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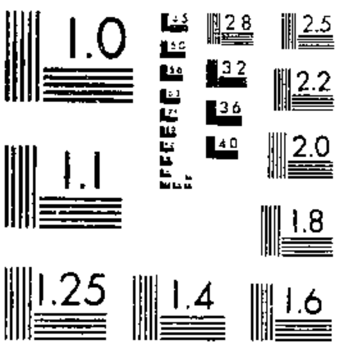

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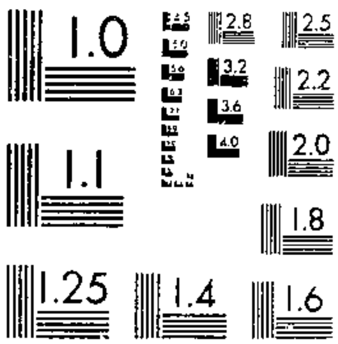

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TECHNICAL BULLETIN No. 70 FEBRUARY, 1928

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE COMBINED HARVESTER-THRESHER IN THE GREAT PLAINS

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IN COOPERATION WITH THE AGRICULTURAL EXPERIMENT STATIONS OF TEXAS, OKLAHOMA, KANSAS, NEBRASKA, AND MONTANA

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INTRODUCTION

The introduction and use of the small "combine" or combined harvester-thresher for harvesting the wheat crop has been responsible for a marked change in the harvesting methods in the Great Plains during the last nine years. Farmers in the Wheat Belt, from Texas to Montana, have set aside their headers and binders and have used combines in ever-increasing numbers. Thirty per cent of the Kansas wheat crop was cut with combines in 1926, whereas in 1918 the machines were used for the first time.[2]

[1] This bulletin, which is a complete report of the combined harvester-thresher investigation made in 1926 supersedes the preliminary report Harvesting Wheat with a Combined Harvester-Thresher in the Great Plains Region, 1926, which covered only certain phases of the study.

[2] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF AGRICULTURAL ECONOMICS, and KANSAS STATE BOARD OF AGRICULTURE. COMBINED HARVESTER-THRESHERS AND KANSAS WHEAT. 4 p. 1926. [Mimeographed.]

Individual localities can be pointed out in the Great Plains in which practically the entire wheat crop is cut with the combine. The problem of deciding whether to continue harvesting with binders or headers, or to purchase a combine, is puzzling many farmers, especially those who live in areas where a general change has not been made. The information contained in this bulletin was gathered for the purpose of assisting wheat growers to arrive at a decision. It should also be of value to college extension workers, county agents, and farm-equipment manufacturers and dealers who are called upon to consult with farmers on the relative merits of different harvesting methods for their farms.

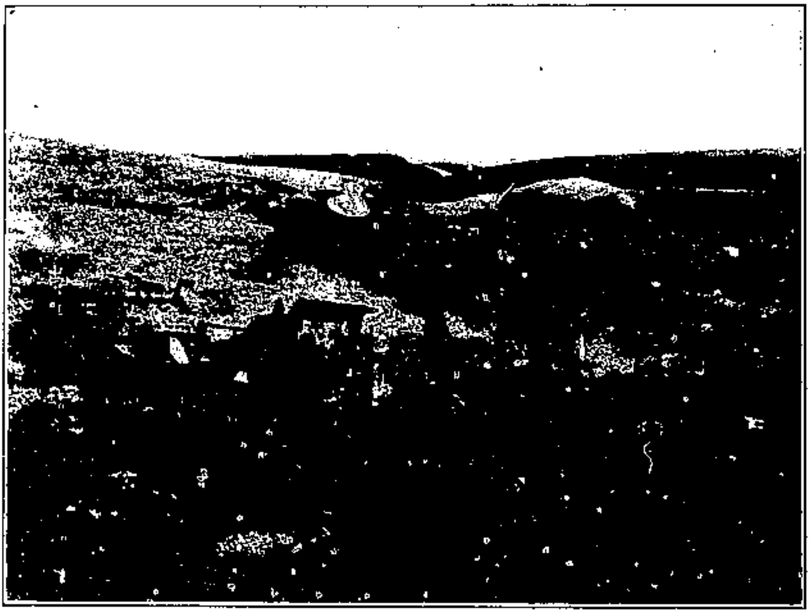

FIG. 1.—The type of combined harvester-thresher now in common use on the Pacific coast

DEVELOPMENT AND USE OF THE COMBINE

Combines were first used in California and have now been used for many years in other wheat-growing districts of the Pacific coast. Some of the combines used on the Pacific coast cut a swath as wide as 40 feet, and required crews of 5 men, and as many as 36 horses or mules. The threshed grain was run into sacks which were sewed when full, dumped to the ground, and picked up later. The threshing unit on these early machines obtained its power from a large ground-drive wheel. Later models were equipped with an engine which propelled the machine and furnished power for the threshing unit. Because of their size the use of combines of these types was not considered practicable for the farms of the Great Plains. About 15 years ago a few of these machines were brought into the Judith Basin of Montana, where some are still in use. One or two were carried as far south as Nebraska, but their usefulness there was short lived. The present type of combine used on the Pacific coast is considerably larger than the machines in common use in the Great Plains, and is generally pulled by horses because of the hilly character of the wheat land. (Fig. 1.)

The first small combine put on the market was manufactured early in the present century. In 1905 this small horse-drawn combine, which cut a 7-foot swath, was manufactured in Idaho. Satisfactory reports are made of its work; yet the duration of its existence was rather short, and its use was confined to the intermountain and Pacific Northwest States. A little later other small combines were manufactured. These machines were used only in the far West. The later small prairie-type combine, equipped with an auxiliary engine and pulled by horses or a tractor, was introduced in 1918. (Fig. 2.) This gave the farmers of the Great Plains a machine which, with the developments that have followed in the succeeding years, has proved to be practical, efficient, and economical under most of the conditions of that region. The newness of the machine, its high cost, and the deflation of farm prices during the five years following its introduction kept the number in use at a comparatively low figure. Since 1922, however, the numbers purchased have been increasing rapidly elsewhere as well as in the Great Plains.

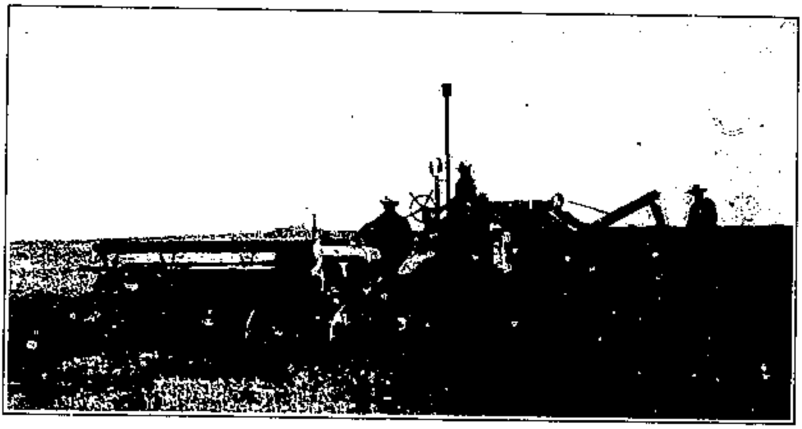

FIG. 2.—A type of combined harvester-thresher used in the Great Plains. Some combines are equipped with a grain tank, but this outfit delivers the grain directly into the wagon, which is pulled along with the machine

New model combines, with a cut of 8 or 10 feet, drawn by a tractor, and with a direct power-drive from the tractor itself, were introduced in 1926. (Fig. 3.) Such a machine has specific advantages because it requires a smaller investment than do the large machines with auxiliary motors and it is operated by a smaller crew. These power-driven combines were used on farms which had comparatively small acreages of wheat.

The use of the small combine has not been entirely restricted to the wheat-growing areas of the Great Plains for, during the last two years, farmers in the Corn Belt and Eastern States have been buying and using them for harvesting various crops.

SCOPE OF THE STUDY

During the harvest season of 1926 the United States Department of Agriculture, in cooperation with the agricultural colleges and experiment stations of Texas, Oklahoma, Kansas, Nebraska, and Montana, conducted a study in selected districts of those States, the purpose of which was to determine the practicability and cost of harvesting wheat with a combine.

Detailed information was obtained from a large number of combine users and was recorded by the investigators. In compiling this information no individual records were discarded because of inexperienced operators or because unusual difficulties were encountered, so the data presented here reflect the results obtained by a number of combine operators under a variety of conditions. For the purpose of making comparisons of harvesting costs for different methods, information was obtained from a number of farmers in the same district who were using binders or headers for harvesting their wheat.

FIG. 3.—A type of power-drive combined harvester-thresher recently introduced to farmers of the Great Plains

DESCRIPTION OF DISTRICTS AND TYPE OF FARMING

Conditions in the districts where the combine studies were made are normally favorable to the use of the combine. The prevailing topography is level to slightly rolling. The small acreage on the slopes along streams did not necessitate the use of leveling devices on the combines, and the slightly rolling fields affected the harvesting operations only when the soil was soft. The soil types range from sandy or silt loams to clay loams. In those cases in which the soil type affects the draft of the combine or the footing of the tractor, it may affect the harvesting operation. After rains, some of the tractors lacked sufficient power to pull the combine up the slopes at normal speed.

The same general type of farming prevails in the districts in which records of combines were obtained. Wheat is the important crop, and on many of these farms it constitutes the only important enterprise. On most of these farms the income from livestock enterprises is negligible. The average size of farms and the wheat acreage per farm vary for the different districts, but in all districts the wheat acreage, including the fallow land for wheat, comprised 60 per cent or more of the acreage under cultivation on the farms visited. The importance of the wheat crop on the farms on which combines were used is shown in Table 1. There was an average of 362 acres in wheat, 21 acres in barley, and 14 acres of oats, all of which could have been harvested with a combine. The combine could have been used to harvest sorghum in the districts where that crop is grown. Other crops were harvested with the combine, but the machines were bought primarily to harvest wheat and would not have been bought to harvest the small acreages of other crops grown on these farms.

TABLE 1.—*Average size of farms and average number of acres in crops on farms where combines are owned*

State	Number of farms	Land in cultivation	Crop							Fallow land	Size of farms
			Wheat	Corn	Barley	Grain sorghums	Oats	Hay	Other		
		Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Texas	46	670	512	9	52	70	19		2	6	[1] 1,026
Oklahoma	61	303	266	5	3	8	9	10	2		348
Kansas	28	330	230	48		18	11	20	3		428
Nebraska	80	673	320	183	32	1	23	17	14	74	911
Montana	57	711	442	2	6		3	13	1	244	904
Total or average	271	575	362	68	21	16	14	12	5	77	[1] 761

[1] Size of 12 farms not obtained.

The acreage of wheat on the 271 farms where records of combine operations were obtained ranged from 65 to 1,200 acres. Table 2 shows the distribution of farms according to acreage of wheat and the average acres in other crops for farms of each size group. Of these farms, 99 had 240 acres or less in wheat, 83 had 241 to 400 acres, 50 had 401 to 560 acres, and 39 had more than 560 acres. In each of these groups there were other grain crops which could have been harvested with a combine.

TABLE 2.—*Average number of acres in crops on farms with different acreages of wheat where combines are owned*

Area in wheat (acres)	Number of farms	Wheat			Fallow land	Other crops		
		Winter	Spring	Total		Barley	Oats	Miscellaneous small grain
		Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
240 or less	99	158	16	174	24	9	12	2
241 to 400	83	255	64	319	72	18	15	1
401 to 560	50	325	156	481	145	24	15	
561 to 720	18	516	139	655	112	58	20	2
721 to 880	13	495	282	777	140	46	12	
881 and over	8	912	149	1,061	150	61	22	5
Total or average	271	281	81	362	76	21	14	1

Area in wheat (acres)	Other crops—Continued					Total Cultivated	Size of farm
	Grain sorghum	Corn	Hay	Miscellaneous crops	Total other crops		
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
240 or less	13	56	11	4	107	305	421
241 to 400	7	83	13	5	142	533	664
401 to 560	13	66	12	4	134	760	922
561 to 720	56	40	13	8	197	964	1,410
721 to 880	20	64	13	3	164	1,090	1,438
881 and over	42	141	6	2	279	1,490	2,672
Total or average	16	68	12	5	137	575	[1] 761

[1] Size of 12 farms not obtained.

The livestock enterprises on these farms were relatively unimportant as compared with wheat. The average number of livestock for each district is given in Table 3.

TABLE 3.—*Average number of livestock on farms for each district surveyed*

State	Number of farms	Average number per farm							
		Horses		Cattle				Swine	Sheep
		Work	Other	Milk cows	Beef cattle	Young cattle	Total		
Texas	46	8	10	4	33	26	63	12	38
Oklahoma	51	6	2	6	4	5	15	9	1
Kansas	28	8	1	6	17	7	30	5	
Nebraska	89	9	2	5	12	13	30	54	2
Montana	57	7	1	3	3	3	9	6	2
Total or average	271	8	3	5	12	11	28	23	8

Mechanical power and large units of machinery are widely used in the region. The number of farms with and without tractors and trucks is shown in Table 4. Nearly all farms have one tractor or more and about 50 per cent of the farms use a motor truck. A few farms were operated entirely by mechanical power.

TABLE 4.—*Number of farms with and without tractors and trucks*

State	Number of farms	Farms having tractors of 12-drawbar horsepower or less		Farms having tractors of 15 or 16 drawbar horsepower		Farms having tractors of 17 or 18 drawbar horsepower		Farms having tractors of 20-drawbar horsepower or more		Farms having trucks[1] of—		Farms not having—	
		Number having 1 tractor	Number having more than 1	Number having 1 tractor	Number having more than 1	Number having 1 tractor	Number having more than 1	Number having 1 tractor	Number having more than 1	1 ton or less	More than 1 ton	Tractor	Truck
												Number	*Number*
Texas	46	10	5	26	6	4		6		21	2		23
Oklahoma	51	22	3	10	3	11		4		21	1	4	30
Kansas	28	10		11		1				3		6	25
Nebraska	89	20	15	45	11	16		7		46	8	1	36
Montana	57	7	4	22	6	10	2	15	4	31	1	3	25
Total	271	69	27	114	26	42	2	32	4	122	12	14	139

[1] 1 farm had 3 trucks.

The amount of labor used on farms was obtained for all districts except the one in Texas, and is shown in Table 5. On a few farms where wheat only was grown the operators were on the farm only during seeding and harvest. Over one-half of the farms were operated by one man with the help of some extra labor during the harvest season. A number of the farms on which two men were available for the entire year were operated by father and son or on a partnership basis. Few operators employed labor that was hired for the entire year. Nearly all farms hired extra labor during the harvest season and a number used extra help during the entire summer. On the average these farms used the equivalent of 3.4 months of extra labor in addition to the regular labor. This extra labor was used principally during the harvest season and for preparing the land for seeding; it was either family labor, available for a short time, or labor which was hired for the busy season. Day labor, equivalent to the labor of one man for 19.5 days, was used, principally for harvesting and threshing.

TABLE 5.—*Labor used on farms on which combines are owned*

Acres in wheat	Number of farms[1]	Number of farms using yearly labor of— 1 man	2 men	3 men	4 men	5 men	Average number of men used annually per farm	Average seasonal labor: Man-months per farm	Man-days per farm	Number of farms on which less than 1 year's labor was used
240 or less	87	57	12	3	2	------	1.1	2.8	15.0	13
241 to 400	76	37	23	6	1	1	1.4	3.7	17.0	8
401 to 560	43	25	11	2	1	------	1.3	4.0	18.4	4
561 to 720	8	4	2	------	2	------	2.0	5.9	58.0	------
721 to 880	8	4	2	1	1	------	1.9	2.0	42.1	------
881 and over	3	------	1	------	------	2	4.0	4.0	44.7	------
Total or average	225	127	51	12	7	3	1.3	3.4	19.5	25

[1] Labor reports were not obtained from 40 farms in Texas.

Conditions in general are the same throughout the Great Plains region, but certain characteristics of each district caused differences in local farm organization and affected the use of the combines. Such factors as size of farms, topography, type of soil, and climate all have an effect on the adaptability and use of the combine in the district.

OCHILTREE COUNTY, TEX.

Ochiltree County is located along the northern border of the panhandle. The average precipitation in this section is 24 inches annually. The harvest season comes at a time when the monthly rainfall is less than 3 inches.

The average size of all farms, as reported by the 1925 census of agriculture, was 918 acres, the average wheat acreage being 168 acres per farm. The farms on which the records were obtained were somewhat larger than those reported by the census and had an average of 512 acres in wheat. Grain sorghum is the principal cultivated crop. Some barley and oats were grown.

A few ranches had large herds of cattle and a few had flocks of sheep. The smaller farms which were mostly sown to wheat have little pasture, and on them livestock is unimportant.

ALFALFA COUNTY, OKLA.

The selected district in Oklahoma was Alfalfa County, which is located on the northern border of the State just west of the ninety-eighth meridian. The average annual rainfall is 28 inches, and the monthly rainfall during the harvest season normally is between 3 and 4 inches. The soil is principally a silt loam, although some of the soils are somewhat sandy.

According to the census reports for 1925 the average size of farm was 212 acres, of which 97 acres were in wheat. The farms on which records were obtained averaged 348 acres and had 266 acres in wheat. Other crops and livestock were unimportant on the farms on which combines were owned.

OTTAWA COUNTY, KANS.

Ottawa County [3] is just east of the ninety-eighth meridian in the northern part of Kansas. The annual precipitation and the rainfall during harvest are much the same as in Alfalfa County, Okla. The 1925 census of agriculture reports the average size of farms as 255 acres, with 82 acres in wheat, 44 acres in corn or sorghum, 8 acres in oats, and 10 acres in hay. The average size of farms included in this study was 426 acres, with 230 acres in wheat, 66 acres in corn and grain sorghum, and 20 acres in hay. A few farms reported herds of cattle; many farms in the section would be classed as general farms, although wheat is the important crop on the farms that use combines.

PERKINS COUNTY, NEBR.

Perkins County lies just east of the northeast corner of Colorado. The annual precipitation is about 18 inches with less than 3 inches of rainfall during the month of harvest. The soils are silt or sandy loams, and in some fields the soil is so loose as to affect the draft of the combine or the traction of the tractor.

According to the 1925 census of agriculture the average size of farms here was 546 acres, 94 in wheat, 132 in corn, and small acreages of oats, barley, rye, and hay. The farms on which records were obtained averaged 911 acres in size, of which 329 were in wheat and 183 in corn. Hogs are an important enterprise, equaling wheat in value of annual production on some of the farms.

THE JUDITH BASIN IN MONTANA

Judith Basin and Fergus Counties lie almost in the geographical center of Montana in what is known as the Judith Basin. The average annual precipitation is about 17 inches, and the rainfall during the harvest months is usually low. The harvest season in 1926 was unusually rainy, and some harvesting was delayed until October. The soil in the basin is a clay loam underlain, at a depth of 2 to 5 feet, with a layer of coarse gravel. For these counties, according to the 1925 census, the average size of farm was 702 and 839 acres, respectively. Both winter and spring wheat are grown; the average is 103 and 160 acres of wheat per farm. Other crops were unimportant. Combines have been used for a longer period in this district than in the other districts.

