, since the draft per horse will be less.

In considering the amount of work done per horse on the different sizes of binders, the last column of Table I, showing the amount of grain per foot of cut, must be studied. Most binders when in use do not cut the full width of the cutter-bar a great part of the time, as it is difficult to drive so as to take a full swath at all times without occasionally missing some grain, and most drivers, therefore, will err on the safe side by allowing a few inches of the cutter-bar to travel over stubble. This margin will be practically the same for a six-foot cutter bar as for the eight-foot, but the percentage of the sickle which is idle will of course be greater for the six-foot than for the eight-foot size.

From these facts, it is apparent that the cost of cutting wheat with a binder will vary with the size of the outfit used, the cost being lowest with the eight-foot cut. In the past many farmers have been prejudiced against the large binders because of the heavy side draft on the horses, but this objection no longer holds, as with most modern

binders it has been overcome entirely. In most cases where there is a considerable acreage to be cut and the necessary horses are available the purchase of the large binder will prove to be the most profitable because of the greater efficiency in the use of both man- and horse-labor.

Other factors which influence the amount of work done per day, and therefore the cost, are yield per acre, especially of the straw, the character of the soil, whether soft or firm, rough or smooth, and the topography of the farm, whether level or hilly. The working ability of the horses used also has considerable bearing on the acreage covered. The condition of the working parts of the machine, particularly the sickle, will likewise affect the amount of work done per day.

The figures here given are intended to approximate the average conditions so far as possible. In order to make them comparable, an arbitrary value for both man- and horse-labor has been used in all cases in calculating the cost of doing the work by the various methods, although these values will vary in different parts of the country. For the same reason the data collected have been adjusted to a uniform day of 10 hours; that is, if a man reported 18 acres as an average day's work with an eight-foot binder, working 12 hours per day, in tabulating the data his figure would be changed to 15 acres per day of 10 hours, since his rate of cutting was $1\frac{1}{2}$ acres per hour. In applying the figures to any particular farm, therefore, the prevailing cost of man- and horse-labor, as well as length of day, should be substituted.

Assuming man-labor to be worth $2 per day, including board (which is probably not far from the actual cost on a large percentage of farms during harvest, although temporary help may cost considerably more), and horse-labor 12 cents per hour, or $1.20 per day (a figure which it is believed will represent a fair average for the country as a whole, being slightly above the cost for parts of the Middle West and West, but lower than most of the Eastern States), the approximate cost of cutting wheat with the different sized binders is shown in Table II. No figures have been given for the five-foot binder, as this size is no longer in common use.

As would naturally be expected, the eight-foot binder drawn by four horses is more economical than the six- or seven-foot binder drawn by either three or four horses, as the cost for both man- and horse-labor is lower. The highest cost per acre for man-labor is of course found where the six-foot binder and three horses are used. In this case the cost of the man-labor per acre in cutting wheat is 18 cents, or 50 per cent more than where the eight-foot binder is used. The difference in the horse-labor per acre between the six-foot

machine drawn by three horses and the eight-foot outfit with four horses is 5 cents per acre, or about 18 per cent. Where the seven-foot binder with three horses is used the cost per acre for horse-labor is only 1 cent greater than where the eight-foot binder and four horses are used. In other words, horse-labor is utilized almost as economically on a seven-foot binder drawn by three horses as on an eight-foot outfit drawn by four horses, but the cost of man-labor is greater on the smaller machine. The charge per acre with the seven-foot binder is exactly the same with either three or four horses when the values of man- and horse-labor bear the relation which they do in this table, as the cost for horse-labor is less where only three horses are used, while that for man-labor is correspondingly lower where four horses are used. This point is well worth considering where hired help is scarce and extra horses are available.

TABLE II.—*Labor cost of cutting one acre of wheat with binders of different sizes and with varying numbers of horses, man-labor at $2 per day, and horse-labor at $1.20 per day of 10 hours (based on figures in Table I).*

Width of cut and number of horses.	Cost per acre.		
	Total labor.	Man-labor.	Horse-labor.
6-foot, 3 horses	$0.51	$0.18	$0.33
6-foot, 4 horses	.57	.17	.40
7-foot, 3 horses	.45	.16	.29
7-foot, 4 horses	.45	.13	.32
8-foot, 4 horses	.40	.12	.28

In actual practice it often is possible to hire horses from neighbors as low as 75 cents each per day and board, many farmers being willing to hire their horses out at a very low figure in addition to their board, when they have no work for them. The cost of horse-labor per hour therefore is frequently less with a hired horse under these conditions than where the horse is owned and maintained during the entire year.

INTEREST AND DEPRECIATION.

In this bulletin the interest charges on the various machines have been computed in all cases at 6 per cent on one-half the cost of such equipment, which figure represents the average investment. Many men fail to consider interest charges at all, whereas others allow interest on the first cost of their equipment for each year of its life. This is incorrect, as the value of the equipment decreases each year of its life, and if charges are made against it for depreciation it is obvious that interest should not be charged against these amounts during subsequent seasons. Assuming that the equipment is worthless at the end of its life (that is, ignoring its junk value), the average amount invested will be 50 per cent of its first cost, and the

method here used of charging interest at 6 per cent on one-half of the first cost for each year distributes the interest charges equally over its entire life, since it would be unfair to charge the first season's use with interest on the full value and the last season's use with interest only on the remaining value.

It is difficult to arrive at any satisfactory figures for depreciation charges on binders, as the life of these machines varies within wide limits; the acreage they cover per year also varies, and the care they receive, both in and out of use, has considerable effect on their years of service. The small binders are found most commonly in the Eastern States, where the acreage covered annually (including all crops on which they are used) is comparatively small.

