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Progress Report on the Use of the Combine in South Dakota

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PROGRESS REPORT
ON
THE USE OF THE COMBINE IN SOUTH DAKOTA

Departments of Farm Economics
Agronomy, and Agricultural Engineering
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Table of Contents

The Use of the Combine in South Dakota

Its Relation to the Quality and Price of Small Grain, Cost of Harvesting, and Efficiency of Operation

GABRIEL LUNDY, K. H. KLAGES and J. F. GOSS*

INTRODUCTION

Use of the combined harvester-thresher for the harvesting of cereals has increased rapidly in the Great Plains area in the past few years. The introduction and ever greater employment of this new method of harvesting small grains has brought with it some problems that must be faced by both the user of the combine and by the parties taking over the grain in its course to the terminal markets. In view of the problems arising from the introduction and use of the combine in South Dakota it was deemed worthwhile to determine the extent to which this new method of harvesting is adapted to the conditions in this state.

As a result of the preliminary information secured during the 1927 season**, it was considered desirable during 1928 to find out how much variation there was in the quality of the combined grain delivered to local elevators and how the combined grain compared in general characteristics with grain harvested by other methods. While the quality of a crop is determined by many factors, such as climatic conditions throughout the growing season and during harvest, by soil conditions, and by general cultural methods, it is primarily determined by the judgment with which the farmer manages his harvesting operations.

The percentage of moisture contained in grain together with the secondary effects of such moisture, if high, constitutes one of the main factors determining the general quality and commercial grade. This emphasizes the necessity of having definite knowledge as to how moisture contents of lots of grain vary with different treatments at the time of harvest. It is therefore important for the producer to know how early in the season he may combine his grain, how soon after a rain it is dry enough, and how early in the morning the machine may be operated in order that the moisture content of the grain may be low enough so that it can be handled and stored with safety.

The need for investigation relative to the quality and price of combine grain was also emphasized by the complaints of the grain trade to the effect that much combined grain of high moisture content was being delivered to the elevators. The handling of such immature or moist grain created new problems of storage and treatment to prevent heating and spoiling. Naturally if the men in the grain trade should find themselves subject to greater risk, and greater handling costs, it would be expected that they would endeavor to reflect these losses to the farm-

* Acknowledgement is made for valuable suggestions and criticism received from A. N. Hume, M. R. Benedict, R. Patty and R. E. Post.

** The United States Department of Agriculture cooperated with South Dakota State College in 1927.

er in the form of lower prices for such grain. In an orderly system of marketing, the price received should, of course, be related to the quality of the grain delivered.

Naturally the economic justification for the use of the combine can not be based on the price of the grain alone, although that is an important factor. Field costs must also be considered.

Claims of lower costs for harvesting and threshing seems to have been the cause for the increasing sale and use of the combine. These claims appear to have been substantiated by earlier investigations dealing with mechanical performance and cost of operation. While general information is available on the use of combines, it nevertheless seemed desirable to have supplementary information applicable to South Dakota conditions. During the 1927 season some data were therefore secured on costs of operation as well as on field losses by the different methods of harvesting and threshing. The advisability of making use of the combine is dependent to some extent not only on the mechanical losses incident to this method as compared with other methods of harvesting and threshing under normal conditions, but also on the efficiency of operation under adverse conditions as encountered in weedy fields or in lodged grain.

Combines in South Dakota and Area of Study

The first combine was used in South Dakota in 1919. There is no record of any other until 1922. In 1925 there were possibly 25 combines in the state. In 1927 there were 180 machines on record. The distribution of these is shown in Fig. 1. In 1928 the number had increased to at least 648. Fig. 2 shows the distribution of the machines reported in 1928. It will be seen that the greatest number of combines is employed in the central and western portions of South Dakota, but there are some machines in the eastern counties. The greatest increase in number of

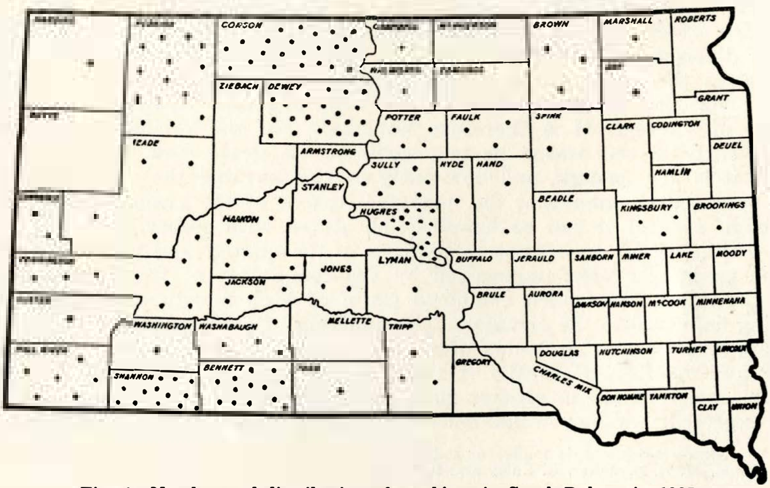


Fig. 1—Number and distribution of combines in South Dakota in 1927, 180 machines were on record.