The farms on which combines were owned averaged 904 acres in size, of which 442 acres were in wheat. The general practice in the basin is to summer-fallow wheat land once in three years. An average of 244 acres were summer-tilled. Other crops were unimportant on these farms, and there was little livestock other than the work stock.

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[3] Ottawa County is not located in the typical combine area of Kansas, but was chosen because it is near the present eastern limit of the combine area in that State and so it was thought that rainfall would be an important factor during the harvest season. It is felt that the data from Alfalfa County, Okla., are fairly representative of wheat-growing sections of south-central Kansas, where the farms are larger and more combines are used than in Ottawa County.

AGE OF COMBINES, AND ACCESSORY EQUIPMENT USED

Nearly one-half of the combines in use on these farms were bought in 1926. Only 83 of the 268 machines had been in operation more than two seasons. The average age of all machines recorded was 2.4 years.

Since combines were first introduced into the districts the size and type has been changed somewhat, and some new equipment and accessories have been added. The purchaser now has a wider range of choice of equipment. Some accessories may be wanted, under certain conditions, that would not always be used. The most important items of this new equipment, which have been added since the first prairie type of harvesters were introduced are, the extension to the cutter bar and platform, the straw spreader, and the grain tank. Straw bunchers, sacking attachments, self-feeders, and straw carriers are not often used in the Great Plains. Table 6 shows the number and size of combines purchased, by years.[4] The combines on which records were obtained were purchased in 1917 or later. The combines bought between 1917 and 1921 had a 12-foot cut or a 9-foot cut on which the cutting capacity of the machine had been increased by the addition of a 3-foot extension to the cutter bar and platform.

TABLE 6.—*Number of combines by year of purchase and width of cut*

Width of cut (feet)	Number of combines bought in—										
	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	Total
8										25	25
10										11	11
12	1	2	5	15	12	8	4	9	7	3	66
14									1		1
15						3	1	7	13	31	55
16							2	12	40	52	106
18							1				1
20								1		2	3
All sizes	1	2	5	15	12	11	8	29	61	124	268

Table 7 shows the number of combines of each size using extension cut or other usual additional equipment. The change from the 12-foot to the 15-foot and 16-foot combine was made by increasing the length of the cutter bar rather than by making a corresponding increase in the size of the separator. Of the few combines purchased in 1923, one-half were 12-foot combines; one-third of those purchased in 1924 were 12-foot; and only one-eighth of those purchased in 1925 were 12-foot machines.

[4] The number of combines included in Table 6 and those which follow depend upon the data to be shown. Certain combines have been omitted from some of the tables because of incomplete data or other irregularities which render them not comparable with the combines included in the study.

TABLE 7.—*Numbers of combines of each type and size using various items of accessory equipment*

Type of combine	Width of cut (feet)	Number of combines	Extension cut	Straw spreader	Wagon elevator	Grain tank
Tractor drawn, with power take-off	8	25				25
	10	10		7	1	9
Tractor drawn, with auxiliary engine	12	56 [1]	23	12	36	19
	15	51	31	38	20	22
	16	104	51	78	40	64
	20	3	3	2		3
Horse drawn	12	3	2		3	
	15	3	1	1	3	
	16	2	1	1	1	1
Total		257	112	137	113	143

[1] One machine used a sacking attachment.

One-half of the machines equipped with an auxiliary engine made use of the extension cut. Of the 56 machines with a 12-foot cut, 23 were regular 9-foot machines with a 3-foot extension. None of the 9-foot combines was used without an extension. Of the 51 machines with a 15-foot cut, 31 were regular 12-foot machines with 3-foot extension, and of the 104 combines with a 16-foot cut, 51 were 12-foot machines with a 4-foot extension. For a given make of machine the threshing and separating capacity may be the same for a 12-foot as for 15-foot or 16-foot cut. The separating capacity of the machines differs somewhat between machines of the same cutting width but of different model. For most of the machines, the thresher could handle ordinary yields of grain without difficulty even with the extension cut added. A few farmers whose wheat was very heavy did not use the extension in 1926, although it had been used in previous years. If the yield is very heavy or if the grain is lodged, the extension may be removed to prevent reducing the rate of travel.

The tendency has been toward a wider cut for the combine, but with the auxiliary engine in use there seems to be a place for smaller machines in this district. In 1926 the smaller power-drive machines, were introduced, and 25 of the 124 combines which were purchased that year were 8-foot, and 11 were 10-foot machines. Only 3 of the machines purchased were 12-foot combines, whereas 83 were 15-foot or 16-foot machines.

The recent models of combines used in the Great Plains usually are equipped with a straw spreader to scatter the straw instead of leaving it in a narrow strip. Straw spreaders were more generally used on the 15-foot and 16-foot machines than on those with a 12-foot cut. The 12-foot machines were earlier models, and on many of them the straw spreader was not included as a part of the regular equipment. A few farmers who had spreaders were not using them. In some cases where the straw was heavy the spreader was removed because the spreader was giving trouble; in other cases it was removed, and the straw dropped so it could be burned in the windrow.

A few combines were equipped with straw bunchers, which catch the straw and drop it in piles on the field. Few bunchers, however, are used in the districts of the Great Plains region, as the straw is not saved for feed and it is not heavy enough on the field to interfere with later cultivation of the soil.

The common practice in the Great Plains is to handle the threshed grain in bulk. A few machines were equipped with sacking attachments, but all except one of the combines for which records were obtained used either tanks on the combine or wagons to handle the grain. In cases in which the grain is hauled by truck there is a distinct advantage in using the tank on the combine as the grain can be run directly from this tank to the truck, and the labor of shoveling is eliminated. When grain is stored on the farm or hauled to market in wagons, there may be no saving in labor from using a grain tank on the combine. The grain tank generally is built on new machines, and it has been added to many of the older ones. When motive power is insufficient, as on hilly land, or in light soil, or when a light tractor is used, it may be necessary to remove the tank and substitute a horse-drawn wagon to relieve the tractor of some of the load. If the bottom of the tank is high enough, the grain spout can be left open and the grain allowed to run directly into a horse-drawn wagon. Some farmers report considerable side draft on combines which do not have a grain tank unless a grain wagon is attached to the machine.

Other accessories, such as self-feeders and straw carriers, may be used to facilitate stationary work to be done with the separator. Some stationary threshing is done without these attachments, but additional labor is then required for feeding the machines and disposing of the straws.

ACRES CUT ANNUALLY BY COMBINES

In 1926 an average of 533 acres of small grain had been harvested by each tractor-drawn combine on the farms visited. Of this acreage, 518 acres or 97 per cent was in wheat, and the remaining 3 per cent was used as follows: Barley 12 acres, oats 2, and other small grain 1 acre. Two-thirds of this acreage harvested was on the home farm.

The harvesting season for all crops came at practically the same time of the year, and the acreage of other crops was so small that the harvesting season was not generally prolonged by crops which ripen at different times during the season. In the Judith Basin of Montana both spring and winter wheat are grown and, as there is a difference of one or two weeks in the time of ripening of the two kinds of wheat, the harvesting season is somewhat longer. As a result, the acreage cut per machine was somewhat greater there than in the other districts.

Tractor-drawn combines of all types and sizes cut annually 553 acres per machine or 20 acres more than their 1926 average. Of this acreage, 365 acres were cut on the operator's own farm, and 188 acres were cut for others. Figure 4 shows the acres cut annually by combines of different types and sizes. The average represents acres cut per machine in all areas regardless of kind of grain harvested. This figure indicates the acreage which a machine of a given size may be expected to cut in this region.

Table 8 shows the distribution of combines by total acres cut annually and by size of machine. Boldface figures indicate that the average acres cut per year for combines of the specified sizes lie within the limits given in the first column.

TABLE 8.—*Distribution of combines by average acres cut annually and by size*

Acres cut annually	Combines					
	8-foot	10-foot	12-foot	15-foot	16-foot	20-foot
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
100 or less	1					
101 to 200	7		4			
201 to 300	**11**	1	19	3	1	
301 to 400	4	3	13	10	9	
401 to 500	1	**2**	**11**	11	22	
501 to 600		2	4	**11**	18	
601 to 700	1	2		5	**10**	
701 to 800			1	2	13	
801 to 900			3	3	11	1
901 to 1,000				4	10	
1,001 to 1,100				2	5	
1,101 to 1,200					2	1
1,201 to 1,300			1		2	1
1,301 to 1,400					1	
Total	25	10	50	51	104	3

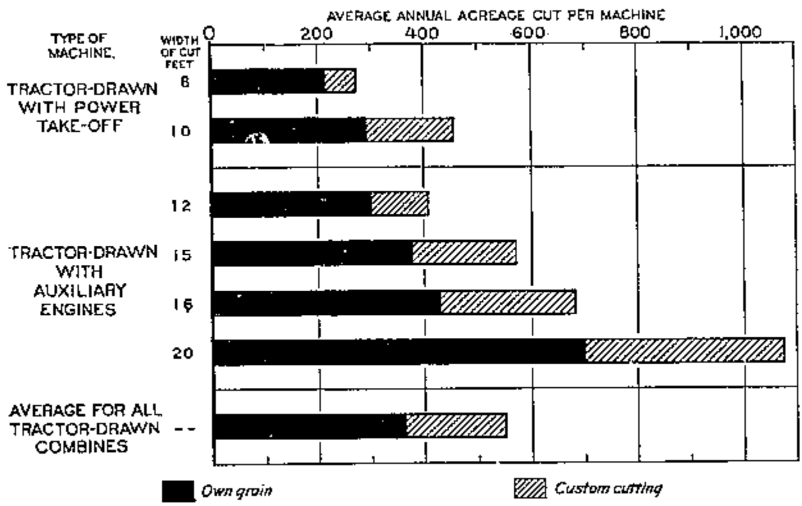

FIG. 4.—Acres cut annually with combines of different types and sizes

Of the machines with a direct power-drive, the 8-foot machines averaged 275 acres each, whereas the 10-foot machines averaged 457 acres. The proportionally higher acreage cut by the 10-foot machines may be due in part to regional differences in the Great Plains. A large proportion of the 10-foot machines were reported in the Judith Basin of Montana, where both winter and spring wheat are grown, and where the acreage per farm is larger than in the other areas of the Great Plains.

Of the combines equipped with auxiliary engines an average of 408 acres was cut by 12-foot machines, 574 acres by 15-foot machines, 682 acres by 16-foot machines, and 1,077 acres by 20-foot machines. Not all of the difference in acres cut annually can be explained by differences in the size of the machines. The 12-foot combines were mostly older machines and were not used for custom cutting to the same extent that the larger combines were. The wheat acreage per farm in the particular locality and the length of the harvesting season also affected the acreage cut by each combine.

Custom cutting was done with machines of all sizes, but the larger machines usually did a larger proportion of outside work than the small machines. Some operators purchased a machine larger than necessary to handle their own crop for the express purpose of cutting for others. The size of the machine in such cases has only a general relation to the acreage of the operator's own grain. On some farms the machine was too small to care for the owned crop; on others the capacity was not fully utilized.

The acreage which a combine will cut annually is determined jointly by the length of the harvesting season and the daily capacity of the machine. In some sections, where the weather conditions are such that the grain may be allowed to stand for a considerable period without great danger of loss from shattering or damage from weather, the long harvesting season may enable the operator to cut his crop with a small machine. On the other hand, under conditions of heavier rainfall or greater loss from weather, a larger machine would be required to harvest the same acreage. The size of machine needed to cut a given acreage should be estimated from the daily capacity of the combine and the number of days the machine probably will be used.

In addition to the 249 tractor-drawn combines similar to that shown in Figure 2, there were 8 horse-drawn combines. Three of these were 12-foot, three were 15-foot, and two were 16-foot machines. On the basis of work done during the harvesting season, these horse-drawn combines compared favorably with the tractor-drawn machines. These machines cut an average of 511 acres of small grain annually, just 42 acres less than the average cut by tractor-operated machines.

POWER AND LABOR

Of the three different forms of motive power used with 257 combines, 83 per cent were drawn by tractors and were equipped with an auxiliary engine. At present the size of tractor used and size of combine is not always coordinated. In many cases the tractor used was purchased primarily for other farm work and as a result the tractor in these cases may be larger or smaller than the size best suited to the combine. Where the tractor is already available, or is to be used for other work, it may be good practice to use the available power rather than to purchase the tractor which is best fitted to the size of the combine. Other differences in horsepower of tractors used may arise from differences in soil types or in topography. On farms with a rolling topography or light soil a larger tractor may be required than on farms with a level surface and firm soil. The motive power must be sufficient to provide a steady rate of travel under all conditions. A few operators used two tractors (fig. 5) and others supplemented the tractor power with horses where the surface was rolling or the ground soft.

The size of tractor used on combines of different width of cut is shown in Table 9. Of the combines equipped with auxiliary engines and cutting a 12-foot swath, 34 per cent were pulled by tractors of 12 drawbar horsepower or less, 55 per cent were pulled by 15 or 16 horsepower tractors, and 11 per cent were pulled by tractors of larger size than 16 horsepower. Larger tractors generally were used on the 15-foot and 16-foot machines. Only 14 per cent of the 51 machines with a 15-foot cut used tractors rated at 12 horsepower or less, whereas 61 per cent used tractors of 15 or 16 horsepower, and 25 per cent used larger tractors. There is little difference in size of tractors used on 15-foot and 16-foot combines. Of the 104 machines with a 16-foot cut, only 17 per cent used tractors of less than 15 horsepower, 43 per cent used 15-horsepower or 16-horsepower tractors, and 40 per cent used tractors larger than 16 horsepower. The 15-horsepower tractor was most generally used on machines with auxiliary engines, and is the proper size under most conditions. Smaller tractors do not have sufficient power when pulling on soft or hilly land, whereas tractors larger than 15 horsepower seldom are necessary for most 15-foot or 16-foot combines.

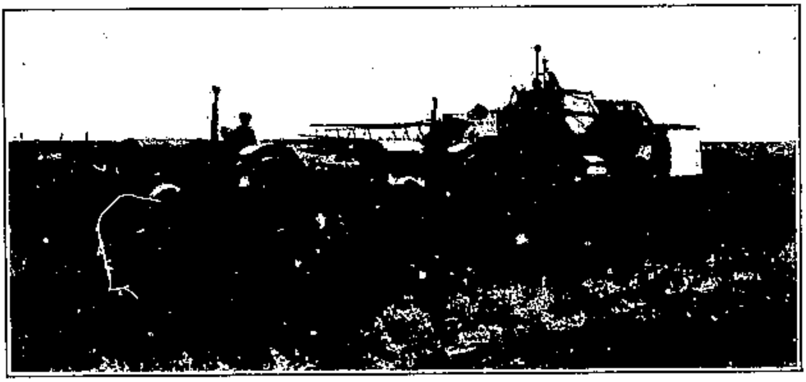

FIG. 5.—Because of soft ground and excessive weight 2 tractors are pulling this combine

TABLE 9.—*Power and labor used on combines of different types and sizes*

Type of combine	Width of cut	Combines	Number of combines using— Tractors with drawbar rating of— 12 horsepower or less	15 or 16 horsepower	17 or 18 horsepower	20 to 30 horsepower	31 to 45 horsepower	Horses 6	Horses 8	Horses 10	Man labor[1] Combine operators	Helper	Tractor or horse drivers
	Ft.	*No.*											
Tractor drawn with power take off	8	25	25								28		
	10	10		10							10	1	7
Tractor drawn with auxiliary engines	12	56	19	31	3	3					55	7	56
	15	51	7	31	9	3	1				51	8	52
	16	104	18	45	29	12					106	25	104
	20	3		1		2					4	3	3
Horse drawn	12	3						1	2		3		3
	15	3							2	1	3		3
	16	2							2		2		2
All types		257	69	118	41	20	1	1	6	1	262	44	230

[1] For size of crew see Table 15, p. 21.

Two men form the standard crew for a combine with auxiliary engine—one man on the tractor and one on the combine. Some operators use an extra man on the combine or to relieve the tractor driver. Others, who can put in long hours, use two complete crews of two men each.

Thirty-five of the 257 combines, or 14 per cent, were power take-off outfits, that is, the motive power was furnished by the tractor which also supplied power for the threshing unit. Twenty-five of these outfits were 8-foot and 10 were 10-foot machines. There was complete uniformity in the size of tractor used for machines of both sizes (Table 9) as they are made purposely for operation with tractors of a particular make and size.

Where fields are rolling or the soil is sandy, the tractor does not always have sufficient power to maintain a uniform cylinder speed in the combine. This tends to reduce threshing efficiency. On the larger machine some operators supplement the power by adding a second tractor or a team of horses. On the smaller outfit this is practically impossible because of its design.

The power take-off type of combine is intended for operation by only one man, but some owners used two men. Practically all of the 8-foot machines were run by one man, but the majority of the owners of the 10-foot machines used two men.

FIG. 6.—A combine drawn by eight horses. A team is required to pull the wagon which receives the grain from the machine as it is threshed

Eight combines, or 3 per cent of the total number, were pulled by horses or mules. (Fig. 6.) Eight animals ordinarily are required to pull the machines. Table 9 shows that one operator used 6 head on his machine, and one operator used 10. The size of combine and of horses, the soil, and the topography all influence the number of horses or mules it is necessary to use.

DURATION OF HARVEST SEASON

The proportion of the time in which a combine will be used during any harvesting season is chiefly dependent upon weather conditions. Few farmers in 1926 completed their harvest without delay. In addition to delays from inclement weather, some time was lost while waiting for, or making repairs on the machine, and some of the operators did not work on Sundays. The number of days available for cutting the crop on most farms was ample, but some operators in Montana were pressed for time in which to complete their harvest. Table 10 shows the duration of the harvest season and the average number of days worked in each district. The length of the harvesting season applies only to the operator's own grain and does not include the time used in cutting for others unless the custom cutting was done before the operator's own harvest was completed.

TABLE 10.—*Duration of harvest season and days used in cutting*

State	Number of farms	Duration of harvest season (days)	Days used in cutting	Percentage of days used
Texas	45	25	16	64
Oklahoma	50	14	9	64
Kansas	28	13	9	69
Nebraska	87	16	10	62
Montana	56	35	14	40
Total or average	266	21	12	56

The duration of season as reported was determined by taking the difference between the date when the operator's own harvest began and the date on which it ended. It includes Sundays and days on which no work was done as well as the working days. Not all the favorable days between the starting and finishing dates were spent in cutting on the operator's own crop, for many farmers postponed a part of their own harvest in order to do custom work for others. The length of season indicates the time the operator's grain stood after the earliest grain was ready for cutting, but the number of cutting days reported is less than the number of days favorable for harvest.

The average duration of the harvest season on all farms was 21 days. The length of the season ranged from 13 days in Kansas to 35 days in Montana. On the average, these operators were cutting during 12 days, or 56 per cent of the time, during the harvesting season. In Texas, Oklahoma, Kansas, and Nebraska the harvesting season had no more than the normal amount of moisture, and approximately two-thirds of the total time was used in harvesting the operator's own crop. In Montana the rainfall during the harvest season was abnormally high, and work on the operator's crop was done on only 40 per cent of the total days in the harvest season.