In Table III are shown some figures on the cost for interest and depreciation on binders, based on approximate figures for the cost, life, and acres covered annually. All three of these items vary in different sections. The acres cut annually by a binder do not seem to have a very direct influence upon its life except where the acreage is extremely large. There is a certain deterioration due to age which appears to limit the length of life in years whether the binder does a fair amount of work each season or not.

TABLE III.—*Approximate cost, life in years and acres, and annual interest and depreciation charges on binders.*

Type of binder.	Approximate cost.[1]	Acres covered annually (all grain).[1]	Life in—		Average annual cost per acre.		
			Years.[1]	Acres.[1]	Interest at 6 per cent on average investment.	Depreciation.	Total.
6-foot	$125	50	15	750	$0.07½	$0.16½	$0.24
7-foot	135	100	11	1,100	.04	.12	.16
8-foot	145	150	10	1,500	.03	.09½	.12½

[1] Approximate figures based on tabulation of 235 reports. There is a variation in the cost of binders in different States, depending largely upon the freight rates. The acres cut annually, and life in years, also vary widely in different sections and with different care.

REPAIRS.

The amount of repairs required by a binder depends to a great extent upon the care it receives. If kept well oiled and otherwise in proper condition, the repairs, except for the replacement of the canvas, should be practically negligible. Occasional breaks will occur, but most of the parts liable to breakage can be replaced at slight expense. Many farmers have reported the use of a binder for several years without a cent being spent for repairs, whereas in other cases repairs have ranged from $10 to $15 annually. As a rule the most expensive item of repairs, as stated above, is the canvas. The number of acres which can be cut with one canvas varies considerably,

being influenced by the number of acres cut annually, and the care given it when idle. Where a binder covers a large acreage each year the acres cut with one canvas may be twice as great as with a binder used on only a small number of acres each year, as it deteriorates whether used or not. If properly protected when idle, a binder canvas should cut from 400 to 800 acres and perhaps in some cases 1,000 acres.

In western New York (see United States Department of Agriculture Bulletin 338) it was found that it cost nearly 60 cents per day of use to keep a grain binder in repair, or 0.058 cent per acre cut, and that before a binder is worn out 25 per cent of its first cost, on an average, must be spent to keep it in running order.

The percentage of the first cost represented by repairs is usually less for small binders than for the larger sizes, because of the much smaller amount of work ordinarily done by them during their years of service, while their first cost is only slightly less than for the larger sizes. It is believed that 20 per cent of the first cost for six-foot binders, 25 per cent for seven-foot, and 30 per cent for eight-foot machines will approximate the average repairs required for these outfits. Repair charges for six-, seven-, and eight-foot binders figured on this basis are shown in Table IV.

In the eighth column of Table V the approximate cost of binder twine per acre will be found. This varies, of course, with the yield of straw. The twine required in the West is usually about 2½ pounds per acre, while in the East the average is nearer 3 pounds. The cost per pound is generally slightly higher in the West than in the East, but it has been figured in all cases on the basis of 3 pounds per acre, and as costing 11 cents per pound, which is a little higher than the average price in the East during the season of 1916 but slightly less than the retail price to the western farmer during the same season.

From the figures given in Tables I to IV, inclusive (to which the twine cost must be added, as well as cost for shelter, if any), it is an easy matter to calculate the comparative cost of cutting an acre of wheat with a six-, seven-, or eight-foot binder. The figures from the tables mentioned (excepting the shelter cost) have accordingly been summarized in Table V and show that the cost of cutting an acre of wheat ranges from 88.4 cents where an eight-foot binder is used to $1.173 for a six-foot binder, each machine being drawn by four horses. In other words, the expense of cutting an acre of wheat with the smaller outfit is nearly 33 per cent greater than where the larger binder is used. The figure in which the farmer is most interested, however, is the cost per bushel, which is readily found by dividing the cost per acre by the average yield. In the last column in Table V are given the costs per bushel for the different sized outfits, based on a yield of 16 bushels per acre, which is about the average yield for the country as a whole. This shows approximately 7

cents per bushel for the six-foot, 6 cents for the seven-foot, and 5½ cents for the eight-foot binder. Where the yield is above the average the cost per bushel will, of course, be reduced.

TABLE IV.—*Repair costs on binders.*[1]

Type of binder.	Total repairs during life.	Per cent of first cost spent for repairs during life.	Cost of repairs per acre cut.
6-foot	$25.00	20	$0.033
7-foot	33.75	25	.03
8-foot	43.50	30	.029

[1] Calculations based on prices given in Table III.

The cost for shelter has been omitted in all cases because this item varies so greatly and in many cases is insignificant, since a great many binders, particularly in the West, have no shelter whatever except for the canvases and sickles, which usually are taken off and stored in a dry place during the winter. In the East binders are sheltered almost universally when not in use, ordinarily in barns or other buildings which are used primarily for other purposes, and a legitimate charge against a binder for shelter under these conditions is practically negligible. On the other hand, where a binder is sheltered in a substantial implement shed the annual cost for interest, depreciation, taxes, and repairs may amount to from $3 to $5, or even more, as it occupies considerable floor space and does not permit of other implements being stored on top of it.