The distribution of farms according to the length of the harvest season is shown in Table 11. In extreme cases the combines were operated for nearly two months. Over one-half of the operators worked three weeks or less and only one-fifth of them worked longer than four weeks. The extremely long harvest season was due to unfavorable weather or to the fact that some operators delayed cutting their own grain in order to do custom work for others.

TABLE 11.—*Farms classified according to length of harvest season in days on own crop*

Length of harvest season	Number of farms	Length of harvest season	Number of farms
4 or less	7	37 to 40	0
5 to 8	22	41 to 44	3
9 to 12	28	45 to 48	2
13 to 16	52	49 to 52	6
17 to 20	46	53 to 56	3
21 to 24	31	57 to 60	1
25 to 28	20		
29 to 32	18	Total	226
33 to 36	12		

The distribution of farms according to number of days cutting on own crop is shown in Table 12. On the modal farm the cutting of owned wheat extended over about 15 days, although on a few farms the cutting season lasted a month. The combines were operated throughout the season for the most part, and on those farms which needed only a few days of cutting, the operator finished the season by cutting for others.

TABLE 12.—*Farms classified according to the number of cutting days on own crop*

Number of days	Number of farms	Number of days	Number of farms
4 or less	26	37 to 40	
5 to 8	61	41 to 44	
9 to 12	82	45 to 48	
13 to 16	46	49 to 52	
17 to 20	31	53 to 56	
21 to 24	12	57 to 60	
25 to 28	5		
29 to 32	1	Total	260
33 to 36	2		

RATE OF HARVESTING

The rate of harvesting with a combine varies with the size of the machine and between machines of the same size. Table 13 shows the distribution of combines according to size and acres cut per day irrespective of the number of working hours. Boldface figures in Table 13 indicate that the average acres cut per day for combines of the specified sizes fell within the limits given in the first column.

TABLE 13.—*Distribution of combines according to acres cut per day and by size*

Acres cut per day	Combines					
	8-foot	10-foot	12-foot	15-foot	16-foot	20-foot
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
10 or less	2					
11 to 15	10		2			
16 to 20	**13**	2	9	2	1	
21 to 25		5	17	4	1	
26 to 30		**2**	**19**	10	15	
31 to 35		1	6	**13**	11	
36 to 40			2	15	**35**	1
41 to 45			1	6	20	
46 to 50				1	18	1
51 to 55					2	1
56 to 60					1	
Total	25	10	56	51	104	3

The average-group operators of the 12-foot combines worked 2.2 hours per day less than did those who cut more than the average number of acres. Average-group operators of the 15-foot machines cut 0.6 of an hour less, and those who had 16-foot machines, 1.1 hours less per day than did those who cut more than the average. Rate of travel was slightly greater for machines that cut more than the average. For the 15-foot and 16-foot sizes the yield was slightly lower, but the effect of the yield was negligible.

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Acres cut per day by combines is dependent upon size of machine, yield of grain, rate of travel, length of day, and efficiency of the crew. The number of acres cut per day by machines of a given size was practically the same in all areas. Table 14 shows the acres cut per hour and per foot of cut by combines of different types and sizes.

TABLE 14.—*Acres cut per hour and per foot of cut by combines of different types and sizes*

Type of combine	Width of cut	Combines	Yield per acre	Rate of travel	Length of day	Cut per day	Cut per hour	Cut per hour per foot of width
	Feet	*Number*	*Bushels*	*Miles per hour*	*Hours*	*Acres*	*Acres*	*Acres*
Tractor drawn with power take-off	8	25	17	2.4	10.3	16	1.6	0.10
	10	10	24	2.7	9.8	26	2.6	.26
Tractor drawn with auxiliary engine	12	56	17	2.8	10.2	27	2.6	.22
	15	51	18	2.8	10.3	35	3.4	.23
	16	104	21	2.8	10.7	40	3.7	.24
	20	3	25	2.4	10.7	48	4.5	.22
All tractor drawn		240	19	2.8	10.4	33	3.2	
Horse drawn	12	3	11	2.5	10.0	23	2.3	.19
	15	3	13	2.7	10.2	30	2.9	.19
	16	2	14	2.5	11.5	38	3.3	.21
All horse drawn		8	12	2.5	10.3	29	2.8	

An average of 33 acres was cut in a 10.4-hour day by the tractor-drawn and an average of 29 acres in a 10.3-hour day by the horse-drawn machines. For the tractor-drawn combines there is an increase in acres cut per day by each size of machine over the next smaller size, amounting to 62 per cent, 4 per cent, 30 per cent, 14 per cent, and 20 per cent, respectively. The 10-foot machines cut 62 per cent more than the 8-foot machines, and 96 per cent as much as that cut by the 12-foot machines. The comparatively high degree of efficiency for the 10-foot machines, as compared with the 12-foot, is probably due to the fact that the smaller combines were new, whereas the 12-foot machines were mostly older machines. Of the horse-drawn machines, the 16-foot cut a daily acreage 27 per cent greater than the 15-foot machines, which in turn cut 30 per cent more than the 12-foot combines.

At times the amount of work done in a day is restricted by the hours during which the combine can be used. The average length of day for all operators was 10.4 hours. In a few instances the combines were operated the full 24 hours of the day, and not uncommonly the machines were used for 15 or 16 hours. In more instances, however, under conditions of high humidity, some time was allowed for the grain to dry, and the working day was thus shortened.

The rate of cutting per hour by a machine should be determined by the length of the cutter bar and the rate of travel. Some time is lost in the field in turning, oiling, making minor adjustments, and removing the grain from the combine. Because of the variation in time lost on different machines, the rate of travel and the hours worked per day do not accurately indicate the distance covered. The usual rate of travel is from 2.5 to 3 miles per hour and is apparently not related to the size of machine. Such differences as are shown in Table 14 indicate a higher rate of travel for machines equipped with auxiliary engines. Unless the advantage of a higher speed is offset by greater loss of time in the field the rate of cutting should be increased in proportion to the increase in rate of travel. Where the crop is heavy the rate of travel may be limited by the capacity of the separator to handle the grain.

The larger machines, of course, would cut a greater acreage in a given length of time than would the smaller machines. The 8-foot power-drive machines cut an average of 1.6 acres per hour and the 10-foot machines 2.6 acres. The difference in rate of cutting is greater than can be accounted for by the difference in the size of the machine. Machines with auxiliary engines having a 12-foot cut averaged 2.6 acres per hour, those with a 15-foot cut averaged 3.4, and those with a 16-foot cut averaged 3.7 acres. The difference in rate of cutting for these machines is approximately proportional to the difference in size, and the greater acreage cut by the wider machines is presumably due to the advantage of size.

The rate of cutting per hour for each foot of cut, with due allowance for time lost in the field, should depend entirely upon the rate of travel. As there is no apparent relation between the size of the machine and the rate of travel per hour, little difference is shown in the rate of cutting per foot of width for machines of different sizes. The high rate of cutting per hour and per foot of width for the 10-foot machines probably is due to fewer stops and less time wasted in the field.

FACTORS INFLUENCING THE RATE OF HARVESTING

The size of the machine is the most important single factor directly affecting the rate of cutting. With two other factors, rate of travel and yield of grain, remaining constant, the rate of cutting per hour, as derived from 214 reports of combines equipped with auxiliary engines, would be increased 0.27 acre by the addition of each foot to the length of the cutter bar.[5]

On this basis a 10-foot machine in 20-bushel wheat, traveling at 2.5 miles per hour, should cut 20.5 acres in a 10-hour working day. A 12-foot machine should cut 25.9 acres, a 15-foot machine 34 acres, a 16-foot machine 36.7 acres and a 20-foot machine 47.5 acres. These estimates of operation check fairly closely with the averages given in Table 14.

The reported estimated rate of travel does not accurately represent the ground covered by the machine in a given time. The reported figures make no allowance for lost time and do not give a true average rate of travel. An increase in acres cut, proportionally less than the increase in rate of travel, is indicated by the average relation that exists between acres cut per hour and the reported rate of travel.

Yields ordinarily reported in the Great Plains have little effect on the rate of cutting per hour. Except in cases of heavy yields, the machine can handle the cut grain without difficulty. Where yields of wheat exceed 30 bushels per acre it may be necessary to reduce the rate of travel in order that the combine may handle the grain without undue loss; and when cutting lodged grain, in cases in which a great deal of straw is handled, the rate of travel may be reduced.

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[5] This increase is an average relationship shown by a linear multiple correlation analysis giving a coefficient of correlation of 0.81. The regression equation on which it is based is: $D=0.27\ A-0.004\ B+0.255\ C-1.21$, in which A is the length of the cutter bar in feet, B is the acre yield in bushels, C is miles traveled per hour, and D is the number of acres cut per hour. This means that, with other factors remaining the same, an increase of 1 foot in the width of machine would be expected to increase the rate of cutting 0.27 acre per hour. For each additional bushel of yield with no change in other factors the rate of cutting would be expected to decrease by 0.004 acre per hour. Each increase of 1 mile per hour in rate of travel was associated with an increase of 0.255 acre cut per hour.

RELIABILITY OF COMBINES

The reliability of a combine depends upon whether it functions properly when needed. Its degree of reliability is best measured, in this study, by time lost because of mechanical difficulties when harvesting. Interruption of work through machine failure not only involves the expense of reconditioning the machine but, at times, it means the loss of the services of high-priced labor during the repair period, and, if the delay is an extended one, the more serious loss of time. Frequent occurrences of this nature will render the machine unreliable and make it an unprofitable investment. Frequently, delay is the result of inefficient operation, which may be caused either by unfamiliarity with the machine or by carelessness, with a resultant unwarranted reflection on the reliability of the machine. This is especially true of new equipment of a complicated design which involves many mechanical principles. The personal element is perhaps the largest single factor influencing the apparent reliability of a machine of this type unless it is thoroughly understood by the operator.

If a machine is considered a profitable investment by its operator there is little doubt that it is reliable. In the Great Plains region only three of the interviewed operators expressed doubt as to the profitableness of their investment in a combine. On the other hand, some of those who thought that their machines were a profitable investment doubtless sustained a loss in using this method instead of other methods of cutting or of hiring the grain harvested with a combine. This is especially true with owners of some of the older machines. Other operators were doubly handicapped by the use of second-hand outfits and by a lack of experience. The data gathered, however, show that, whether due to the merits of the combine or pride of ownership, or overenthusiasm on the part of some of the operators, the combine was almost unanimously considered a reliable harvesting machine by Great Plains operators.

Many of the farmers, when they purchased their combines, were familiar with the operation of threshing machines, and had been using headers for some years. Such experience was helpful to them in the use of their combines. They understood, roughly at least, the operation, care, and possibilities of the combine. There were others, however, without this experience who were handicapped when trouble developed, and depended to a great extent upon a representative of the manufacturer for assistance. Other farmers hired operators with some ability and training to look after their machines; still others used their regular farm hands, some of whom knew practically nothing of the operation of a combine. With such operators, the fact that many of the machines got through the harvest with practically no trouble was possibly the result of good fortune rather than of mechanical skill. The results of such operation, however, may cause trouble in future harvests.

Most of the delays during harvest were caused by replacement of parts because of breakage, wear, or poor alignment; the duration of the delay depended upon the accessibility of the part on the machine and its availability on the market. Service given by manufacturers, especially on the new machines, doubtless saved operators much expense for repairs and the possible hiring of expert labor. The service rendered by the manufacturers, both of an advisory nature and in supplying necessary accessories through their agencies, is closely related to the reliability of the combine. Adequate service at harvest time involves a minimum of delay, and with no other type of farm machinery is delay accompanied with more hazard than with the combine. Once the crop is ripe, the speed with which it is harvested frequently determines the quantity of grain that is saved from losses over which the operator has no control.

Service is naturally best in those localities in which the machines are in more common use, as the business done by dealers there justifies a more complete stock of repair parts. Dealers are frequently criticised, and sometimes justly, for poor service and failure to supply repair parts, because of a small volume of business, change in machine models, etc. Perhaps the best service these dealers could hope to render would be in stocking in advance those parts which are most subject to replacement. They would thus be guaranteed a reasonable turnover of stock, and at the same time be meeting at least the greater portion of the needs for repairs.

ELEMENTS OF COST IN HARVESTING WITH A COMBINE

Operating expenses for harvesting with a combine consist of the costs of fuel and lubricants, use of tractor, labor, and repairs. Fixed charges to be made against the combine are charges for depreciation and interest on the investment. Taxes, insurance, and cost of housing might also be added to the charges made against the combine.

LABOR

The crew used on the combine itself is fairly well standardized in the Great Plains. Machines with power-drive from the tractor can be operated by one man who drives the tractor; the machines with auxiliary engines require the labor of two men, one on the tractor and one on the combine. Additional help is used on many machines either because the labor is available on the farm or because of an effort to minimize the time necessarily lost in the field.

Table 15 shows the labor used on machines of different types and sizes. Of the 25 machines with an 8-foot cut, only 3 were operated by more than one man. Of the 10-foot machines, only 3 were operated by one man and 6 were operated by two men.

TABLE 15.—*Number of combines operated by crews of different sizes*

Type of combine	Width of cut (feet)	Number of combines	Number of combines operated by crew of [1]—				
			1 man	2 men	3 men	4 men	5 men
Tractor drawn, with power take-off	8	25	22	3			
	10	10	3	6	1		
	12	56	1	48	7		
Tractor drawn, with auxiliary engine	15	51		42	9		
	16	104		81	20	2	1
	20	3			2	1	
Total		249	26	180	39	3	1

[1] Includes combine operator, tractor driver, and helpers on the combine, but not grain haulers.

With a few exceptions, the combines with auxiliary engines were operated by at least one tractor driver and one man on the combine. This crew can handle the unit, but many farmers used extra men, and a few who worked all night used two complete crews. Of the 56 machines with a 12-foot cut, 1 was operated by 1 man, 48 used crews of 2 men, and 7 used crews of 3 men. Of the 51 machines with a 15-foot cut, all used crews of 2 or more men, 1 used an extra tractor driver, and 8 used additional helpers. Of the 104 machines with a 16-foot cut, 2 used extra machine operators on the combine, and 25 used additional helpers around the machine. The 20-foot machines all used crews of 3 men or more. More of the farmers with the large machines used extra men in order to reduce the time for oiling and making minor adjustments in the field.

The available data do not indicate that an increase in acres cut per day will result from the use of an extra man on the combine. Unless some greater efficiency in threshing is gained, the employment of extra help will not be justified by the additional work done. The extra man, in a great many instances, is used to relieve the regular workers or is carried as a sort of insurance against lost time because of machine adjustments or breakdowns that may be repaired in the field.

The reduction in amount of hired harvest labor with combine harvesting, as compared with that used with other methods, is an important consideration with many farmers. On the tractor-drawn combines from which records were obtained, 53 per cent of the labor was that of the owner or unpaid labor on the farm. Some of the hired labor used was regularly employed on the farm, and a part represented labor exchanged with neighbors. The small amount of hired labor renders the farmer comparatively independent of transient labor for his harvesting operations.

A higher grade of labor usually is hired for work on the combine than would be employed for harvesting with a binder or header, and wages are somewhat higher. Table 16 shows the number of paid and unpaid workers used in operating combines. Wages for the different operations differ somewhat in the different localities and show a still wider variation for different farms in the same locality. Table 17 shows a frequency distribution of rates of payment for combine operators, tractor drivers, and haulers. The most common rates paid for combine operators were $5 or $6 per day, but rates as low as $4 or as high as $8 were not uncommon. Customary rates for tractor drivers were $4, $5, or $6, and $4 was the usual wage for haulers. Helpers on the combine usually received wages similar to those of the haulers.

TABLE 16.—*Paid and unpaid labor on combines*

Type of combine	Width of cut (feet)	Number of combines	Number of combines using [1]—					
			Operators		Helpers		Drivers	
			Paid	Unpaid	Paid	Unpaid	Paid	Unpaid
Tractor drawn, power take-off	8	25	20	8				
	10	10	7	3		1	2	5
Tractor drawn, with auxiliary engine	12	56	22	33	4	3	29	27
	15	51	15	36	3	5	28	24
	16	104	30	76	14	11	62	42
	20	3	3	1	2	1	3	
Horse drawn	12	3		3			2	1
	15	3	1	2			2	1
	16	2	1	1			1	1
Total		257	99	163	23	21	129	101

[1] For size of crew see Table 15, p. 21.

TABLE 17.—*Rates paid for labor in combining and hauling*

Rate per day	Combine operators	Tractor drivers	Haulers	Rate per day	Combine operators	Tractor drivers	Haulers
Dollars	*Number*	*Number*	*Number*	*Dollars*	*Number*	*Number*	*Number*
1.00			2	6.00	65	52	9
2.00		1	11	6.50	3	1	
2.50	1	2	11	7.00	17	7	1
3.00	3	8	22	7.50	10	3	
3.50	6	9	28	8.00	20	6	1
4.00	20	50	110	8.50	1		
4.50	3	7	4	10.00	7	1	
5.00	97	82	27	12.00	1		
5.50	8	6				[illegible]	

The economy in the use of man labor is shown by a comparison of man-hours per acre for different methods of harvesting. Where a binder is used and the grain is cut, shocked, and threshed from the shock, the labor per acre is about 3.6 man-hours. Where the wheat is harvested with a header the labor per acre is about 2.8 man-hours as compared with about 0.75 man-hour for harvesting with a combine.[6]

The comparison given includes only the labor furnished by the farmer and does not include the labor furnished by the thresher. The cost of this threshing labor is included in the rate paid by the farmer for threshing. To obtain the saving in total labor made, approximately one hour per acre should be added to the figure given for harvesting with either a binder or header. A machine operated by a crew of five pitchers and three machine men, and threshing 1,200 bushels in a 10-hour day, would be equivalent to one man-hour of labor per acre in wheat that yields 15 bushels per acre.

The total labor for harvesting and threshing is reduced from approximately 4.6 man-hours for cutting with a binder and threshing with a stationary thresher, or 3.8 man-hours for cutting with a header and threshing with a stationary thresher, to about 0.75 man-hour per acre in cases where the work is done with a combine.

In each district, however, the labor of cutting, shocking, and hauling bundles to the thresher was furnished by the farmer, and is included in the labor used for harvesting and threshing when grain is cut with a binder. The labor required, where a header is used, includes cutting and stacking but does not include pitching into the separator. The labor required for hauling grain is not included in either case.

The crew to operate a combine would be no larger than that for cutting grain with a binder and for shocking. For a grain acreage so large that more than one binder would be needed, a combine would reduce the size of the harvest crew. As compared with the crew of a header, the crew of a combine would be 2 or 3 men, rather than 6 men. The use of the combine also eliminates the crew necessary for stationary threshing.

The labor needed for hauling the grain from the combine depends upon a number of conditions and the labor of hauling varies on different farms. Table 18 shows the farms that used different numbers of haulers for combines of each size. On several farms

[6] Labor and materials used for binding and heading are taken from data used in compiling the following bulletin: WASHBURN, R. S., COST OF PRODUCING WINTER WHEAT IN CENTRAL GREAT PLAINS REGION OF THE UNITED STATES. U. S. Dept. Agr. Bul. 1198, 30 p., illus. 1924.

the hauling was contracted at a fixed rate per bushel, and the time and crew required was not determined. On some farms a part of the wheat was hauled on contract, and a part was hauled by the farm or hired labor.

TABLE 18.—*Labor for hauling grain from combines*

Type of combine	Width of cut (feet)	Number of combines	Number of combines using—				
			1 hauler	2 haulers	3 haulers	4 haulers	5 haulers
Tractor drawn, with power take-off	8	20	16	3	1		
	10	8	4	3	1		
Tractor drawn, with auxiliary engine	12	45	27	16	1		1
	15	38	14	19	4		1
	16	90	33	30	21	5	1
	20	2	1	1			
Total		203	95	72	28	5	3

The number of haulers used depends upon the bushels threshed per day, the distance hauled, the facilities for loading and unloading, and equipment for hauling. The man labor required is probably least when the grain can be run directly from the combine tank into a truck and can be unloaded by dumping. Unless the distance is too great, one man can haul the grain from the machine. When the grain is stored on the farm and must be scooped into the bin, additional labor is needed. Some farmers, who had no grain tank on the combine, were hauling grain by truck and used one or two men for scooping the grain from the wagons to the truck. Where the hauling was by wagons rather than by trucks, no scooping at the combine was necessary, but where the distance is long a larger crew of haulers would be required. Often an extra hauler with a team and wagon was used to insure against delay in taking the wheat from the machine.

The average distance from market was about 5 miles, but the distance for all machines ranged from a fraction of a mile to 25 miles. Trucks were generally used for the long hauls. A 16-foot combine, equipped with a grain tank and harvesting 800 bushels per day, would require the full time of one 60 or 65 bushel truck to haul the grain to an elevator which is 5 miles distant.

POWER, FUEL, AND LUBRICANTS

The charge to be made for the use of the tractor, in combining, would probably vary somewhat with size of tractor, and in actual accounting it would be affected largely by the amount of other work for which the tractor was used. Except for a few instances in which a tractor was hired, the tractor was used for other farm work. A few tractors were hired for 50 or 60 cents per acre, with driver and fuel furnished by the combine operator. The rate may be applied regardless of size of the tractor, for although a larger tractor would be used on large combines, the acreage covered would be proportional to the size of the combine, and the total returns would be commensurate with the size of tractor.

The fuel used in the tractor varies for the different sizes and for individual tractors of the same size. As the large combines usually are pulled by large tractors, the fuel consumption per tractor is larger for the 15-foot and 16-foot than for the 12-foot machines. A larger acreage is cut by the wider machines, however, and, as shown in Table 19, the fuel used in the tractor is less per acre for the large machines. The average for all combines equipped with auxiliary engines is 0.8 gallon of fuel per acre. The average tractor fuel consumption per acre is 0.94 gallon for the 12-foot machines, 0.84 gallon for the 15-foot machines, and 0.75 gallon per acre for 16-foot machines.

TABLE 19.—*Fuel and lubricants used in tractors*

Type of combine	Width of cut	Combines	Area cut	Grain threshed	Fuel and oil used per tractor								
					Gasoline	Kerosene	Distillate	Fuel			Oil		
								Total	Per acre	Per bushel	Total	Per acre	Per bushel
	Feet	*No.*	*Acres*	*Bush.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*
Tractor drawn with power take-off	8	25	213	3,647	114	127	21	262	1.23	0.072	12	0.05	0.003
	10	10	202	7,108	200	139	42	381	1.30	.054	12	.04	.002
Tractor drawn with auxiliary engines	12	64	287	4,876	153	100	10	269	.94	.055	13	.04	.003
	15	50	357	6,385	148	124	27	299	.84	.047	12	.03	.002
	16	103	423	8,609	201	97	18	316	.75	.036	15	.03	.002
	20	3	637	16,918	202	------	133	425	.67	.027	13	.02	.001
All tractor drawn, with auxiliary engines	------	210	375	7,253	178	103	21	302	.80	.041	13	.04	.002

The combines which had direct-power drive from the tractor used more fuel per acre in the tractor than did those equipped with auxiliary engines. The fuel used in these machines should be compared to the total fuel used in machines that have two power units.

Gasoline or kerosene is commonly used for tractor fuel, although a few of the operators used distillate. The quantity of fuel used per day by a given machine is approximately the same regardless of the kind of fuel.

The quantity of fuel and lubricants used by combines with auxiliary engines was reported separately for the tractor and for the auxiliary engine. Table 20 shows the quantity of fuel and oil used in the auxiliary engine. With one or two exceptions the farmers used gasoline as the motor fuel in the combine engine. The figures for fuel consumption per acre show the larger machines to be slightly more economical than small machines. Machines with a 12-foot cut used 0.61 gallon per acre, those with a 15-foot or 16-foot cut used 0.59 gallon per acre. The difference in average fuel consumption between the groups is less than the variation shown between combines of the same size. Differences in condition of the engine, rate of travel, yield of wheat, and size of machine, affect fuel consumption.

TABLE 20.—*Fuel and lubricants used in the auxiliary engine*

Type of combine	Width of cut	Combines	Area cut	Grain threshed	Gasoline and oil per engine					
					Fuel			Oil		
					Total	Per acre	Per bushel	Total	Per acre	Per bushel
	Feet	*Number*	*Acres*	*Bushels*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
Tractor drawn with auxiliary engine	12	54	287	4,876	176	0.61	0.036	7	0.02	0.001
	15	50	357	6,366	211	.59	.033	8	.02	.001
	16	103	423	8,660	249	.59	.029	11	.03	.001
	20	3	637	16,918	250	.39	.016	12	.02	.001
Total		210	375	7,253	221	.59	.031	9	.02	.001

The average relation between size of machine and fuel consumption per acre shows the machines with longer cutter bars to be more economical than those with the shorter ones. This economy may be due in part to the use of the extension cut on a number of machines. The separators on some of the 15-foot or 16-foot machines were the same size as those on the 12-foot combines, and consequently required less fuel per acre cut. The difference between the quantities estimated for a 10-foot machine and for a 20-foot machine is only 0.13 gallon per acre.[7]

Rate of travel per hour has a more significant effect on the consumption of fuel. Presumably the quantity of fuel used in the engine, during a given period of time, differs very little whether the machine travels at 2 or 3 miles per hour. Consequently a 15-foot machine, cutting grain that yields 20 bushels per acre, would burn approximately 1 gallon of fuel per acre if traveling at 2 miles per hour, but would use proportionally less if traveling at 3 miles per hour. For economical use of gas in the auxiliary engine, it would be advisable to pull the machine at as high a speed as is consistent with clean harvesting and threshing.

In heavy wheat it may be necessary to reduce the rate of travel in order that the combine may thoroughly separate the grain. This effect of yield on fuel consumption per acre is reflected in the relation between the rate of travel and fuel consumption per acre.

At the same rate of travel, differences in the yield of grain per acre have some separate effect on fuel used. The estimated fuel used by a 15-foot machine traveling 2.75 miles per hour in grain that yields 10 bushels per acre is 0.54 gallon per acre; for a 20-bushel yield, under the same conditions, the estimated fuel consumption is 0.62 gallon; and for a 30-bushel yield the fuel consumption is 0.71 gallon per acre.

Since the quantity of fuel per acre used in threshing grain with a high yield is not much greater than that used for threshing grain

[7] This estimate is based on a multiple linear correlation analysis of fuel used per acre as affected by size of machine, yield of grain, and rate of travel per hour. The coefficient of correlation is +0.92. The effect of each factor on fuel used is estimated from the regression equation, $E=2.127-0.013\ A+0.0084\ B-0.536\ C$, when E is the fuel used per acre, A is length of cutter bar in feet, B is yield of grain in bushels, and C is miles traveled per hour. The average relationship expressed is that, with no change in the other factors, an increase of 1 foot in width of cut would be associated with a decrease of 0.013 gallon of fuel for each acre cut. An increase of 1 bushel per acre in yield would be associated with an increase of 0.0084 gallon of fuel used per acre, and an increase of 1 mile per hour in rate of travel would reduce the fuel consumed by 0.536 gallon per acre. In making these estimates care must be taken to keep the measure of the causal factors within the limits of the data on which the correlation is based.

with a low yield, the quantity of fuel per bushel is affected largely by the yield of grain. For high yields, the fuel used per bushel is small compared with that for low yields. The lubricants used for the auxiliary engine make a small item of expense, and the amount is roughly proportional to the fuel used.

Fuel consumption per bushel of grain is largely dependent upon the yield per acre, but in general the quantity of fuel required per bushel is less for the large than for the small machines.

The total quantity of fuel and oil used for harvesting with a combine is shown for each type of machine in Table 21. The average fuel used per acre, in units with auxiliary engines, is 1.39 gallons. For combines with the power drive from the tractor, the fuel per acre is slightly less than for the combines with auxiliary engines, and the quantity of fuel per acre is generally less for large than for small machines. The 8-foot power-drive machines show a smaller fuel consumption per acre than do the 10-foot power-drive machines; but the yield of grain was consistently higher where most of the 10-foot machines were used, and the higher fuel consumption is due, in part at least, to the heavier grain. The fuel consumption per bushel is less for the 10-foot than for the 8-foot combines.

Table 21.—*Total fuel and lubricants used in the tractor and auxiliary engine*

Type of combines	Width of cut	Combines	Fuel			Oil			Grease		
			Total	Per acre	Per bushel	Total	Per acre	Per bushel	Total	Per acre	Per bushel
	Ft.	*No.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*	*Lbs.*	*Lbs.*	*Lbs.*
Tractor drawn, with power take-off	8	25	202	1.23	0.072	12	0.05	0.003	13	0.06	0.004
	10	10	381	1.30	.054	12	.04	.002	18	.06	.002
Tractor drawn, with auxiliary engine	12	54	445	1.55	.091	20	.06	.004	18	.06	.004
	15	50	510	1.43	.030	20	.05	.003	18	.05	.003
	16	103	565	1.34	.085	20	.06	.003	17	.04	.002
	20	3	675	1.06	.043	25	.04	.002	38	.06	.002
All tractor drawn, with auxiliary engine	-------	210	523	1.30	.072	22	.06	.003	18	.0[illegible]	.002

The quantity of oil has the same general relation to size of machine as has the fuel used. The grease used on the tractor and combine is a small item of cost and, as reported, shows more variation between machines of the same size than does either fuel or oil.

REPAIRS

The cost of repairs on 256 combines, operated in 1926, as reported by the operators, averaged $20 per machine for the season. In addition to this cash cost, an average of two days of man labor was used in putting repairs on the combine and fitting the machine for the season's work. This average figure, shown in Table 22, does not represent the average repair cost for a machine for the entire length of its service. The average age of machines for which this figure is obtained is only 2.4 years, so that practically all machines were comparatively new and would be expected to show low costs for repairs. During the first year of operation, practically all repairs are made as a service by the manufacturer where broken parts show defective material or workmanship, and therefore are not reported by the farmer as costs. A group of older machines would show much higher charges for repairs. Average costs of repairs shown are much higher on the 12-foot machines than on the others, and it is this group that had been longest in service.

TABLE 22.—*Average cost of repairs on combines in 1926*

Type of combine	Width of cut	Combines	Age of combines	Cost of repairs	Labor on repairs
	Feet	*Number*	*Years*	*Dollars*	*Days*
Tractor drawn with power take-off	8	25	1.0	4	0.6
	10	10	1.0	1	.3
Tractor drawn with auxiliary engine	12	56	4.9	40	3.4
	15	51	1.8	16	1.5
	16	103	1.7	18	1.9
	20	3	1.7	8	.2
Horse drawn	12	3	8.0	56	3.0
	15	3	1.3	5	----------
	16	2	1.5	24	2.0
Total or average	----------	256	2.4	20	2.0

Table 23 shows repair costs per acre of grain harvested for machines of all ages over 1 year. The repairs per acre on the 12-foot machines increased from 7.5 cents for the second season to 17.4 cents for the eighth season. The repairs on the 15-foot machines increased from 5.4 cents per acre for the second season to 9.8 during the fifth season. In general, repairs per acre are less for the large than for the smaller machines. Because of the inadequacy of repair data on older machines the average does not represent the allowance which should be made for cost of repairs.

TABLE 23.—*Cost of repairs reported on combines of different ages after the first year per machine and per acre*

Type of combine	Width of cut	Second year		Third year		Fourth year	
		Total	Per acre	Total	Per acre	Total	Per acre
	Feet	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
Tractor drawn, with auxiliary engine	12	30	7.5	33	8.7	34	9.9
	15	29	5.4	37	7.2	38	7.5
	16	20	4.4	45	6.3	----------	----------
Average	----------	29	5.5	36	7.7	----------	----------

Type of combine	Fifth year		Sixth year		Seventh year		Eighth year	
	Total	Per acre	Total	Per acre	Total	Per acre	Total	Per acre
	Dollars	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
Tractor drawn, with auxiliary engine	35	10.3	41	12.5	42	11.3	70	17.4
	45	9.8	----------	----------	----------	----------	----------	----------
Average	----------	----------	----------	----------	----------	----------	----------	----------

The repair cost per acre is probably affected less by the acreage cut than is the depreciation charge per acre. Table 23 indicates that on the machines which have been in use for about one-half the expected life of eight years of the machine the cash cost of repairs would be slightly less than 10 cents per acre. In computing harvesting costs, an allowance of 10 cents per acre is made for purchase of repairs on the combine.

Most of the tractors were purchased primarily for other work, but certain repair and labor costs are chargeable to the cost of operating the combine. To prorate these costs is difficult, as there are many variables. What part of these costs to charge to harvesting, when repairs are necessary shortly after harvest begins or at the beginning of another job following harvest, is questionable. Lack of data precludes the fixing of a yearly or acre charge for these costs. Perhaps the most equitable charge that could be made would be based on the total yearly acreage covered by the tractor. The total yearly repair and labor costs, divided by the total acreage over which the tractor was used, would give a per-acre charge which could be made against the tractor for each acre harvested.

FIRST COST AND DEPRECIATION

The combine, with its economy in the use of labor and greater convenience in harvesting, has a disadvantage compared with other harvesting machines in that it requires a large original investment and consequently has high depreciation and interest charges. The first cost of the machine varies with the size and type of machine purchased. Power-drive machines with an 8-foot or 10-foot cut may be priced as low as $1,000, whereas the larger machines equipped with auxiliary engines may cost $2,000 or $3,000, depending upon the make and size of machine. With so large an investment required, many farmers who have a small wheat acreage hesitate to buy a combine.

Table 24 shows the average cost to farmers in the Great Plains of machines of different types. This cost varies somewhat with the location, the terms of purchase, and the accessory equipment purchased with the machine.

TABLE 24.—*First cost of combines*

Type of combine	Width of cut (feet)	Number of combines	Average cost of combines
Tractor drawn, with power take-off	8	25	$1,043
	10	10	1,260
Tractor drawn, with auxiliary engine	12	56	1,810
	15	51	2,084
	16	104	2,315
	20	3	3,315
Horse drawn	12	3	1,812
	15	3	1,903
	16	2	2,290
Total or average		257	1,995

For the most part, the machines have been used for too short a time to determine the length of service to be expected under ordinary farm conditions. Moreover, the combine is in the process of development, and a machine may decrease in value as much from becoming obsolete as from actual wear and tear. Estimates of the operators indicate that, on the average, the machines were expected to last for about eight seasons. The expected length of life apparently has little relation to the acres cut annually and under conditions of actual operation is probably affected more by the mechanical ability of the operator, and the care given, to the machine than by the amount of work done each season. For the 257 combines included in this part of the study, depreciation as derived from first cost, estimated length of service, and acres harvested annually, is 44 cents per acre. Depreciation is one of the most important costs to be considered in harvesting with a combine.

Assuming no relation between the acres cut annually and the life of the machine, the charge for depreciation would be a fixed cost, and the charge per acre would depend largely upon the acres cut each year. Table 25 shows the depreciation charge per acre for different machines with varying acres harvested.

TABLE 25.—*Depreciation in value of combines per acre for different acreages cut*

Type of combine	Width of cut (feet)	Number of combines	Average cost of combine	Yearly depreciation [1]	Depreciation per acre harvested annually		
					100 acres	200 acres	300 acres
Tractor drawn with power take-off	8	25	$1,013	$126	$1.20	$0.63	$0.42
	10	10	1,200	152	1.52	.76	.51
Tractor drawn with auxiliary engine	12	56	1,810	218	2.18	1.09	.73
	15	51	2,084	251	----------	1.26	.84
	16	104	2,315	279	----------	1.40	.93
	20	3	3,315	399	----------	----------	1.33
Horse drawn	12	3	1,812	218	2.18	1.09	.73
	15	3	1,903	229	----------	1.14	.76
	16	2	2,290	276	----------	1.38	.92

Type of combine	Depreciation per acre harvested annually							
	400 acres	500 acres	600 acres	700 acres	800 acres	900 acres	1,000 acres	1,100 acres
Tractor drawn with power take-off	$0.31	-------	-------	-------	-------	-------	-------	-------
	.38	$0.30	$0.25	-------	-------	-------	-------	-------
Tractor drawn with auxiliary engine	.54	.44	.30	-------	-------	-------	-------	-------
	.63	.50	.42	$0.36	-------	-------	-------	-------
	.70	.56	.46	.40	$0.35	$0.31	-------	-------
	1.00	.80	.66	.57	.50	.44	$0.40	$0.36
Horse drawn	.54	.44	-------	-------	-------	-------	-------	-------
	.57	.46	.38	.33	-------	-------	-------	-------
	.69	.55	.46	.39	.35	.31	-------	-------

[1] Depreciation is based upon an expected life of 8.3 years as determined from estimates of 257 combine owners.