TABLE V.—*Cost of cutting 1 acre of wheat with binder, calculated from data shown in Tables I to IV, inclusive.*

Width of cut and number of horses.	Cost of cutting 1 acre of wheat.							Cost per bushel for 16-bushel yield.
	Total.	Man labor.	Horse labor.	Interest.	Depreciation.	Repairs.	Twine.[1]	
6-foot, 3 horses	$1.113	$0.18	$0.33	$0.07½	$0.16½	$0.033	$0.33	$0.0695
6-foot, 4 horses	1.173	.17	.40	.07½	.16½	.033	.33	.0733
7-foot, 3 horses	.97	.16	.29	.04	.12	.03	.33	.0606
7-foot, 4 horses	.97	.13	.32	.04	.12	.03	.33	.0606
8-foot, 4 horses	.884	.12	.28	.03	.09½	.029	.33	.0552

[1] Based on 3 pounds per acre, and costing 11 cents per pound (see text).

AUXILIARY BINDER ENGINES.

A factor in reducing the cost of harvesting with a binder under certain conditions is a small gasoline engine attached to the binder and furnishing power to operate the mechanism, which is ordinarily driven by power from the horses through the medium of the bull wheel. The use of these binder engines, as they are called, has increased considerably during the last two or three seasons, particu-

larly in certain sections where wet ground has made the operation of the binder difficult.

The use of these engines not only lessens the draft for the horses (usually to a sufficient extent to permit of the binder being pulled by one or two horses fewer than the number commonly used), but also permits cutting heavy grain at slower speeds for the outfit as a whole than would be possible without such an auxiliary source of power (since the sickle runs at a constant speed at all times), and allows the grain to be harvested with a binder on ground where the bull wheel would slip if it were required to transmit power to the cutting and binding mechanism.

These engines cost about $150, but their use is by no means confined to the binder alone, as most owners who have them use them for numerous other odd jobs about the farm where belt power can be utilized. Under these conditions their estimated average life is about 9½ years. In some instances the engines are used practically every day of the year for pumping water, except while on the binder. Under such conditions the overhead charges of depreciation, interest, and repairs, which would be chargeable against harvesting, amount to a very small figure, while the operating expenses will be only about three-fourths of the daily labor cost of one horse, and the engine will in nearly every case decrease the number of horses required by at least one.

The owners of these outfits report that from 2 to 5 gallons of gasoline are required to operate the engine per day, the average being a fraction less than 4 gallons, while about 1 pint of lubricating oil per day appears to be a fair average. With gasoline at 20 cents per gallon, and lubricating oil at 40 cents, this would make the daily operating expense amount to about 85 cents. The overhead charges will vary according to the amount of other work done by the engine annually.

The engine not only decreases the number of horses required, but in most cases will effect a considerable increase in the acres cut per day. Reports from farmers who have used these outfits indicate that an increase of from 4 to 5 acres per day may be expected in the area covered with the binder under the conditions existing where they were being used, which were for the most part unfavorable conditions such as those previously mentioned.

The repairs on the outfits concerning which the reports were received had averaged slightly less than $3 annually, although the average age was only 3½ years. The repairs during the latter years of the engines' lives would in all probability be somewhat higher than this figure.

The possibility of effecting a saving in the cost of harvesting wheat under many unfavorable conditions by means of the binder engine

seems great enough to warrant careful consideration of these outfits on the part of many wheat growers who would have use for such an engine in other ways.

SHOCKING.

The practice of shocking wheat after being cut with a binder is almost universal. It is occasionally possible to thrash wheat immediately after being cut with a binder, the bundles being loaded directly on to the wagons from the piles left by the binder, but this is not common, partly because the wheat may not be fit to thrash and partly because a thrashing outfit is not available when needed.

Hauling bundles to the stack without shocking is also practiced to some extent, and where this can be done a saving of about 1 cent per bushel is effected; but in the majority of cases the wheat is placed in some kind of shocks before being stacked or thrashed.

The cost of shocking wheat varies with the yield, condition of the bundles, size of machine used in cutting, and the amount of carrying done by the binder. The character of the shocks also will have some effect, although it takes practically as long to build a poor shock as a good one.

The average acres shocked per day by one man, tabulated according to yield per acre, are shown in Table VI. It will be seen that the acres shocked per day in the two groups having yields of over 20 bushels are disproportionately less than in the two groups with yields of 20 bushels or under. This seeming irregularity is accounted for by the fact that a large percentage of the reports on low yields come from sections having a large acreage and light straw. The average cost of about 1 cent per bushel as shown in Table VI is, therefore, approximately correct. On account of the relatively small cost of shocking compared with the protection it affords, many men shock their wheat even if it is to remain in the field but a very short time.

TABLE VI.—*Acres shocked per day per man and cost per acre and per bushel in relation to yield per acre. (Based on labor at $2 per day, 264 reports.)*

Yield per acre.	Average yield per acre.	Acres shocked per day per man.	Cost per acre.	Cost per bushel.
Under 20 bushels	15	12½	$0.16	$0.01
20 bushels[1]	20	12	.16½	.008
21 to 30 bushels	26.2	8¾	.22	.009
31 bushels and over	37.4	7½	.26½	.007

[1] A number of men reported their yield as 20 bushels per acre, and it was deemed advisable to leave these estimates in one group.

COMPARISON OF COSTS—OLD METHODS VS. NEW.

It is very interesting to compare the costs of cutting wheat as it is usually done to-day with the methods in use 75 years ago. It is very generally believed that modern methods always result in greatly

reducing the cost of an operation, but from the cost figures given below it will be seen that the principal effect of improved harvesting machinery has been to increase to a very large extent the amount of work which one man can accomplish in a day with the assistance of horse-labor and machines over what was formerly done by man-labor alone.