COMPARISON OF COSTS OF HARVESTING GRAIN

Costs of harvesting grain differ in various sections of the country according to differences in the prices of the cost factors. There is some variation in prices of machines, wages of labor, and prices of fuel and lubricants in different parts of the Great Plains. Some variation in costs per acre also occurs with differences in yields of grain, although this variation is less when costs are computed on an acre basis rather than on a bushel basis. A wide difference in acre costs also occurs on different farms under similar conditions of weather, prices, and yields. Variations in such factors as length of life of the machine, repairs, acres cut per day, and mechanical ability of the operator cause variations in costs so that computations representing averages are not applicable to individual farms. Figure 7 shows a general comparison of harvesting costs for different acreages of grain cut by binders, headers, or combines.[8]

The costs of harvesting with a combine used for making the graph shown in Figure 7 are computed by applying prices to the average quantities of labor and material used as shown by the previous tables

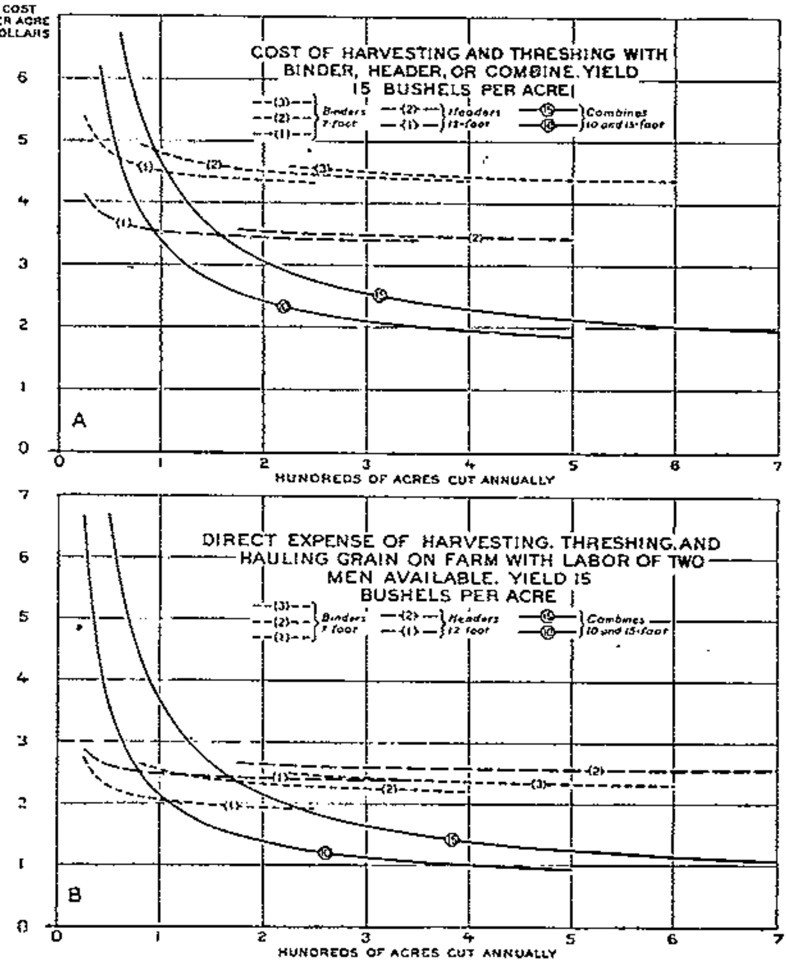

FIG. 7.—Comparative harvesting, threshing, and hauling cost with binders, headers, and combines

on combine operation. Rates of payment for labor and material used for binding and heading are comparable to the rates applied to the elements of cost for combining.[9]

With interest and depreciation included in costs, the large investment in machinery causes a high harvesting charge per acre when a

[8] In using the cost data shown in the tables and curves it is important, therefore, that the individual keep clearly in mind the fact that differences in costs do occur from farm to farm.

[9] Labor and materials used for binding and heading are taken from data used in compiling the following bulletin: WASHBURN, R. S. Op. cit.

small acreage is cut. Depreciation charges are based in all cases on an estimate of 8.3 years as the life of the combine, and the same yearly depreciation is charged regardless of the acreage cut. In actual service it seems likely that the yearly depreciation would be less for small than for large acreages. The amount of work done probably would affect the length of service of the machine, particularly in instances where very high or very low acreages were cut. Then depreciation charged to the binders is based on 10 years of service, whereas that charged against the headers is based on 15 years of service.

The cost curve for combines shows the effect of acreage cut on cost per acre and emphasizes the necessity of having a large acreage in order to decrease the acre cost. As the investment in the 10-foot machine is smaller than that in the 15-foot machine, and other costs per acre are approximately the same, the total acre cost of harvesting is less for the 10-foot than for the larger machine. The unit cost of operation in the Great Plains in 1926 was generally lower for the smaller combines, including the 10-foot machines.

The cost curves of the combine and binder indicate that if harvest and threshing costs alone are considered the small combine is a more economical machine than the binder where 60 or more acres of grain are to be cut. With a 15-foot combine harvesting costs would not be reduced unless approximately 100 acres were cut.

When a header is used, costs are somewhat lower than the acre cost for harvesting with a binder. As compared with a header, the 10-foot combine probably would be more economical where 100 or more acres were to be cut. The 15-foot combine would not be more economical than the header unless the acreage was as large as 150 acres.

For larger acreages, the cost of cutting and threshing with a combine is much lower than for either a binder or a header. The small combine apparently is more economical than is the large size, up to the limit of its capacity, but the cost per acre decreases rather slowly after the acreage cut is greater than 300 or 400 acres, and the advantage of getting the grain cut and threshed quickly probably would more than equal the small reduction in costs shown. In cases in which more than 300 acres are cut, the difference between acre costs with 10-foot or 15-foot machines is small, and the variation between costs on separate machines is such that in many instances the larger machine probably would be as economical as the smaller one, or more economical. Table 26 shows the factors considered in computing the costs used in Figure 7, A.

TABLE 26.—*Charges per acre with different harvesting methods*

Item of cost	10-foot combine		15-foot combine		7-foot binder		12-foot header	
	Per acre charges							
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Man labor [1] ...man-hours	0.69	$0.41	0.65	$0.39	3.6	$1.80	2.8	$1.40
Horse labor [2] ...horse-hours					5.9	.59	4.1	.41
Tractor		.60		.60				
Fuel [3] ...gallons	1.30	.32	1.43	.36				
Oil [3] ...do	.04	.03	.05	.04				
Grease ...pounds	.06	.01	.05	.01				
Twine [4] ...do					2.0	.28		
Repairs		.10		.10		.05		.05
Threshing [5]						1.50		1.50
Variable costs		1.47		1.50		4.22		3.30
	Annual charges							
Depreciation [6]		$152.00		$251.00		$22.50		$13.33
Interest [7]		37.80		62.52		0.75		6.00

[1] Labor on combines charged at 60 cents per hour; on binder and headers at 50 cents per hour.
[2] Horse labor charged at 10 cents per hour.
[3] Fuel charged at 25 cents, oil at 75 cents per gallon.
[4] Twine charged at 14 cents per pound.
[5] Threshing charged at 10 cents per bushel; 15-bushel yield assumed.
[6] Based on 8.3 years life for combine, 10 years for binder, 15 years for header.
[7] Annual charge per machine based on one-half the first cost at 6 per cent.

The farmer on his own farm, with a certain supply of labor and power available, may be more interested in actual payments than in total charges as shown in Figure 7, A. The costs which he must meet in cash are of first importance. Figure 7, B shows the estimate of immediate costs for different machines with no allowance made for unpaid labor, power, or interest on the investment. To harvest with a combine the grain crop on a farm that has available the equivalent of the labor of two men would require the hired service of one man for hauling, running expenses for operating the combine, and a charge for replacement of the machine. With one binder, no additional labor would be needed for cutting; the extra threshing labor might be exchanged, and the only immediate costs would be for twine, operating expenses of the binder, and cost of threshing. If more than one binder, or if a header, is used, more labor necessarily would be hired for harvest.

Table 27 shows the cash cost factors considered in the comparison shown in Figure 7, B. These costs would be less when a binder (fig. 8) is used than when a small combine is used, unless 110 or more acres were to be cut. For acreages less than the approximate maximum to be cut with a binder, the cost is less than that for a large combine. With a header (fig. 9) the immediate costs are somewhat higher, and the harvesting costs might be reduced with the use of a small combine if 80 or more acres were to be cut. A large combine would be more economical for cutting more than 175 acres. For larger acreages than those shown the harvesting costs would be lower where a combine was used.

TABLE 27.—*Cash costs per acre incident to harvesting by different methods where the labor of two men is available and threshing labor is exchanged*

Item of cost	Combines				7-foot binder cost			12-foot header cost	
	10-foot		15-foot						
	Quantity	Cost	Quantity	Cost	1 machine	2 machines	3 machines	1 machine	2 machines
Extra labor [1] ...man-hours	0.40	$0.16	0.30	$0.12		$0.27	$0.36	$0.80	$0.96
Fuel [2] ...gallons	1.30	.32	1.43	.30					
Oil [2] ...do	.04	.03	.05	.04					
Grease ...pounds	.06	.01	.05	.01					
Twine [3] ...do					$0.28	.28	.28		
Repairs		.10		.10	.05	.05	.05	.05	.05
Threshing [4]					1.50	1.50	1.50	1.50	1.50
Variable costs		.62		.63	1.83	2.10	2.19	2.35	2.51
Depreciation [5]		152.00		251.00	22.50	45.00	67.50	13.33	26.67

[1] Charged at 40 cents per hour.
[2] Fuel charged at 25 cents, oil at 75 cents per gallon.
[3] Twine charged at 14 cents per pound.
[4] Threshing charged at 10 cents per bushel for a 15-bushel yield.
[5] Based on 8.3 years' life for a combine, 10 years for binder, 15 years for header.

FIG. 8.—Harvesting wheat with a binder. If there are 110 or more acres of grain to harvest the cash costs will be lowered by using a small combine

If extra labor is needed, or additional charges are made, on a given farm, the cash costs would be somewhat higher, and the point where a combine would prove profitable would lie somewhere between the acreages indicated in Figure 7, A and B.

The harvesting and threshing costs for binders and headers are based upon yields of approximately 15 bushels per acre. With higher yields, the threshing costs would increase proportionally to the increase in yield, and a comparison of harvesting costs would show a still greater advantage for the combine. The cost of combining as computed from the available data are for yields averaging 20 bushels per acre. Costs per acre for the combine are so little affected by differences in yield that the cost for combining a yield of 15 bushels would be practically the same as for a yield of 20 bushels per acre. It is only when the grain is very heavy and the rate of travel or width of swath taken must be reduced that yield has an appreciable effect on acre cost of cutting with a combine. Even then the cost does not increase as fast in proportion as do separator charges with increased acre yields.

CUSTOM WORK WITH COMBINES

A farmer who has a small acreage of grain may find it advisable to obtain a combine for his own grain and to depend upon doing some custom cutting for his neighbors. More than half of the combine owners did some custom work with their machines.

The profit in custom cutting depends largely upon the rate received per acre. In those districts in which the combine had been used for only a short time the rate per acre was higher than in other districts

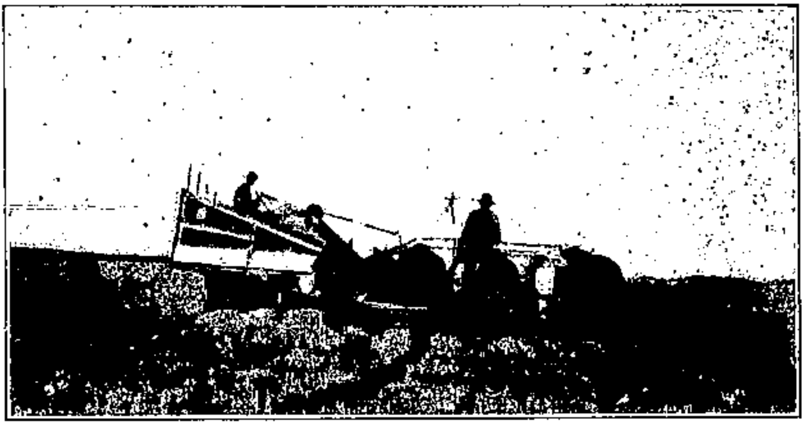

FIG. 9.—Harvesting wheat with a header. If there are 80 or more acres of grain to harvest the cash costs will be lowered by using a small combine

in which the machines were in more general use. The acre rates varied from $4 in Texas to $2.50 in Montana. The general rates were about $3 per acre in most of the localities. The charge for cutting is usually higher during the first part of the harvest season than later. Those who expect to hire their grain harvested with a combine are willing to pay a higher rate in order to have the work done early and so reduce the risk of loss from the shattering, lodging, or bleaching of the grain. Later in the season, as more operators finish their own acreage, competition for cutting may reduce the rate. An operator who wishes to contract a large acreage for his machine may charge less than the customary rate if the cutting may be postponed until the latter part of the season.

Table 28 shows the owned acreage and the custom acreage cut by machines of different sizes. For many of the groups the amount of custom work is almost as great as the cutting on home farms. Except for differences in charges for cutting, the returns per acre for custom work are nearly the same, for all groups of machines. The net returns (exclusive of fixed charges, depreciation, and interest and repairs) would be approximately $2 per acre from cutting at the rate of $3 per acre. This would represent the expected return to the combine owner after deducting costs of labor, fuel, and lubricants. Many farmers do much of the work themselves, and are interested primarily in the return to themselves for the use of the combine and tractor. With no charge for labor the returns would be approximately $2.50 per acre.

TABLE 28.—*Custom work done by combine owners in addition to cutting their own crops*

Type of combine	Width of cut (feet)	Number of combines used for custom work	Acres, own crop	Acres, custom cutting	Charges per acre for cutting	Total receipts	Total expenses [1]	Returns: Combine [2] Total	Returns: Combine [2] Per acre	Returns: Combine and labor [3] Total	Returns: Combine and labor [3] Per acre
Tractor-drawn with power take-off	8	12	200	128	$2.47	$317	$93	$224	$1.75	$285	$2.23
	10	10	202	104	3.32	546	117	420	2.61	501	3.04
Tractor-drawn with auxiliary engine	12	23	223	201	2.78	558	129	420	2.13	500	2.48
	15	30	294	280	2.90	855	208	647	2.24	744	2.67
	16	79	306	324	3.02	978	195	783	2.42	880	2.72
	20	3	637	363	2.80	1,052	254	798	2.20	941	2.59

[1] "Expenses" include charges for labor, fuel, oil, and grease. No other charges are included.
[2] Total returns to combine is the profit for use of combine and tractor with cost of labor, fuel, and lubricants deducted, but with no charge made for depreciation and repairs.
[3] Return to combine and labor is the profit for operating a combine and tractor with charges made for fuel and lubricants, but with no deduction made for labor, depreciation, or repairs.

Whether this return would increase the net earnings of the farmer would depend upon the value of his labor in doing other work on the farm, or upon the cost of hiring labor to perform the needed work in his absence. It might be more profitable for the farmer to allow the machine to be idle and to use his time to prepare his land for the succeeding crops.

The possibility of doing cutting for others may enable a farmer who has a small grain acreage to own and operate profitably a combine for his own grain because the saving in his own harvest bill is supplemented by profit from outside work.

With an increase in the number of combines in a locality, and resulting competition among combine owners, the rates for cutting may be reduced until the margin in custom cutting is decreased. Those in the Great Plains who are considering the purchase of a combine with the expectation of doing custom work should consider a possible decrease in the rate of pay for cutting and a smaller acreage to cut each year.

MINIMUM ACREAGE ON WHICH A COMBINE WOULD REDUCE HARVESTING COSTS

Many of the combine operators purchased their machines for use primarily on the home acreage, whereas others anticipated additional work for neighbors as a means of partially paying for their investment. Although the average acres cut per year (fig. 4) show that the larger machines were used on the larger acreages, there is a wide range in acres cut with each size of machine as indicated in Table 8, due chiefly to the influence of custom cutting.

The minimum acreage for which a combine will be profitable is determined largely by the cost of other possible methods of harvesting. With a combine, the acre cost will be less for a large than for a small acreage, and the profitable minimum acreage will be set at a point below which some other method will prove cheaper. The actual cost of the harvesting and threshing operations should be supplemented by a consideration of the probable effect of each method on the labor program of the farm, the effect on following crops, and the effect on the condition and value of the grain threshed.

In a locality where binders are used in preference to headers, an operator may find his harvest costs decreased by a 10-foot combine if he has 60 acres or more of grain to cut. Based on the cost figures used in constructing Figure 8, A, his acre-cost of harvesting would be approximately $4.60. In the Great Plains region custom work was being done for $3 per acre at the time of this study and, based upon present combine operating costs, an operator could hire his cutting more profitably at that rate than purchase his own combine, unless he has at least 125 acres. With a 15-foot machine, his own acreage should be at least 100 acres before the costs would be less than harvesting with a binder, and he should have 200 acres to cut before his cost would be less than the cost of hiring the grain cut with a combine. The profitable minimum acreage, in cases in which heading is the alternative, would be somewhat greater than where a binder is used.

Table 29 shows the average of estimates made by farmers as to the minimum acreage for which they would own a combine. The average of the estimates ranged from 127 acres for the 8-foot combine to 400 acres for the 20-foot machine. The minimum for 10-foot combines was estimated at 196 acres, and the minimum for the 15-foot machine averaged 276 acres.

TABLE 29.—*Owners' estimates of minimum acreage for which a combine is profitable*

Type of combine	Width of cut	Number reporting	Average minimum
	Feet		*Acres*
Tractor drawn with power take-off	8	24	127
	10	10	196
	12	47	209
Tractor drawn with auxiliary engine	15	46	276
	16	82	290
	20	3	400
Horse drawn	12	3	158
	15	3	250
	16	2	400
All farms		220	248

In most cases the owners who made these estimates were considering the header as the alternative harvesting machine, and they considered factors other than the difference in cost of harvesting by combines and by other methods.

In cases in which the combine was used for custom work, the acreage of owned grain necessary for profitable operation of the combine would be still smaller than either the estimate of the operators or the computed figure.

HARVESTING AND THRESHING LOSSES

HARVESTING LOSSES

Losses of grain resulting from the different methods of harvesting were determined in Oklahoma, Kansas, Nebraska, and Montana. The actual losses were determined by counting the heads left on 12 measured plats, selected at random, one-fourth square rod in area, in each of the harvested fields.

Loss counts were taken after threshing on some fields that had been cut with binders. The heads left in the spaces between shock rows and those left in four or more shock bottoms were counted. The average distance between shocks was determined by measuring the area occupied by 10 shock rows, and the space occupied by 10 shocks in a row. From these figures it was possible to compute the loss in terms of heads per square rod.

A head sample was cut from each combine-harvested field studied, and from a number of bound and headed fields. The head samples were obtained by cutting all the heads from twenty-four 4-foot lengths of drill rows taken at random in the field. Later the heads were counted and threshed, and the grain was weighed. From these data it was possible to calculate a yield per acre as well as the average weight of grain per head.

By combining the data on losses and the yield figures it was possible to calculate the percentage of the total yield of grain which was left in the field. The average total and percentage losses of grain from the headed and bound fields, from which head samples were not taken, were calculated by using the average yield per acre and size of head obtained from the samples from the combined fields in the same locality.

The average losses sustained in five districts in harvesting 259 fields with combines, 59 fields with headers, and 34 fields with binders are shown in Table 30. The figures given are the average numbers of heads lost per square rod. The heads listed as "cut and dropped on ground" were loose, as they had been cut off by the machine. Those listed as "not cut because on short and lodged stalks" were not cut off but had been passed over by the harvesting machine. Those listed as "not cut because of faulty operation" represent arbitrary estimates based on some preliminary counts and are a measure of the number of uncut spots in the field. These losses varied from zero to as much as five heads per square rod in some fields, depending upon the driver's skill in guiding the tractor. A few of the heads on the ground had been cut off by grasshoppers before harvest.