For example, the average cost of cutting with a binder, as shown in Table V, is $1.022 per acre, and the average cost of shocking, as shown in Table VI, is 20.5 cents, or a total of $1.23 for the two operations. In the Transactions of the New York State Agricultural Society, volume 10 (1850), page 550, the cost of cradling and binding (and the shocking was probably done at the same time) is given as 70 cents per acre on a 20-bushel yield. In the Report of the Department of Agriculture for 1853, page 143, the cost of cradling, binding, and shocking an acre of wheat, where the yield was also about 20 bushels, is given as 75 cents per acre.

In other words, the cost of cutting, binding, and shocking wheat to-day, with an average yield of 16 bushels per acre, would be slightly less than 8 cents per bushel, whereas in the cases just mentioned it was a little under 4 cents per bushel. The average farm price per bushel for wheat during the 10 years 1906–1915 was about 87 cents (see United States Department of Agriculture Yearbook for 1915), so it will be seen that the cost of harvesting in recent years has represented about one-eleventh of the selling price of the crop, whereas when hand methods were used the cost of harvesting represented less than one-thirtieth of the selling price. The cost of harvesting to-day, therefore, represents a greater percentage of the selling price of the crop than it did when the old hand methods were used. However, to-day two men (one shocking), with three or four horses, will cut, bind, and shock about eight times as much wheat as two men cutting with a cradle and binding by hand. It should be borne in mind, of course, that the price for labor at the time cradles were used was considerably less than at present. To make a direct comparison of the cost of the two methods the same price for labor should be used in both cases. If man labor was worth $2 per day (the figure which has been used in the computations herein), the cost per acre by the hand methods would be approximately $1.60 as against $1.23 with the binder, where the yield was 16 bushels per acre.

It is also interesting to compare the amount of work done per day per horse with that accomplished by one man using the old hand methods. By Table I it will be seen that the acres cut per horse in one day varied from about 3 to 4¼ acres. To cradle, bind, and shock 1 acre per day where the yield was about 20 bushels was a fair or average day's work for one man; a good, experienced hand

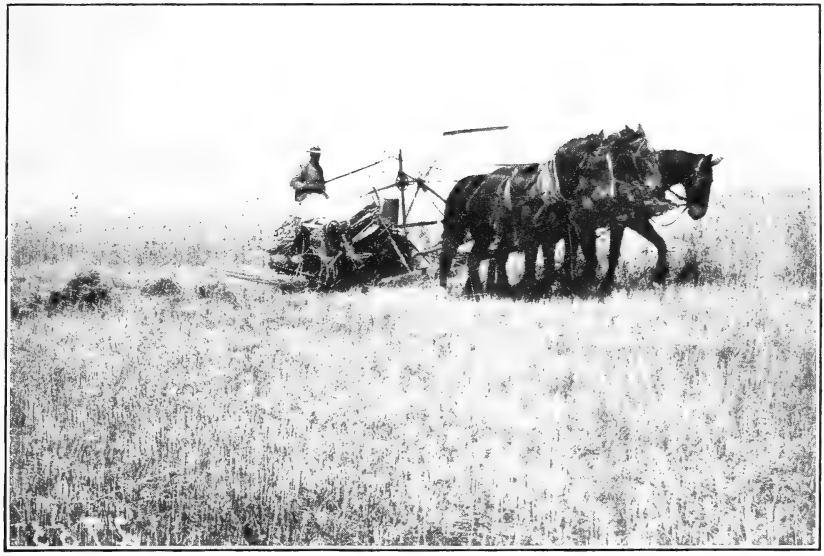

FIG. 1.—BINDER IN OPERATION.

FIG. 2.—HORSE-DRAWN HEADER IN OPERATION.

FIG. 1.—HORSE-DRAWN COMBINE IN OPERATION.

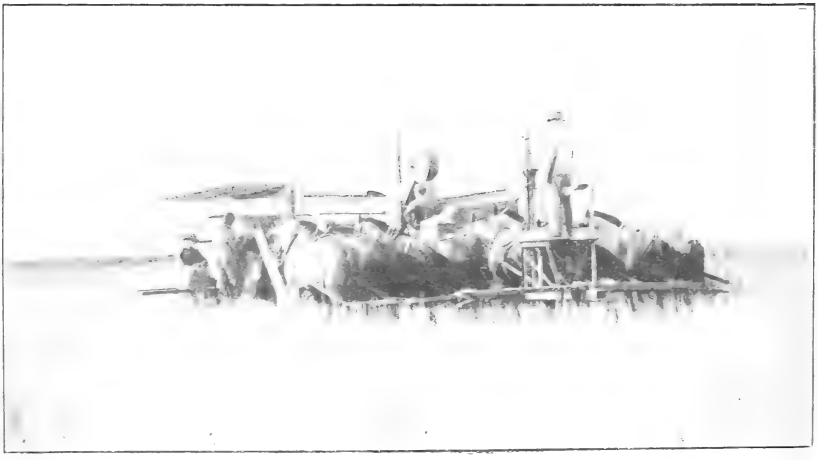

FIG. 2.—THE SMALL COMBINE; A TYPE THAT HAS ATTAINED GREAT POPULARITY IN RECENT YEARS.

could, however, do considerably more. It would seem, therefore, that the work done by a horse in one day is not much more than three times the amount performed by a man, although the working power of a horse usually is considered to be ten times greater than that of a man (Kent). This is accounted for probably by the fact that the horse's strength is less directly applied to the work than is that of the man, there being greater losses through friction and a much greater amount of weight to be moved. From the figures shown in Tables I to VII, inclusive, it will be seen that the cost of cutting, shocking, and stacking wheat ranges from about 11 to 15 cents per bushel.

STACKING.

The acreage covered per day by a given crew in stacking wheat depends upon the yield, distance hauled, size of loads, and method used. For example, two men and four horses, with either one or two of the bundle wagons which are commonly found in the wheat-growing sections of the Northwest, where both men pitch and no one is required on the load, will be able to stack more wheat, other things being equal, than will two men following the usual practice in the East of one pitching while the other man loads. The wagons used in the two cases are usually very different, the western "bundle wagon" being especially built for use in the manner above mentioned, whereas with the type of wagon usually found in the East it would be impossible to haul a very large load in this way, because of the difficulty of putting many bundles on such a wagon in such a way that they would carry well. Although the loads hauled on the western bundle wagons do not contain quite so many bundles as do those in the East when loaded by hand, they are put on in less time and with one-half the man-labor, which more than offsets this objection. If two bundle wagons are available each man can pitch on a load and take it to the stack, where one will pitch off while the other stacks. This combination is probably the most efficient crew which can be used in stacking wheat, provided the haul is not too long. It is especially recommended for consideration by eastern wheat growers, as in many cases it would be an easy matter to place a temporary rack on their wagons, thus making them well suited for use in the manner described. The adoption of this method would materially reduce the cost of stacking.

Six acres per day for two men and one team appears to be a fair day's work in stacking wheat under most eastern conditions, whereas in the western sections where the more efficient methods are employed 8 acres per day for two men and two horses and 10 acres per day for two men and four horses would appear to be a fair average. Based on these figures the cost of stacking per acre for man- and horse-labor would be as shown in Table VII. No allowance has

been made for the use of the wagon in any case, as this is a factor which is exceedingly hard to determine with accuracy, since the wagons are used for so many other purposes. If properly cared for they will last many years and the cost would, therefore, be practically negligible.

From the figures in this table it will be seen that the cost of stacking wheat varies from 80 cents to $1.06½ per acre, or from 5 to 6½ cents per bushel on a 16-bushel yield. The cost of stacking is little if any greater than the cost of hauling from shock to the separator when thrashing. Having the grain in stacks expedites thrashing somewhat and at the same time reduces the number of men and horses required.

Where stacking is properly done the grain is better protected in stacks than in shocks.[1] In wet seasons or when thrashing can not be done soon after cutting, the importance of this protection is increased. A sweating process also takes place in the stack, which improves to some extent the color, condition, and test weight of the grain and its milling and baking qualities. The improvement may be sufficient to obtain a better market grade, with resulting higher price when sold. A similar sweating process apparently may take place in shock-thrashed wheat after being placed in the bin, but to take advantage of this the farmer must have storage room for his thrashed grain and must also get it thrashed from the shock while it is in as good condition as when placed in the stack.

TABLE VII.—*Labor cost per acre and per bushel of stacking wheat with man-labor at $2 and horse-labor at $1.20 per day of 10 hours.*

Operation.	Number of horses.	Acres covered per day.	Labor cost per acre.			Cost per bushel (16-bushel yield).
			Man.	Horse.	Total.	
1 man pitching and 1 man loading (1 wagon)[1]	2	.6	$0.66½	$0.40	$1.06½	$0.06½
2 men pitching (1 wagon)[2]	2	.8	.50	.30	.80	.05
2 men pitching (2 wagons)[2]	4	10	.40	.48	.88	.05½

[1] Hayracks are commonly used in the East. [2] Western type of bundle wagon.

Other advantages of stacking are that it makes it possible in wet weather to thrash the wheat more completely from the straw, thus saving more of the grain, and to remove more of the chaff, thus securing cleaner grain. Thrashing can begin sooner after rains if wheat is stacked, especially if the stacks are protected by a cover of any kind. In thrashing from the shock after a period of rainy weather the grain secured is nearly always somewhat damp and tough, as the tendency is to begin thrashing too soon after rains. Stacking also permits early fall plowing, which is particularly de-

[1] Acknowledgment is due Messrs. Clyde E. Leighty and Carleton R. Ball, agronomists in charge of Eastern and Western Wheat Investigations, respectively, for information concerning the effect of stacking on the quality of wheat.

sirable in certain sections (see Farmers Bulletin 678, "Growing Hard Spring Wheat.").

The two more important advantages of stacking, therefore, are the protection from the weather and, generally, the improved quality of the grain. These results are likely to follow *good* stacking. Where the stacking has been poorly done there is often a different story, the grain being in worse condition when thrashed from the stack than it would have been if thrashed after a reasonable time in the shock.

HEADERS.

Thousands of acres of wheat are harvested annually by means of the header, but this machine is, for the most part, an auxiliary of the binder for reasons mentioned below. Although usually there is a slight saving in harvesting with the header compared with the binder, in most sections there are some seasons when it is impracticable to run the header, so that it is very common to have binders on farms where headers are used. (See Pl. I., fig. 2.)

The principal advantages of the header, in addition to its economy under certain conditions, are that it eliminates considerable hand labor, covers more ground per day, saves the cost of twine, expedites thrashing because of the smaller amount of straw handled, and will harvest short grain that could not be cut and bound with a binder. In certain sections headers are kept largely for the last-mentioned purpose, since in areas where there is little rainfall there will often be a fair yield of wheat on straw that is altogether too short to handle with a binder. In such cases the header will remove the heads and place them in the header wagons with practically no loss. In some localities it is frequently desirable to plow the stubble immediately after harvest, and when a field has been headed there are no shocks to interfere with or delay this work.