TABLE 30.—*Average harvesting losses in cutting wheat with combines, headers, and binders in five districts in the Great Plains in 1926*

District	Method of harvesting	Number of machines	Heads of wheat lost per square rod: Cut and dropped on ground: Shock rows	Heads of wheat lost per square rod: Cut and dropped on ground: Total	Heads of wheat lost per square rod: Not cut because—: On short or lodged stalks	Heads of wheat lost per square rod: Not cut because—: Of faulty operations	Heads of wheat lost per square rod: Total	Average weight of grain per head [1]	Grain lost per acre		Yield per acre [1]	Percentage of grain lost [2]
								Grams	*Pounds*	*Bushels*	*Bushels*	
Winter wheat:												
Alfalfa County, Okla.	Combine	42	----------	56	23	2	81	0.50	14.50	0.24	26.5	0.91
	Header	18	----------	102	21	2	125	.50	22.05	.37	26.5	1.40
	Binder	13	210	285	5	2	292	.50	51.50	.86	26.5	3.28
Ottawa County, Kans.	Combine	28	----------	111	36	2	149	.29	16.29	.27	10.5	2.50
	Header	11	----------	147	37	1	185	.29	20.23	.34	10.5	3.10
	Binder [3]	5	32	257	15	1	273	.29	29.85	.50	10.5	4.58
Perkins County, Nebr.	Combine	88	----------	117	81	2	200	.48	33.48	.56	19.0	3.50
	Header	10	----------	149	53	2	204	.48	34.15	.57	19.0	3.57
Judith Basin and Fergus Counties, Mont.	Combine	32	----------	67	50	1	118	.87	34.85	.58	24.8	2.58
	Header	2	----------	145	22	0	167	.87	49.74	.83	24.8	3.68
	Binder	1	401	566	12	0	578	.87	172.16	2.87	24.8	12.75
Spring wheat:												
Judith Basin and Fergus Counties, Mont.	Combine	59	----------	86	27	0	113	.78	31.04	.52	35.9	2.23
	Header	5	----------	151	20	0	171	.78	46.97	.78	35.9	3.37
	Binder	15	130	231	5	0	236	.78	64.83	1.08	35.9	4.66
Hill County, Mont. [4]	Combine	10	----------	125	105	0	230	.71	58.26	.97	9.6	9.92
	Header	13	----------	152	51	0	203	.60	45.88	.76	9.0	8.34
	Binder	2	----------	286	36	0	322	.66	72.15	1.20	8.3	16.22

[1] Figures are assumed to be the same for each method of harvesting, except in Hill County, Mont.
[2] Percentages indicate actual and not computed losses.
[3] Fields raked after shocks were removed.
[4] Loss data only obtained on machines in this county.

The variation in losses from harvesting winter wheat with combines is shown in Table 31.

TABLE 31.—*Losses by percentage classes, by States, by 190 combines harvesting winter wheat*

Percentage of loss	Number of combines in—				
	Oklahoma	Kansas	Nebraska	Montana	All States
0 to 0.9	29	2	6	4	41
1 to 1.9	11	11	29	14	65
2 to 2.9	2	8	14	7	31
3 to 3.9		4	14	2	20
4 to 4.9			7	2	9
5 to 5.9		2	5	1	8
6 to 6.9			5		5
7 to 7.9			4		4
Over 8		1	4	2	7
Total	42	28	88	32	190

In 41 of the 190 fields of winter wheat cut with the combine the loss was less than 1 per cent, in 106 fields the loss was less than 2 per cent, and in 137 fields it was less than 3 per cent. Losses greater than 3 per cent occurred in uneven or partly lodged grain, on rough land, when poor machines were used, when operators were careless, and in very windy weather. The losses in the district in Oklahoma, as shown in Table 32, were less than in the other districts because of uniform crop development there and the favorable harvesting season. The weighted average loss in harvesting winter wheat with combines was 2.63 per cent. Losses in the use of headers in the same districts averaged 3.27 per cent. Losses in the use of the binder, as determined in two districts, were calculated as 6.06 per cent for conditions that were the same as those for which the above average losses for the combine and header were determined. These average percentage losses are based on an average yield of 20.4 bushels per acre. The average total losses as computed would be 32 pounds per acre for combines, 40 pounds for headers, and 74 pounds for binders.

TABLE 32.—*Average losses from using combines, headers, and binders for harvesting winter wheat*

Machine used	Number of machines	Average per cent lost				
		Oklahoma	Kansas	Nebraska	Montana	All States
Combine	190	0.91	2.50	3.50	2.58	2.63
Header	41	1.40	3.10	3.57	3.68	3.27
Binder	18	3.28	4.58			6.06

The loss figures do not include any losses around the stacks and threshing machines, incident to threshing headed and bound wheat, which are of considerable importance. Neither do they include losses by machines which were practically worn out or which were cutting in fields that showed severe hail losses or appreciable lodging. One old combine in Montana was losing 28 per cent of the total crop, and some fields which had suffered from hailstorms showed losses of 12 per cent. Determinations of shattering losses were not made because no such losses were observed in Oklahoma and Kansas and practically none in Nebraska and Montana.

The heads cut off and dropped on the ground were the greatest source of loss from the combine and from the header. A few wheat heads were broken off by hail or wind or were chewed off by insects before harvesting, but nearly all of the heads found on the ground were dropped in harvesting or hauling. In cutting with the combine some heads fell in front of the cutter bar instead of upon the canvas, others were thrown on the ground by the reel slats, and others were blown or jarred from the platform. Similar losses occurred when the header and binder were used. Additional losses where the header was used occurred when heads fell between the canvases, or between the elevating canvas and the header barge, or were blown, thrown or jarred off the barge in loading or before they reached the stack. Careless loading, careless driving of header barges, and high winds, were responsible for the greater losses in using the header than the combine. These were also the chief sources of loss from the header reported by Bracken in Utah.[10] Wheat usually was cut at a lower point when the header was used than when the combine was used, so that fewer heads were left by the header on short and lodged stalks, but the additional handling of the headed grain resulted in a higher total loss.

The counts shown for heads left "on short and lodged stalks" are less than the actual number of heads found, as an attempt was made to record the number of heads of average size. The heads on the ground and on the lodged stalks probably were representative of the size of the heads which were harvested. The heads on the short stalks were small, and the number actually found was recorded as the approximate number of heads of average size to which these small heads were equivalent.

The losses in binding include cutting losses mentioned for the combine, the loss between the canvases mentioned for the header, and, in addition, the heads dropped from the binding platform and the bundle carrier, the heads left where the bundles were dropped, the heads left in shock bottoms, and those dropped from the bundle wagons. The heads left in shock bottoms were the chief source of loss in bound, unraked fields. In the district in Kansas, the short crop was so poorly bound that nearly all of the shock rows were raked after the bundles were hauled to the thresher. Even after the raking the total losses exceeded 50 pounds of grain per acre.

The binder usually cuts the grain closer to the ground and leaves fewer heads on short and lodged stalks than do combines or headers. The losses sustained by the three harvesting methods are in the order of the number of times the crop is handled after cutting. Few heads which reach the canvas of the cutting platform of the combine ever are lost, whereas the heaviest losses in heading and binding occur after the heads have fallen on the canvas.

The harvesting loss sustained by many combine operators was less than 10 pounds of wheat per acre. The smallest harvesting loss found in harvesting winter wheat with the combine was 0.3 per cent,

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[10] BRACKEN, A. F. LOSSES IN HARVESTING AND THRESHING GRAIN. Jour. Amer. Soc. Agron. 17: 508-514. 1925.

in Oklahoma, and the highest was 15.4 per cent, in Nebraska. Effective harvesting with the combine therefore is possible, but the crop must be erect and of even height, the sickle must be kept lower than the heads on the short and leaning stalks, and the reel must be set to push the heads onto the platform but not to throw them into the air. The sickle and reel can not be adjusted to prevent appreciable losses if the crop is uneven in height. In this investigation the platform was found to be adjusted too much, rather than too little, on many combines that had an extra man to operate the heading device. Many heads were lost in the attempt to avoid cutting too much straw. When the reel was set far enough ahead and low enough down to lift up the heads on the leaning stalks some heads were thrown upward by the reel and did not reach the platform.

Harvesting losses showed little relation to the yield per acre for the different fields. There appeared to be an approximate minimum possible loss for most fields. The better the crop the more easily it could be handled within certain limits, unless the crop was uneven in height or was partly lodged.

FIG. 10.—Making a test on a moving combine to determine the quantity of grain being thrown over. The straw is caught on the canvas while a given quantity of grain is being threshed

Greater losses by all harvesting methods would have been indicated if counts had been made in lodged grain. Combine owners reported, almost without exception, that they were able to harvest lodged grain as well or better with the combine than with the binder. Lodged grain, therefore, would have shown the combine at an even greater advantage.

THRESHING LOSSES

Tests were made on 33 combines and 9 stationary separators in an attempt to determine which did the best threshing. These tests were made by catching the straw and chaff from the machines on a canvas sheet while 2½ bushels of grain were being threshed. (Fig. 10.) The grain then was separated from the straw and chaff on the sheet by winnowing until the wheat that was practically clean could be measured or weighed. Most of the loss estimates do not include the wheat contained in the few heads which passed through the machine, but only the grain which was blown or thrown out with the straw. Any good separator or combine, when properly adjusted, will thresh all the grain from dry wheat heads, and nearly all machines were doing so.

A few machines were tested while threshing damp wheat. They were leaving some grain in the heads, and some allowance was made for these losses. The tests were made on separators while the machines were fed normally and on the combines while they were being pulled at the usual speed. The percentage losses are shown in Table 33.

TABLE 33.—*Threshing losses determined on combines and separators in 1926, by percentage classes and by States*

Percentage threshing loss	State, type, and number of machine									
	Oklahoma		Kansas		Nebraska		Montana		Total	
	Combines	Separators	Combines	Separators	Combines	Separators	Combines	Separators	Combines	Separators
0 to 0.9	1		1	2	3		8	3	13	5
1 to 1.9	1		3	2	3		1	1	8	3
2 to 2.9	1		1		1		2		5	
3 to 3.9	1			1	1		1		3	1
4 to 4.9					2				2	
5 to 5.9	1								1	
6 to 6.9					1				1	
Total	5	0	5	5	11	0	12	4	33	9

Thirteen of the 33 combines were losing less than 1 per cent of the grain being threshed, and 21 were losing less than 2 per cent in this way. All losses of 2 per cent and over were probably due to poor adjustment or to overloading of the thresher. Eight of the nine separators tested were losing less than 2 per cent. The operator of the one separator that was losing more than 3 per cent was aware of having insufficient power for efficient operation, but a larger tractor was not available for the machine. The average loss with combines was 1.9 per cent and with separators was 1.2 per cent, as calculated from the mean values of the loss classes in Table 33.

The results show that, whereas, on the average, the combines were wasting more grain than were the separators, many of the combines were operated with no greater waste. One combine in Montana was losing practically no grain. The more uniform feeding of the combine partly offsets the generally more skillful operation of the separators. Most of the combine operators were not familiar with necessary adjustments, because of their inexperience. In heavy wheat, at the usual rate of travel, the combine occasionally lacked the capacity to thresh the wheat without some loss in separating it from the straw.

Some of the operators adjusted their machines after the tests were made and thereby reduced their losses materially.

The losses occurring in the separators tested, omitting the one machine which did not have sufficient power, were about the same as those observed by Blauser [11] in Illinois and Bracken [12] in Utah. The

[11] BLAUSER, I. P., REDUCING GRAIN LOSSES IN THRESHING. Ill. Agr. Expt. Sta. Circ. 311, 20 p., illus. 1926.
[12] BRACKEN, A. F., Op. cit.

threshing losses in this study when combines were used were higher than were those shown by Bracken.

The average threshing loss with combines and separators, plus the average harvesting loss when harvesting winter wheat, gives a total loss of 4.53 per cent for combines, 4.47 per cent for headers, and 7.26 per cent for binders. These losses are shown graphically in Figure 11.

The percentage losses for binders and headers do not include the appreciable waste around header stacks and around stationary separators. Preliminary tests indicate that several bushels of grain may be left around each separator setting, especially where gravelly soil prevents a careful cleaning-up operation.

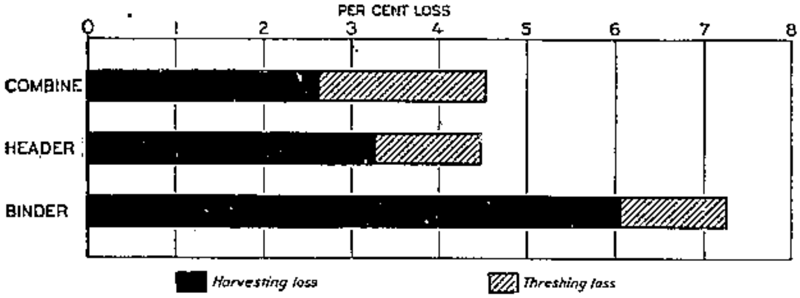

FIG. 11.—Average losses in harvesting and threshing winter wheat by different methods

LOSSES FROM SHATTERING AND LODGING

It has been the popular belief that only certain varieties of wheat are suited to harvesting with a combine. In the Pacific Coast States the most productive varieties are grown in the different localities, almost regardless of the relative shattering of these varieties. Goldcoin (Forty Fold) wheat is grown on rather large acreages in several localities and is harvested chiefly with combines, notwithstanding its susceptibility to shattering. The strain tested at Davis, Calif., in 1924, did not shatter in that year, as indicated in Table 34.

Shattering percentages of nearly all commercial North American varieties of wheat were recorded by V. H. Florell, of the office of cereal crops and diseases, Bureau of Plant Industry, at Davis, Calif., in 1924. Observations on shattering were made about 10 days after the grain was fully ripe. Much of the shattering was due to extremely high winds which occur in the locality where the observations were made. Observations made over a series of years and in more favorable localities probably would show a lower loss for some of the varieties.

The data for the more important varieties show that the hard red winter, club, and durum wheats do not shatter readily. Only two hard red spring varieties, Prelude and Ruby, showed important shattering losses. Quality and Bunyip showed the greatest shattering among the white wheats. Bunyip has been harvested successfully with the combine in the San Joaquin Valley of California. Quality usually can not be harvested with the combine without incurring a decided loss from shattering.

TABLE 34.—*Percentage of shattering at Davis, Calif., in 1924 among the leading North American varieties of wheat about 10 days after maturity*

Class and variety	Per cent of shattering	Class and variety	Per cent of shattering
Soft red winter:		White:	
Fultzo-Mediterranean	95	Quality	95
Goens	95	Bunyip	90
Rudy	95	Federation	25
Trumbull	95	Pacific Bluestem	6
Flint	80	Sonora	5
Gipsy	80	Baart	0
Leap	80	Hard Federation	0
Dawson	60	Surprise	0
Gladden	50	Hard red spring:	
Honor	50	Prelude	100
Purplestraw	30	Ruby	50
Diehl Mediterranean	25	Red Bobs	15
Rice	20	Marquis	0
Fulcaster	15	Red Fife	0
Fultz	10	Kota	0
Grandprize	10	Hard red winter:	
Mealy	5	Blackhull	0
Ashland	0	Kanred	0
China	0	Montana No. 36	0
Currell	0	Turkey	0
Goldcoin	0	Club:	
Harvest Queen	0	Big Club	0
Jones Fife	0	Hybrid 128	0
Mediterranean	0	Jenkin	0
Nigger	0	Little Club	0
Poole	0	Durum:	
Prosperity	0	Acme	0
Red May	0	Kubanka	0
Red Rock	0	Mindum	0
Red Wave	0	Peliss	0
Rupert	0		

The wheats grown in the Great Plains consist of the hard red winter, hard red spring, and durum varieties. The principal variety of hard red spring wheat is Marquis. These same wheats are grown in Minnesota, northern Iowa, Wisconsin, and the northern half of Illinois. These varieties will not shatter enough to prevent harvesting with combines. East and south of the States mentioned, soft red winter wheats are grown largely. The varieties of soft red winter wheat which shattered more than 30 per cent under the dry, windy conditions at Davis, Calif., might suffer losses in the East when left standing for a considerable period after maturity. Fultzo-Mediterranean, Goens, Rudy, Trumbull, Flint, Gipsy, and Leap showed the heaviest shattering losses among the important soft red winter wheats.

Many varieties of wheat lodge badly when grown on wet or rich soils. Wheats which do not lodge are preferable for any method of harvesting. As the combine harvests lodged grain as well as binders and headers do, the introduction of the combine into a region would not necessitate a change to stiff-strawed wheat varieties. In prolonged wet weather, following lodging, some of the grain may be spoiled by contact with the wet soil and the straw also tends to decay. The acreage which a combine could cut without loss, following such conditions, would be limited.

CLIMATIC FACTORS AFFECTING THE USE OF COMBINES

Weather at harvest time is the chief factor determining the acreage per machine that can be harvested safely during a given period. The average annual and summer monthly rainfall at several stations in the Great Plains and humid eastern regions are shown in Table 35.

TABLE 35.—*Average annual and monthly precipitation at 14 stations in wheat-growing sections of the Great Plains and humid eastern regions of the United States*

Station	Record years	Precipitation					
		Annual	June	July	August	September	October
	Number	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Canadian, Tex	17	23.48	3.81	2.19	2.38	2.52	2.10
Alva, Okla	26	28.10	3.64	2.75	3.88	3.18	2.43
Minneapolis, Kans	35	25.01	3.88	3.03	3.02	2.69	1.98
Madrid, Nebr	32	18.23	3.40	2.50	2.40	1.20	1.12
Lewistown, Mont	28	19.80	3.62	2.38	1.47	1.80	1.30
Amenia, N. Dak	30	20.10	3.87	3.01	2.72	1.97	1.29
Watertown, S. Dak	32	21.06	3.02	2.99	3.02	2.02	1.39
St. Paul, Minn	55	28.68	4.41	3.40	3.46	3.42	2.34
Des Moines, Iowa	47	32.25	4.60	3.61	3.54	3.53	2.56
Kansas City, Mo	37	37.37	4.66	4.84	4.75	3.78	2.21
Urbana, Ill	23	33.32	3.10	3.27	3.15	2.80	2.20
Indianapolis, Ind	54	41.48	4.31	4.13	3.33	3.05	2.70
Columbus, Ohio	47	38.02	3.49	3.65	3.22	2.52	2.35
Harrisburg, Pa	58	37.27	3.55	3.87	4.25	2.85	2.95

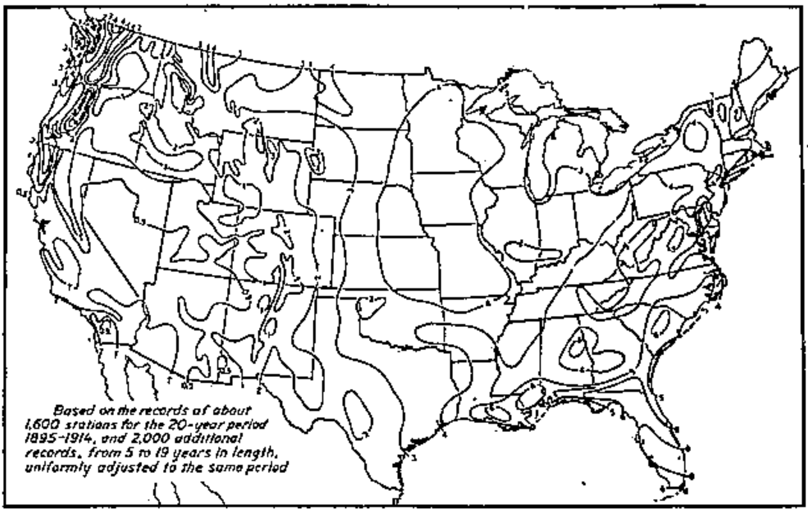

FIG. 12.—AVERAGE JUNE PRECIPITATION, IN INCHES

The most noteworthy feature of the geographic distribution of the June rainfall is the relatively large amount received between the eastern foothills of the Rocky Mountains and the Mississippi River as compared with the annual amount in that region. In most of this area the June rainfall ranges from 3 to 5 inches, being 15 to 20 per cent of the annual amount. East of the Mississippi River the rainfall for the month ranges from about 3 inches along the Canadian border to from 6 to 8 inches near the Gulf coast.