The disadvantages of the header are several. The wheat must be allowed to ripen upon the stalk sufficiently to keep well in the stack, yet, when harvesting is not begun until the grain is in this condition, before it can be completed much of the wheat will be so ripe that considerable loss may result from shattering, especially with certain varieties. It seldom happens that all parts of a large field will ripen evenly; certain low spots where there is a surplus of moisture will remain green for several days after the grain around them is fit to cut with a header. The green heads from such spots, if harvesting is done with a header as soon as the remainder of the field is ready to cut, may cause considerable loss in the stack by reason of heating and molding.

The header requires more men and horses to operate it efficiently than are needed for two binders, five to eight men and ten to sixteen horses being employed in the crews. The same number of men and horses using binders could cut and shock a larger acreage per day

than a single header could cover, but the grain would yet have to be hauled for stacking or thrashing.

The straw remains on the field, which is undesirable in many sections where there is not sufficient moisture in the soil to cause it to decompose if turned under. This feature is also an objection on farms where it is desired to use the straw for bedding, since it requires considerable time and labor to cut and haul the straw after it has been headed.

In those sections where thrashing from the shock is the common practice, and where most of the thrashing is done by large custom outfits whose owners furnish the entire crew, the grain that has been headed, and of course stacked, ordinarily is left until all shock thrashing on the route has been completed, since thrashing from the stack does not require so many men, and no bundle teams. The owner of the rig naturally wishes to complete all the work where his entire crew will be needed before laying some of them off and beginning work that will require fewer men and horses. On the other hand, in those sections where heading is the most common practice, the stacks probably will be given preference, since the crops of the largest growers usually will be headed, and the custom thrashers naturally prefer to make sure of the largest jobs.

The sizes of headers most commonly used are 12 and 14 feet. A six-horse team is found most commonly on the twelve-foot machine, although eight horses are sometimes employed where the grain is particularly heavy or where the land is in such condition as to make a very heavy draft. On the fourteen-foot machine eight horses are used most frequently.

A fair day's work of ten hours with a twelve-foot header is about 24 acres, and with a fourteen-foot machine about 28 acres. The acreage covered in ten hours by a given size of header will not, of course, vary greatly with the different sized crews, provided the crew is sufficient to keep the header at work.

The additional men and horses required vary considerably in different sections and under different conditions—that is, according to the yield of grain, the distance the loads must be hauled to the stacks, and the character of the ground over which hauling is done. For instance, in the wheat-growing sections of Washington and Oregon the ground is hilly and the yield of wheat heavy. Here a common crew is four header wagons, each with one driver and two horses, one man loading, one man stacking, and another to help pitch off at the stack, making a total of eight men and sixteen horses, whereas in the Middle West, where the ground is level and the yield comparatively light, many headers are operated with six horses and only two header wagons, each with a driver and two horses, one loader and one man at the stack, making a total of five men and ten horses.

It is obvious that the cost of harvesting an acre of wheat with headers of the same size will vary with the number of men and horses in the crew, whereas the cost per bushel will depend largely upon the yield. The overhead charges per acre—that is, interest, depreciation, and repairs—will depend, of course, upon the number of acres harvested annually and the life of the machine. The first cost of headers is considerably higher in the Pacific Coast States than in the Middle West, owing to the difference in freight rates. The cost for wagons depends upon the extent to which they are used for other work. The header box itself generally is built especially for use in heading wheat, and the interest, depreciation, and repairs on these boxes should in such cases be charged against the wheat. They are inexpensixe, however, since they usually are made on the farm from cheap lumber; $8 per box probably would be a fair average cost. The repairs to the boxes are practically negligible, being made from odds and ends of lumber which are available. Few header boxes are painted, and yet fewer are sheltered; but since in the regions where they are used there is comparatively little rain their life is longer than might be expected, 10 years probably being a fair average figure. The running gears generally are used for other purposes during the remainder of the year. It is, therefore, impossible to arrive at any reliable figures as to what percentage of the overhead charges on a header wagon are properly chargeable against the wheat.

Based on the figures already mentioned for the crews and overhead charges, Table VIII has been prepared to show the approximate cost of harvesting an acre of wheat with twelve- and fourteen-foot headers, with two common sizes of crews for each.

TABLE VIII.—*Cost of harvesting an acre of wheat with headers of various sizes and different sizes of crews, with man-labor at $2 and horse-labor at $1.20 per day of 10 hours.*

Size of header and crew.	Daily cost of operating the outfit.				Cost per acre.	Cost per bushel.	
	Total.	Man-labor.	Horse-labor.	Interest, depreciation, and repairs on headers.		Based on 16-bushel yield.	Based on 30-bushel yield.
12-foot, with 5 men and 10 horses [1]	$25.40	$10.00	$12.00	[2] $3.40	$1.06	$0.07	.....
12-foot, with 6 men and 14 horses [3]	32.20	12.00	16.80	[2] 3.40	1.34	.....	$0.045
14-foot, with 6 men and 12 horses [4]	29.75	12.000	14.40	[5] 3.35	1.06	.07	.....
14-foot, with 8 men and 16 horses [6]	38.55	16.00	19.20	[5] 3.35	1.38	.....	.046

[1] Crew made up as follows: 1 driver and 6 horses with header; two header wagons with 2 drivers and 4 horses; 1 man loading wagon and 1 man on stack.
[2] Based on annual duty of 300 acres and 24 acres per day.
[3] Crew made up as follows: 1 driver and 8 horses with header; 3 wagons with 3 drivers and 6 horses; 1 loader and 1 man on stack.
[4] Crew made up as follows: 1 driver and 6 horses on header; 3 wagons with 3 drivers and 6 horses; 1 loader and 1 man on stack.
[5] Based on annual duty of 450 acres and 28 acres per day.
[6] Crew made up as follows: 1 driver and 8 horses on header; 4 wagons with 4 drivers and 8 horses; 1 loader and 2 men at stack.