The average rainfall during June, July, and August, in the United States, is shown in Figures 12, 13, and 14. The number and percentage of days during the harvest season on which rains of 0.1 inch or more occurred, during a 13-year period, are shown for several stations in Table 36. The percentage of rainy days was lowest in Montana, was less in Illinois, Iowa, and North Dakota than in Oklahoma, and was highest in Pennsylvania.

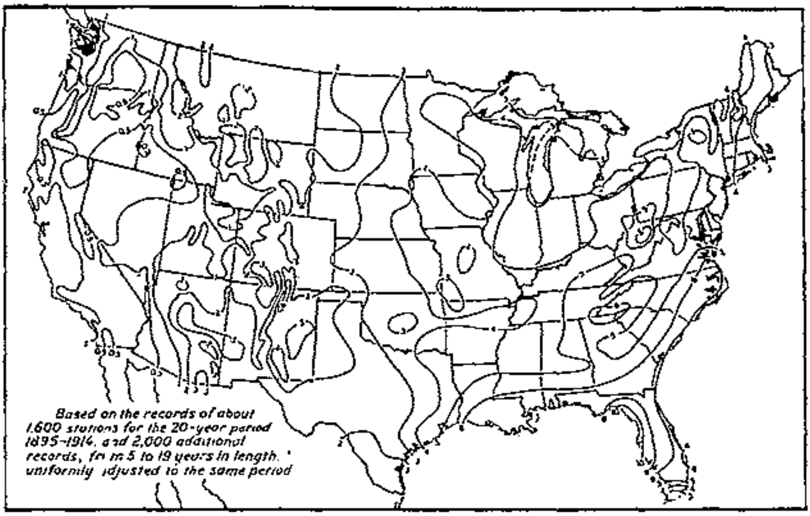

FIG. 13.—AVERAGE JULY PRECIPITATION, IN INCHES

July rainfall results largely from local thunderstorms, which are more numerous in this than in any other month. Over much of the Great Plains the average July rainfall is appreciably less than for June, but to the eastward there is in general an increase in amount over the preceding month. In the southwestern region, including western Texas, New Mexico, and most of Arizona, July is usually the wettest month of the year.

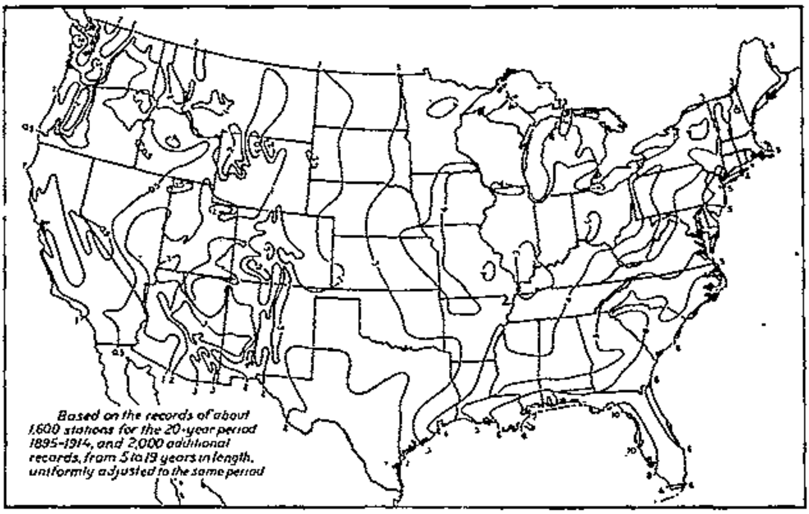

FIG. 14.—AVERAGE AUGUST PRECIPITATION, IN INCHES

In August, as in July, rainfall is largely the result of thunderstorms. In general the geographic distribution of precipitation for August does not differ materially from that of July, although in portions of the Plain States the amounts are usually somewhat less in August.

TABLE 36.—*Duration of harvest season and average number and percentage of rainy days at nine stations in the Great Plains and humid eastern regions of the United States during the 13 years, 1914 to 1926, inclusive*

Station	Duration of harvest season, inclusive dates	Harvest season (days)	Days having 0.1 inch or more of rainfall	
			Number	Percentage of harvest season
Alva, Okla	June 15 to July 15	31	5.6	18.0
Minneapolis, Kans	June 20 to July 31	42	7.3	17.4
Madrid, Nebr	July 15 to Aug. 15	32	5.6	17.5
Amenia, N. Dak	Aug. 1 to Aug. 31	31	5.0	16.2
Lewistown, Mont	Aug. 1 to Sept. 30	61	7.2	11.9
Des Moines, Iowa	July 1 to July 31	31	5.6	18.1
Urbana, Ill	do	31	3.8	12.3
Columbus, Ohio	do	31	6.7	21.6
Harrisburg, Pa	do	31	8.0	25.8

The days on which rains of 0.1 inch or more occurred during the harvest month, at six stations, during a 13-year period, are shown in Figure 15.

Harvesting with the combine has been successfully practiced in the vicinity of Alva, Okla., since 1918. The graph shows that periods of wet weather which would have delayed harvesting considerably occurred at Alva in 1915 and 1921. In the other years the rainy periods were of short duration or were so intermittent that there was no serious interference with harvesting. The graph shows the rain would not have interfered seriously with harvesting in the vicinities of Amenia, N. Dak., Des Moines, Iowa, and Urbana, Ill., but that rains were somewhat more frequent at Columbus, Ohio, and Harrisburg, Pa. At these points rain would have interfered more seriously with harvesting with the combine than at Alva, Okla. At both points, however, harvesting probably could have been done on at least 12 and perhaps 15 days during the month of July each year.

The number of rainy days is not an exact measure of the delays caused in harvesting. A heavy rain causes only a slightly longer delay in harvesting with the combine than does a light rain, because the standing wheat absorbs only a limited quantity of moisture, and it dries rather quickly as soon as the weather clears. A rain of 2 inches or more usually delays shock threshing as long as it delays harvesting with the combine. A rain that is followed by cloudy weather may delay harvest several days, whereas a shower that is followed by a clear sky may cause little delay. Rains that occur in late afternoon may not delay the harvest for more than a few hours.

Evaporation is greater and humidity is less in the Great Plains region than in the Corn Belt, or in the Eastern States. The average relative humidity at 2 p. m. during July is shown graphically for the United States in Figure 16.

It can be seen that the humidity is less in the Great Plains region than in most of the sections east of that region. This would indicate that there would be more delay in harvesting after rains in the Eastern States than is the case in the Great Plains States where combines are now used. Figure 17 presents the comparable average relative humidity at 8 a. m. and shows that the Great Plains and Corn Belt States are very similar in humidity conditions in the early morning. This would indicate that delays in starting combines in the morning would be but little greater in the East than in the Great Plains region.

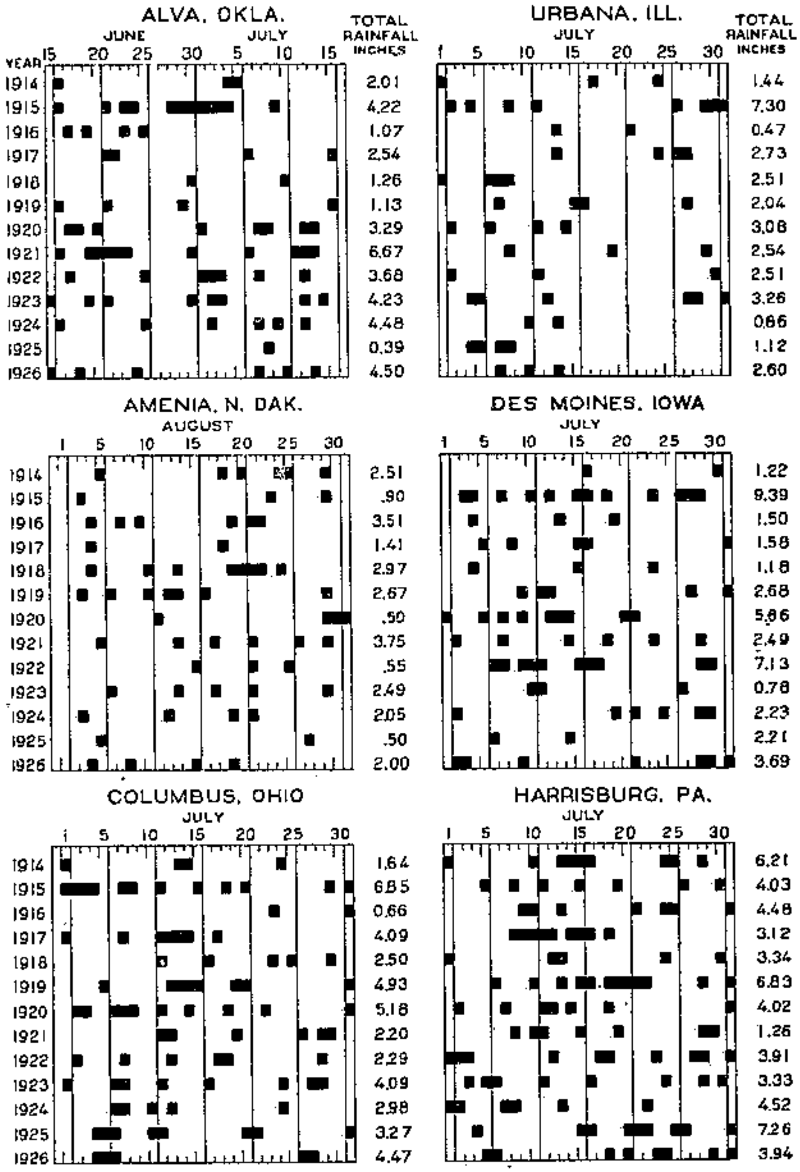

FIG. 15.—Days on which rains of 0.1 inch or more occurred during the harvest month at six stations during 13 years, 1914 to 1926, inclusive

The average number of days on which hail occurs during the frostless season in the United States is shown graphically in Figure 18. The area of greatest hail occurrence is in the Rocky Mountain region where little wheat is grown. The belt of second greatest hail frequency contains important wheat-growing sections of Colorado, Nebraska, and Kansas, and most of the State of Iowa. Hail is a

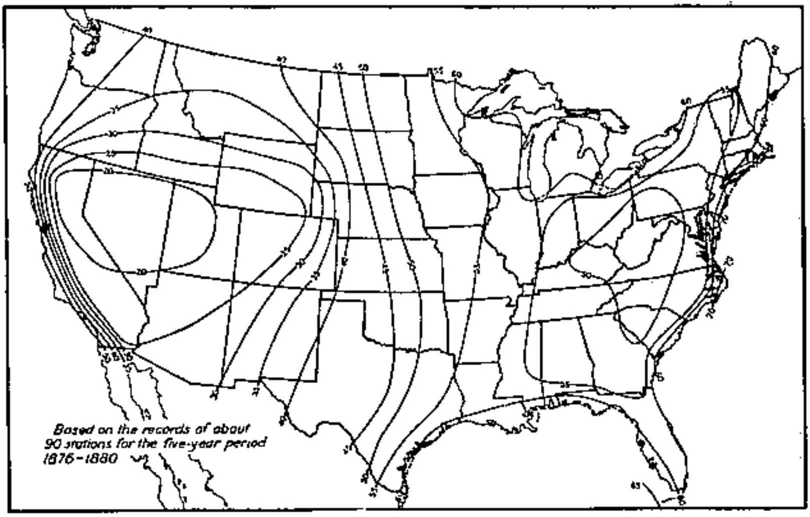

FIG. 16.—Average relative humidity, 2 p. m., local time, July

much greater risk to the wheat crop in the portion of the Great Plains region where combines are now used extensively than in those sections where few combines are used.

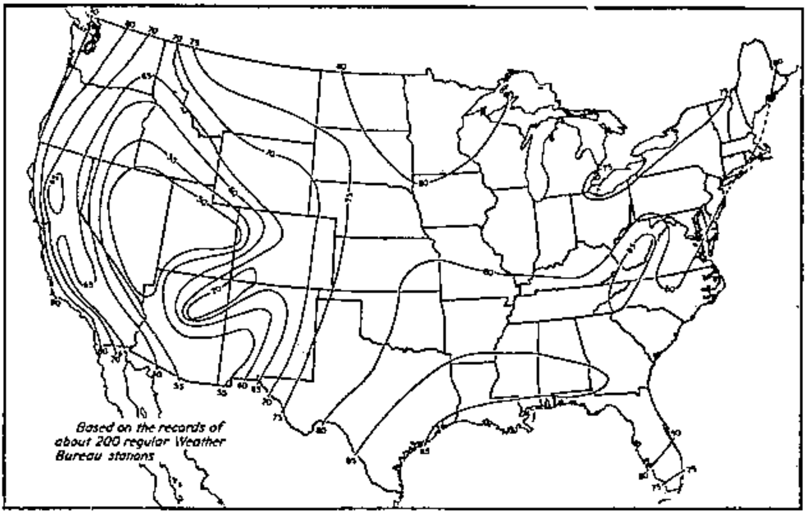

FIG. 17.—Average relative humidity, 8 a. m., seventy-fifth meridian time, July

Many farmers in the Great Plains carried hail insurance on all grain crops. Some farmers feel that there is an added risk when grain is harvested with a combine since the crop must stand from 7 to 10 days longer than when cut with a binder.

High and prolonged winds, coming when the grain is ripe and dry, sometimes cause heavy shattering losses.

Intermittent rains occurring at harvest time may cause a loss of valuable time, the amount depending upon the duration and frequency of the rains and the stage of ripeness of the crop.

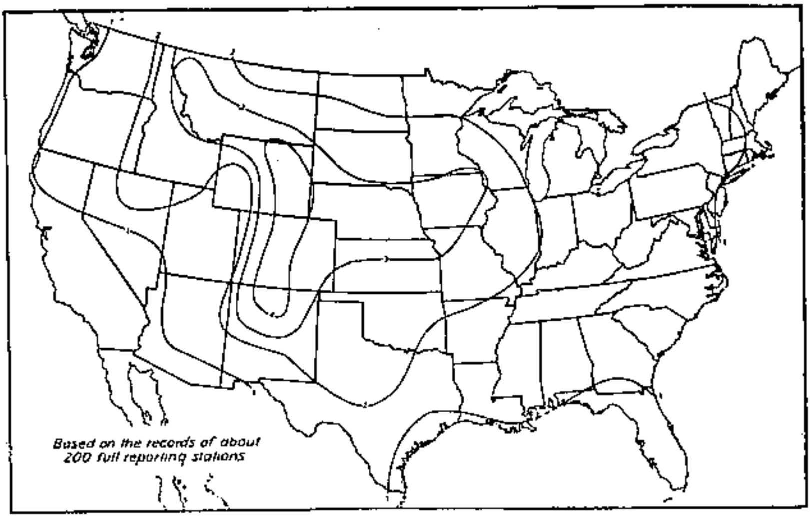

FIG. 18.—Average number of days with hail during the frostless season, 20-year period, 1895–1914, inclusive

MAXIMUM ACREAGE WHICH CAN BE CUT BY A COMBINE

The maximum acreage which can be cut by a combine is dependent upon the size of the machine and the length of the harvest season. In the Great Plains, where the hard winter wheat will stand for a considerable time without deteriorating in quality, the maximum acreage which a combine can cut is very high; many 16-foot machines cut more than 1,000 acres. A 15-foot machine, cutting an average of 35 acres per day, would cut 525 acres in 15 cutting days, or 700 acres in 20 days. The largest acreage reported cut by a 15-foot machine was 1,100 acres. A 10-foot machine cutting an average of 25 acres per day would harvest 375 acres in 15 days or 500 acres in 20 days of cutting. The largest acreage reported as cut by a 10-foot machine was 640 acres.

Owners of 10-foot combines cut, on the average, 25 acres per day, and the 15-foot combines averaged 35 acres per day. At this rate, with a harvest season lasting 15 days, the 10-foot machine would harvest 375 acres and a 15-foot machine, 525 acres. For all 10-foot machines the average cut during the season was 457 acres; the 15-foot machines averaged 574 acres; and the 16-foot machines, 682 acres. The difference in total acres cut was due principally to variations in the length of the harvest season. Most of the machines in all localities were cutting sufficient acreage to reduce the cost per acre to a comparatively low figure. Many of the operators considered that the investment would be warranted with even a smaller acreage than they were cutting. A great many considered that the combine was able to handle a larger acreage than they were cutting.

TABLE 37.—*Owners' estimates of maximum acreages which can be cut satisfactorily with a combine*

Type of combine	Width of cut (feet)	Combines harvesting only winter or spring wheat		Combines harvesting both winter and spring wheat	
		Number reported	Acres harvested	Number reported	Acres harvested
Tractor drawn, with power take-off	8	24	258	1	350
	10	10	427	3	450
Tractor-drawn, with auxiliary engine	12	43	400	9	800
	15	44	648	3	1,100
	16	81	708	9	1,078
	20	3	850	2	1,125
Horse drawn	12	3	450		
	15	3	533		
	16	2	675		
All farms		213	565	27	894

As shown in Table 37, the maximum acreage estimated by farmers is nearly the same as the average number of acres cut annually by machines of the same size. The combines generally were being used almost to their full capacity, and for machines of each size the number of acres cut annually is nearly the same as the estimated maximum acres. Where both spring and winter wheat are harvested, the acreage cut by each machine is increased, and for some groups the average number of acres cut exceeds the number of acres which the operators considered the maximum capacity of the machine.

QUALITY AND CONDITION OF WHEAT HARVESTED WITH COMBINES

Quality and condition of wheat at the time of marketing determine the grade and thus influence, to a considerable extent, the price the grower receives for his product. Both of these important factors are influenced by conditions at harvest time, such as ripeness, prevalence of weeds, and moisture. All of these conditions can be controlled, in some measure, by the operator.

Fear that grain harvested with the combine will not keep in storage has in the past caused some buyers of wheat at both local elevators and at terminal markets to be prejudiced against such grain. There is no appreciable difference, however, in the quality of wheat that is harvested and threshed with a combine, and the quality of wheat that is harvested with a binder or header and threshed by a stationary threshing machine, when the conditions under which each is used are similar.

Many combine operators, especially those who are operating a machine for the first season, have a tendency to begin harvesting before the wheat is fully ripe for harvesting. If hauled directly to the elevator, this wheat is in poor condition because of high moisture content. If a field ripens unevenly, the resulting wheat will be in poor condition, because of the mixture of green kernels. Again, weeds, particularly Russian thistles and sunflowers, affect the keeping quality of wheat by increasing the moisture content of the threshed grain. Cleaner fields and the use of cleaner seed are two ways of reducing the number of weeds at harvest time.