From Table VIII it will be seen that the cost of heading and stacking an acre of wheat varies from $1.06 to $1.38, according to the size of the crew. The cost per bushel will, of course, depend upon the yield. In the last two columns are shown the approximate cost per bushel based on yields of 16 and 30 bushels per acre. The cost per day with the small crews has been divided by 16, and the cost per day with the large crews has been divided by 30, in order to approximate actual conditions, since the larger crews are used more often where the yields are heaviest. From these columns it will be seen that the cost per bushel ranges from 4½ to 7 cents. The cost of cutting an acre of wheat with a header and stacking the heads is very little greater than the cost of cutting when the work is done with a binder. It will be seen, therefore, that there is generally a saving in harvesting with a header when the cost of shocking and stacking, or hauling to the separator, is considered.

COMBINES.

By far the cheapest method of harvesting and thrashing wheat practiced in this country at present is by means of the combined harvester, a machine that cuts the heads from the wheat and thrashes them at the same operation. Unfortunately the use of this outfit has been limited to certain sections where the grain ripens on the stalk. (Pl. II, fig. 1.)

"Combines," as they are commonly called in the sections where they are used, vary considerably in size and weight, according to the type and make. The early forms of combines were just what the name implies, i. e., a combination of two machines, a header and a separator, so arranged that the header delivered the cut heads directly to the thrashing cylinder. The first outfits were drawn by horses, and both the header and separator mechanisms were operated by "bull" or drive wheels. A little later steam was utilized to operate some combines, and still later gasoline engines, either in the form of tractors or mounted on the combines themselves as single units, were used. At present most combines are still drawn by horses, although auxiliary gasoline engines frequently are used to operate the mechanism, the horses merely moving the outfit.

The combine, like most other harvesting machinery, has undergone considerable improvement during the last few years, and instead of being merely a combination of two machines primarily designed for two different kinds of work, the combines of to-day are designed and built for the complete operation of cutting and thrashing the grain. The width of swath cut by combines varies from about 7 to 25 feet. The first combines were used principally on very large areas of wheat, and were of necessity of large size, in order to complete the work during the weather suitable for harvest. They required about

thirty or more horses to pull them, which added considerably to the expense, as many extra horses had to be maintained throughout the entire year so as to be available at harvest time. Of late years the smaller outfits have been increasing in number very rapidly. These small rigs are entirely practicable on small areas, since their price is lower than for the larger types, and their weight is so much less that fewer horses are required to operate them. (See Pl. II, fig. 2.) The amount of work done per day with the different sized outfits is shown in Table IX.

TABLE IX.—*Acres cut and bushels thrashed by different sized combines in a 10-hour day. (65 reports.)*

Width of combines, and horses used.	Acres per 10-hour day.			Bushels thrashed per day (30-bushel yield).	Usual number of men in crew.
	Per combine.	Per horse.	Per foot of cut.		
7 feet, 8 horses	12.4	1.55	1.77	372	2
9 feet, 10 horses	13.6	1.36	1.51	408	2
12 feet, 22 horses	19.9	.90	1.66	597	4 or 5
14 feet, 24 horses	20.6	.86	1.47	618	5
16 feet, 28 horses	27.0	96	1.69	810	5
18 feet, 30 horses	31.0	1.03	1.72	930	5
20 feet, 30 horses	34.0	1.13	1.70	1,020	5 or 6
24 feet, 36 horses	42.0	1.17	1.75	1,260	5 or 6

NOTE.—The number of horses used on the different sizes of combines varies considerably according to the yield of wheat, the condition of the soil, the topography of the field, and the particular type or make of machine. The figures shown in the first column are about the most common teams for the sizes given; the number used in individusl cases on the larger outfits are frequently from 1 to 4 above or below the figures given.

From this it will be seen that there is considerable irregularity in the number of acres cut per day by the different sized outfits, which is due probably to the small number averaged in most of the groups. The yield per acre usually makes but little difference in the acres covered per day except as mentioned below, since the machines must be kept moving at a certain speed in order to do good work. Therefore, in heavy grain, on hilly land, soft ground, etc., it is often necessary to use extra horses in order to keep the outfit moving at the required speed. If the additional horses are not available heavy pulling will cut down the amount of work done per day because of the more frequent resting of the horses that will be necessary.

In the fifth column of Table IX is shown the number of bushels thrashed per day by the outfits of different sizes based on a yield of 30 bushels, which is close to the average yield in the sections where combines are used. The seven- and nine-foot machines usually are operated by two men, one driving and regulating the height of the cutter-bar according to the height of the grain, the other bagging the thrashed wheat and sewing the sacks. The number of bushels thrashed per day per man with the outfits requiring only two men to operate them is considerably higher than with the larger machines which require four or five men, with the exception of the very

largest outfits, which show about the same efficiency as the small ones. It is also interesting to note that the number of bushels thrashed per day per man with these small combines is usually equal to and sometimes greater than the amount of grain thrashed per day with the small thrashing outfits used in the East. When to this is added the fact that two men have covered almost as great an acreage in a day with a combine, cutting, thrashing, and sacking the grain, as two men could cover with a binder, cutting, binding and shocking, the saving which is accomplished through the use of combines is readily apparent.