Experienced combine operators do not start their machines until conditions are right for harvesting. As a result, their wheat is of a quality and in a condition equal to that of any wheat grown under like conditions that is harvested and threshed by other machines. Car-lot shipments of wheat made by some of these men grade as high at the terminals as does wheat that is threshed from the shock or stack.

MOISTURE CONTENT

Moisture content is usually considered an important factor affecting the quality and condition of wheat, and it is one of the important factors in the official grain standards. Grain which has a high moisture content can not be milled satisfactorily and does not keep in good condition while stored.

During recent years much wheat has been of the lower grade because of its moisture content. This has been true whether the wheat was threshed by the combine or by the stationary thresher. Since the introduction of the combine into the Great Plains States most of the tough or damp wheat that reaches the terminal markets is suspected of having been harvested with a combine. As a matter of fact, wheat that is threshed from shocks or stacks, either before it has time to cure or too soon after rains, is damp or tough, just as it would be if threshed when in a similar condition, by a combine.

If the wheat is allowed to stand long enough to dry before harvesting with a combine, the result is satisfactory. Most of the wheat harvested with combines in 1926 was accepted at elevators at the same price as was other wheat of equal grade. During most of the harvest season of 1926, in the Great Plains, wheat harvested with combines had a relatively low moisture content and was in good condition.

In southern Kansas in 1923, samples of wheat collected from combines were found by the department to contain from 10.4 to 16.7 per cent of moisture, and those threshed from shock, 13 to 17 per cent. Wheat threshed from shocks near Delphos, Kans., on July 10, 1926, two days after a rain of about 2.5 inches, contained an average of 13.4 per cent moisture and that harvested with a combine on the same date contained 13.5 per cent. Thirty lots of wheat harvested with combines, June 22, 1926, around Cherokee and Burlington, Okla., contained from 11.2 to 14.8 per cent of moisture and had an average content of 13.2 per cent, and two lots threshed from shocks on the same date had 11.2 and 11.4 per cent. This wheat appeared to be dry and in good condition and weighed 60 to 63 pounds per bushel although it was not as dry as it had been a few days earlier. A rain occurred in this locality on the night of June 23, and on the following day eight lots of wheat harvested with combines contained 15.8 to 17.6 per cent of moisture, the average being 16.8 per cent. One lot, threshed from shocks on the same day, contained 13.8 per cent moisture. This wheat was too damp to thresh well. These results show that wheat will contain a high percentage of moisture either when harvested with combines or when threshed from shocks too soon after a rain.

Around Grant, Nebr., in 1926, wheat harvested with combines shortly after rains contained up to 18.6 per cent of moisture. Later the moisture content was as low as 10.4 per cent. One lot threshed from shocks contained only 9.4 per cent moisture. Sixteen carloads of wheat shipped from Grant during the early part of the marketing season of 1926 showed moisture contents ranging from 9.8 to 16.3 per cent on arrival at Omaha, Nebr. Most of this wheat was harvested with combines, but none of it had heated during shipment.

The moisture content of samples of wheat collected in Hill County and the Judith Basin district of Montana during the 1926 harvest season is shown in Table 38. In these districts a few individual lots of wheat harvested with combines ran considerably higher in moisture content than did any that were headed and threshed, but much of the wheat harvested with combines contained no more moisture than the headed wheat. The samples of wheat harvested with combines contained slightly more dockage than did the samples of the headed and threshed wheat. Much of this dockage consisted of Russian-thistle tips and other weeds which were too green and wet to be screened or blown out at the time the grain was harvested but which had dried enough to make the separation possible by the time the headed stacks were threshed.

TABLE 38.—*Moisture content of Montana wheat harvested by different methods*

District	Method of harvesting	Number of samples	Moisture content (per cent)		
			Maximum	Minimum	Average
Hill County	Combine	19	17.0	9.6	12.2
Do	Header	14	11.4	9.2	10.4
Judith Basin	Combine	29	20.4	10.0	11.4

TEST WEIGHT

Test weight is influenced by climatic conditions. It is usually highest when the grain ripens under favorable weather and the natural moisture content of the grain is down to about 11 to 14 per cent. If wheat is left standing after it reaches this stage, as is likely to be the case when the combine is to be used, and if rains raise its moisture content materially, the test weight is lowered. The test weight per bushel of a given lot of grain is an index to the quantity of flour that may be milled from such grain, and therefore is an important grading factor when the official grain standards are applied. Test weight per bushel should not be confused with legal bushel weight. Test weight is based on the weight of a given volume of wheat, whereas legal weight is based on weight only.

BLEACHING

Wheat that is left standing in the field after it is ripe has a tendency to bleach. In this bleaching process the natural luster is lost and the bran takes a whitish or washed-out appearance. This change takes place under any kind of weather conditions, but its extent depends somewhat upon the length of time it is exposed and the kind of weather it encounters.

In grading, bleached wheat is at a disadvantage when it is placed in the proper subclass under the official grain standards. The official standards provide three subclasses for hard red winter wheat and three for hard red spring wheat. These subclasses are based on the percentages of dark, hard, and vitreous kernels contained in a given lot of grain, and these percentages are considered indicative of quality. The higher the percentage of such kernels, the better the quality of the lot of grain. After grain is bleached there are no dark kernels, and it is extremely difficult to indentify the hard and vitreous ones.

UNEVEN RIPENING

Wheat from a field that apparently is dead ripe may show a high moisture content because of a mixture of green kernels in the grain. Ripening usually is fairly uniform within a field except in low wet spots or in spots where the stand is thin. The wet grain from these spots of green wheat is likely to cause heating in the threshed wheat. Some operators cut around the green spots and harvest them later if they are considered large enough to be worth the trouble. In cutting around spots there is always a loss of grain where the crop is crushed down, except when the small power-drive combine is used; it is mounted directly on the tractor with the sickle directly in front of the machine. Irregularity in the ripening of the crop and soft wet spots in the field are probably the two chief drawbacks to the use of combines in many fields.

WEEDS

Weeds were not a factor in the harvesting of wheat in the districts studied in Texas, Oklahoma, and Kansas. In Montana, however, and to some extent in Nebraska, considerable trouble was experienced with weeds.

Weeds interfere with the use of the combine only when they are high enough to be cut off by the sickle. A few operators cut the wheat rather high in order to avoid cutting weeds, and in doing so they missed some of the wheat heads. A collection of a few large, mature Russian thistles (*Salsola pestifer*) can sometimes stop a combine reel. Ordinarily, only green weeds cause trouble. When chopped by the cylinder teeth, they frequently overload and choke the tailings return and the grain elevator on the combine, thus causing delays and an occasional breakage.

The chief objection to green weeds, however, is their effect on any wheat with which they become mixed in threshing. An experiment to determine the effect of green Russian-thistle tips on the moisture content of wheat was made in Montana in 1926. Ten per cent by weight of green Russian-thistle tips was added to each of two lots of wheat. The moisture determinations of the thistles were made in duplicate. The moisture content of the thistle tips, and of the clean wheat at various intervals after mixing, is shown in Table 39.

TABLE 39.—*Percentage of moisture in Russian-thistle tips and in clean wheat at various intervals after mixing*

Time	Lot 1		Lot 2	
	Tips	Wheat	Tips	Wheat
	Per cent	*Per cent*	*Per cent*	*Per cent*
At time of mixing	71.6	10.0	71.9	13.0
6 hours later	45.5	12.0	50.7	15.8
18 hours later	39.7	14.2	45.1	17.0
30 hours later	25.5	14.0	36.2	17.2
43 hours later	23.2	14.8	32.5	17.4

The thistle tips contained 71.6 per cent moisture at the time they were cut and mixed with lot 1. The moisture from the green tips was rapidly absorbed by the wheat, and the moisture content of the wheat increased from 10 per cent to 14.2 per cent in 18 hours. The thistle tips mixed with lot 2 contained 71.9 per cent moisture at the time of mixing with the grain and the moisture content of the wheat increased from 13 per cent to 17 per cent in 18 hours.

The proportion of green tips to wheat, as prepared for this experiment, is no greater than that found in much of the grain which is threshed during the latter part of the season in Montana. These results show that it may be dangerous to store wheat when harvested with green weeds, even though the wheat itself may be dry enough to store safely were it not for the presence of the weeds.

GRAIN STORAGE

Probably two-thirds or more of the wheat that is harvested with a combine is moved off the farm during harvest or soon thereafter. About 65 per cent of the farmers interviewed stored no wheat on their farms except an ample supply for seed. A few farmers store their entire wheat crop on the farm when they think it is in good condition. Others store only that portion of the crop which is harvested during dry weather, after the crop is fully ripe; they market promptly that which is harvested early in the season or before the grain is dry enough, after showers, to be stored safely. Some farmers who have a long haul to market and would require extra help to move the grain during harvest, pile it on the ground and haul after harvest. This enables them to use the regular crew for both harvesting and marketing the grain, which saves the expense of extra help, although it means additional handling of the grain.

With the increasing use of the combine and the movement of the crop from farm to market in a shorter period than formerly, local and terminal storage facilities have had difficulty in handling the greater volume, especially when a large part of such grain is unfit for storage. Local elevators often take some damp grain when enough dry grain is available to mix with it, but when too much damp grain is delivered they may refuse to accept it.

Moisture is the prime factor in determining the keeping quality of wheat. However, grain which is stored at a high temperature is more likely to go out of condition than is grain which has the same moisture content and is stored at a lower temperature. The physical condition of the grain, the humidity, the air temperature, and the nature and quantity of foreign material also affect the keeping quality of the grain. Such observations as have been made in the hard winter wheat district indicate that under normal conditions the storage risk is considered to be reduced to a safe point when the moisture content of the grain is not over 14 per cent.

Tough grain which is stored during hot summer weather is more likely to go out of condition than is similar grain if stored in cooler weather. The temperature of grain threshed on a very hot day and left standing in either a wagon or grain tank on a combine, exposed to the direct rays of the sun, will rise 5° or 10° above the temperature of the surrounding air. If such wheat is stored in a bin or a railroad car the probabilties are that it will not keep as well as if it had been cooled to the air temperature.

If grain is allowed to stand so that it will be in better condition for storage, rain or hail may cause a greater loss than would have been sustained by harvesting and marketing the greener grain. Weather conditions at harvesting and threshing time may run counter to the best storage condition of the grain so that farmers may have to choose between these hazards.

Terminal and local storage facilities are being taxed by the rapid increase in use of combines. Suitable storage for the threshed grain, or some practical method of drying the moist grain, is needed, unless harvesting can be delayed until the grain is dry. Commercial driers at terminal elevators are used to condition new wheat and wheat that is tough from recent rains, but because of the expensive equipment needed, such driers are practicable only in those places where large quantities of grain are to be handled. Country elevator operators run the grain from one bin to another so that the air passing through the stream of wheat can dry and cool it.

On the farm, where mechanical means for handling grain are not available, grain may be kept cool and well ventilated by equipping bins with ventilators to supply fresh air and to carry off excess moisture. This method will not insure wet grain from going out of condition, but it may prevent serious losses from molding or heated grain in cases in which the moisture content is not excessive.[13]

EFFECT OF THE COMBINE ON FARM ORGANIZATION

The use of the combine in the Great Plains region has not yet had a marked effect upon the farm organization. The same general type of farming has existed on most farms since the range was put into cultivation. Wheat is the main enterprise, and livestock is unimportant on most farms. With the reduction in harvesting costs made possible by the use of the combine some increase in the acreage of wheat on some of the farms may be expected.

The combines in the districts studied enabled the operators to harvest a larger acreage with a smaller labor force than they could have harvested by methods previously used. To take full advantage of the combine, the maximum acreage for an outfit of the size owned should be handled. It naturally follows that the wheat acreage per farm will tend to approach the acreage that can be handled with a single combine. This tendency to increase the wheat acreage may bring some marginal land now on farms into cultivation; or in districts where land is still in range it may result in a further breaking up of grassland. In sections like the one studied in Nebraska, where a choice exists between corn and wheat, wheat will probably replace corn on some of the poorer corn land.

The use of the combine may cause wheat to move farther into the semiarid sections now in pasture, on the one hand, and to replace other crops in the more humid sections of the wheat belt, on the other. An increase in size of farms and an increase in acreage of wheat per farm may be expected in those areas where the combine can be successfully used and where the farms are now too small to allow full utilization of one machine.

[13] Coleman, D. A., and Rothgeb, B. E. heat-damaged wheat. U. S. Dept. Agr. Tech Bul. 6, 32 p. illus. 1927.

POSSIBILITIES FOR THE USE OF COMBINES IN EASTERN AREAS

Combines should not be expected to achieve the same degree of success in the eastern humid regions that they have achieved in the semiarid western wheat-growing regions. Smaller farms and the smaller fields tend to make the combine a less economical method of harvesting wheat. Weather conditions also are somewhat less favorable in the East. A farmer who has a large acreage of crops to be harvested, or who can use his combine on neighboring farms, may find the machine a profitable investment.

The crops to be harvested may consist of wheat, oats, barley, rye, buckwheat, sweet clover, red clover, soy beans, millet, and timothy. A larger acreage of wheat than of oats, barley, or rye could be cut without loss from shattering. As has been shown, several important varieties of wheat that do not shatter readily are now grown in the Eastern States. The weather conditions during the harvest period in many of the Eastern States are but little more humid than those in some sections where combines are now used successfully. These facts, together with the development of the small combine, point to a wider use of this method of harvesting in the more humid sections. In sections in which the straw is fed or used for bedding, some objection to the use of the combine will be made unless some satisfactory method of saving the straw is devised.

SUMMARY

The combined harvester-thresher has given general satisfaction in harvesting wheat in the Great Plains region. Advantages of the combine are as follows: (1) It lowers the cost of harvesting and threshing; (2) it reduces the amount of labor required; and (3) it shortens the harvest and threshing period.

Combines most generally used in the Great Plains region have cuts of 12, 15, or 16 feet, and each is equipped with an auxiliary engine and is drawn by a tractor. Power-drive machines with an 8-foot or 10-foot cutter bar are also used.

In the hands of most operators, combines have proven to be dependable harvesting machines.

Grain acreages cut annually by combines of all types and sizes, according to this study average 553 acres per machine. The capacity of the machine is primarily dependent upon the width of cut and the length of the harvest season. The average for different types of machines ranged from 275 acres for the 8-foot machines, to 1,077 acres for the 20-foot machines. The average cut by 16-foot machines was 682 acres.

In general, wheat was the only crop harvested by the operators included in this study. The acreage of other crops was small, and the time of ripening was so nearly the same as that of wheat that the use of the combine on other crops did not materially increase the capacity of the machines.

The average rate of travel was 2.75 miles per hour, and for most machines it varied between 2.5 and 3 miles per hour. The size of machine has no apparent effect on the rate of travel.

The average length of the working day was 10.4 hours.

Acres cut per hour ranged from 1.6 for the 8-foot machines to 4.5 for the 20-foot machines. The 16-foot combines averaged 3.7 acres

per hour. The cut per hour for each foot of width was approximately 0.23 acre. The rate of cutting depends upon the rate of travel and upon the size of the machine. For yields ordinarily reported in the Great Plains region, the rate of cutting is only slightly affected by the yield per acre.

The more important elements of cost for harvesting with a combine are charges for labor, fuel, repairs, and depreciation on the machine.

On the average, 0.6 gallon of gasoline per acre was used in the auxiliary engine. Fuel consumption per acre in the auxiliary engine is affected somewhat by the size of machine, the rate of travel, and the yield of grain.

A tractor with a drawbar rating of 15 horsepower was most generally used on combines with an auxiliary engine, although one-third of the 12-foot machines were drawn by smaller tractors. Fuel used in the tractors on combines equipped with an auxiliary engine averaged 0.8 gallon per acre. The larger combines were slightly more economical than the small machines in the use of fuel per acre.

Fuel used in both auxiliary engine and tractor averaged 1.4 gallons per acre. The total fuel used per acre in machines with power drive was only slightly less.

Less than one-half of the labor used on combines was hired. The average amount of man labor for harvesting with a combine is 0.75 man-hour per acre, as compared with 3.6 man-hours usually furnished by the farmer for harvest and threshing where grain is cut with a binder, and 2.8 man-hours where the cutting is done with a header. The crew required to operate the combine is smaller than the crew used for heading, or for binding if more than one binder is used.

Repairs are estimated from available data at 10 cents per acre.

For all combines, depreciation averaged 44 cents per acre. There is no apparent relation between the acres cut annually and the estimated life of the machine. The per-acre depreciation charge is less for large than for small acreage cut by the same size of machine.

Interest charges are fixed, and the per-acre charge is less for large than for small acreages.

Under similar conditions, harvesting costs per acre show some variation between farms in the same area.

For small acreages the expense of harvesting with a combine is greater than with either a binder or a header. Where 60 or more acres are to be harvested with a binder, or 100 or more with a header, the small combine may prove more economical than these machines. The large combine may be more economical than a binder if more than 100 acres are to be cut and more economical than a header if 150 acres are to be cut. The choice between a large or a small combine should be made on the basis of the capacity of the machine and the acreage to be cut. Where 300 or more acres are to be cut, the fixed charges of the combine are reduced, and the machine is then operated at the lowest cost.

In cases in which only the usual direct costs are considered, 100 acres could be harvested as cheaply with a binder or header as with a small combine.

The variable costs per acre, based upon charges made for different harvesting methods, are $1.47 for a 10-foot combine, $1.50 for a 15-foot combine, $3.36 for a 12-foot header, and $4.22 for a 7-foot binder.

The average harvesting loss with combines is 2.6 per cent of the total yield as compared with 3.3 per cent for a header and 6.1 per cent for a binder. The actual loss of grain cut with the combine averaged 32 pounds per acre, as compared with 40 pounds with the header and 74 pounds with the binder.

The average threshing loss with combines was 1.9 per cent of the grain threshed, as compared with 1.2 per cent for the stationary thresher.

Factors other than harvest costs which should be included in a consideration of the use of the combine are possibility of loss of grain from weather or from shattering, disposal of straw, and the quality of grain, including the moisture content as it is threshed.

Where combines are available for custom cutting a man will find it cheaper to hire his grain cut than to own a 10-foot machine if he has not more than 125 acres of wheat; he can hire it cut more cheaply than to own a 15-foot machine unless he has more than 200 acres.

A 10-foot combine should harvest 375 acres in a 15-day harvest season. The minimum profitable acreage in the Great Plains for a machine of this size is about 150 acres; the maximum is about 640 acres. A 15-foot combine should harvest about 525 acres in 15 days, with a minimum of 200 and a maximum of 1,100 acres.

Most machines in this study were cutting as much as the operators considered the maximum capacity of the machines.

More than one-half of the combine owners were doing some custom cutting with their machines. The returns from custom cutting may enable an owner with a small acreage to obtain a profit on the investment in a combine even when his own acreage would not warrant his purchasing a machine.

Probably two-thirds or more of the wheat harvested with a combine is moved off the farm during harvest or soon thereafter.

Care must be taken in storing grain which is harvested early or soon after rains.

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