In order to ascertain the cost per bushel for thrashing with a combine it is, of course, necessary to consider depreciation, interest on investment, repairs, and operating expenses of these outfits. (See Tables X, XI, and XII.)

TABLE X.—*Overhead expenses per year, per day, per acre, and per bushel; average cost and estimated life of, and acres cut annually by, different sized combines (65 reports).*

Width of swath.	Average annual overhead expenses on combines.							Average cost.	Estimated life in years.	Average acres cut annually, to date.
	Total.[1]	Depreciation.	Interest on investment at 6 per cent.	Repairs.[2]	Total per—					
					Day.[3]	Acre.[3]	Bushel (30-bushel yield).[3]			
Feet.										
7	$172.49	$106.49	$33.00	$33.00	$9.10	$0.734	$0.0244	$1,100	10.33	235
9	184.04	112.04	36.00	36.00	9.30	.684	.0228	1,200	10.71	269
12	233.26	115.41	50.55	67.40	8.95	.450	.0150	1,685	14.60	519
14	233.31	114.59	50.88	67.84	9.73	.472	.0157	1,696	14.80	494
16	209.05	87.95	51.90	69.20	6.58	.244	.0081	1,730	19.67	858
18	269.37	127.06	60.99	81.32	8.35	.269	.0090	2,033	16.00	1,000
20	310.05	146.25	70.20	93.60	7.93	.233	.0078	2,340	16.00	1,330
24	425.00	250.00	75.00	100.00	8.92	.213	.0071	2,500	10.00	2,000

[1] Exclusive of overhead charges for shelter, taxes, and insurance.
[2] Figured at 3 per cent of first cost for seven- and nine-foot sizes, and 4 per cent of first cost of all larger sizes. (See text.)
[3] Based on figures shown in or derived from Table IX.

TABLE XI.—*Labor costs per day, per acre, and per bushel for different sized combines and crews, man-labor being considered as worth $2 and horse-labor $1.20 per day of 10 hours (65 reports).*

Width of cut and crews most commonly used with each outfit.	Labor cost per day.			Labor cost per acre.[1]			Total man- and horse-labor cost per bushel.
	Total.	Man-labor.	Horse-labor.	Total.	Man-labor.	Horse-labor.	
7 feet; 2 men, 8 horses	$13.60	$4.00	$9.60	$1.10	$0.32	$0.78	$0.0365
9 feet; 2 men, 10 horses	16.00	4.00	12.00	1.18	.30	.88	.0392
12 feet; 4 men, 22 horses	34.40	8.00	26.40	1.73	.40	1.33	.0576
14 feet; 5 men, 24 horses	38.80	10.00	28.80	1.88	.48	1.40	.0628
16 feet; 5 men, 28 horses	43.60	10.00	33.60	1.61	.37	1.24	.0538
18 feet; 5 men, 30 horses	46.00	10.00	36.00	1.48	.32	1.16	.0495
20 feet; 5 men, 30 horses	46.00	10.00	36.00	1.35	.29	1.06	.0451
24 feet; 6 men, 36 horses	55.20	12.00	43.20	1.32	.29	1.03	.0438

[1] Based on acres and bushels per day as shown in Table IX.

TABLE XII.—*Average labor and overhead expenses per day, per acre, and per bushel.*[1]

Width of combine.	Average labor and overhead expenses.				
	Per day.			Per acre.	Per bushel.
	Labor.	Overhead.	Labor and overhead.		
Feet.					
7	$13.60	$9.10	$22.70	$1.83	$0.061
9	16.00	9.30	25.30	1.86	.062
12	34.40	8.95	43.35	2.18	.073
14	38.80	9.73	48.53	2.36	.079
16	43.60	6.58	50.18	1.86	.062
18	46.00	8.35	54.35	1.75	.058
20	46.00	7.93	53.93	1.59	.053
24	55.20	8.92	64.12	1.53	.051

[1] Based on data in Tables IX, X, and XI.

Table X shows the annual overhead expenses based on the average first cost as shown in the ninth column, and annual repairs based on 3 per cent of the first cost for the seven- and nine-foot sizes and 4 per cent for the larger sizes. In this connection it may be pertinent to state that the seven- and nine-foot outfits are, for the most part, individually owned and are used only on the farm of the owner, while the larger rigs are in many cases used more or less for custom work and therefore cover a considerably greater acreage each year. The repairs on the small machines are consequently somewhat less annually, but for the acreage covered and bushels thrashed are slightly higher.

From the last column in Table XII it will be seen that the total cost of cutting and thrashing a bushel of grain with a combine varies from about 5.1 cents for the large outfits to a fraction under 8 cents for the fourteen-foot size. The expense for labor for the small outfits is lower in proportion to the amount of work done per day than for the larger ones, but the overhead charges are slightly greater for the reason that the small outfits are not used as many days annually because of the fact, as previously mentioned, that they are largely owned by individual farmers and do very little custom work. Six cents per bushel is probably a fair general average cost for cutting and thrashing wheat with a combine where the yield is in the neighborhood of 30 bushels. At this rate the cost of harvesting and thrashing wheat is between one-third and one-fourth of the cost in sections where the wheat is cut and thrashed at two separate operations with a consequent increase in man- and horse-labor.

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