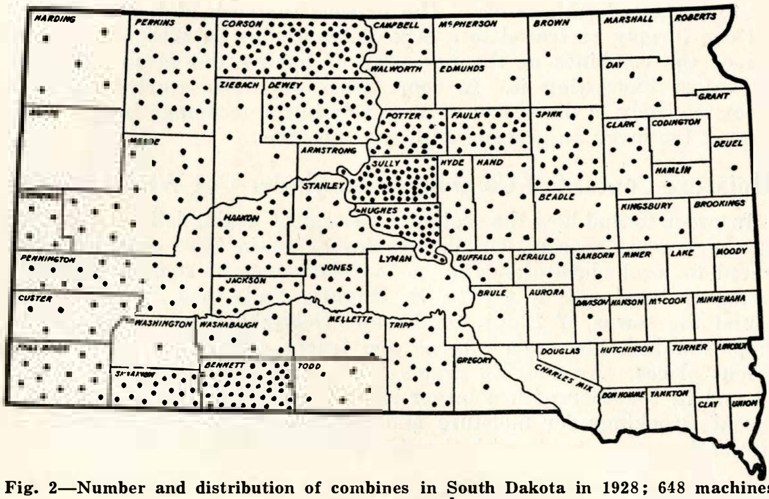


Fig. 2—Number and distribution of combines in South Dakota in 1928; 648 machines were on record.

combines from 1927 to 1928 was in the central and western portions of the state.

The area around Blunt in Hughes county was selected in 1927 as a basis for this South Dakota study because in this area there were a considerable number of combines in operation. During 1928 the field of work was extended to include Sully and Potter counties. In both years, 1927 and 1928, data were also obtained around Brookings where the College operated a combine for experimental purposes.

Effect of Methods and Date of Harvesting on the Moisture Content of Grain

Moisture Content of Combined and Binder-Cut Grain in 1927

Table 1 gives the moisture content of samples of combined grains collected in 1927. It will be noticed that the percentages of moisture of the combined samples ran quite high. Many of the samples were too

Table 1—Moisture contents or samples of combined and binder-cut grains collected in 1927

Kind of Grain	Combined		Binder-cut	
	No. of samples	Percent of moisture	No. of samples	Percent of moisture
Wheat	37	17.2	6	13.1
Flax	20	12.6		
Barley	8	15.6	7	13.8
Oats	5	14.3		
Rye	3	14.9		
Emmer	6	13.7		

wet to be stored with safety. The reasons for such high moisture content can largely be traced to a lack of knowledge on the part of operators of the combines of the necessity of having the grain thoroughly dry before harvesting it. In some cases operators started their machines too early in the season or too early in the mornings in an attempt to cover too large an acreage with one machine.

Moisture Content of Combined and Binder-Cut Wheat in 1928

In order to find how the moisture content of grain, delivered throughout the harvest season, varied, samples of grain were obtained as delivered to local elevators. Due to the abundance of combines there, as already pointed out, a section in Hughes, Sully and Potter counties around the towns of Blunt, Onida, and Gettysburg was selected. The samples were taken from wagons and trucks delivering grain to these various places. Around 250 grams of the grain were put in an airtight can and it, together with a larger sample, was then sent to the laboratory at Brookings for moisture and grade determination. Moisture determinations were made with the Brown-Duvel moisture tester.

Table 2—Moisture content of samples of combined and binder-cut wheat delivered at the local elevators at different dates in 1928.

Date of delivery	Combined Wheat			Binder-cut Wheat		
	No. of samples	Av. percent of moisture	Range in moisture contents	No. of samples	Av. percent of moisture	Range in moisture contents
Aug. 1	2	18.4	16.4-20.4	1	13.1	
Aug. 2	3	19.5	18.4-20.0			
Aug. 3	15	17.4	14.3-23.8			
Aug. 4	25	15.9	13.8-19.9	1	13.8	
Aug. 5	7	14.8	14.0-16.0			
Aug. 6	4	14.8	13.0-15.6	2	13.3	12.6-14.0
Aug. 7	2	14.0	11.4-16.6	1	15.2	
Aug. 8	7	11.9	9.2-13.5			
Aug. 9	32	11.9	8.6-15.8			
Aug. 10	19	12.5	10.0-15.2	3	10.7	10.0-11.2
Aug. 11	5	11.0	8.0-12.0	4	10.2	9.4-11.2
Aug. 12	1	11.0				
Aug. 13	14	9.7	8.0-13.6	2	9.7	9.0-10.4
Aug. 14	3	11.8	11.4-12.8			
Aug. 15	6	12.9	11.0-15.0	2	14.7	13.2-16.2
Aug. 17	17	17.5	14.4-22.0			
Aug. 18	35	15.6	10.4-20.0	5	15.2	14.8-15.6
Aug. 19	2	12.8	11.7-13.9			
Aug. 21	1	16.0				
Aug. 22				1	13.5	
Aug. 23				6	14.2	13.6-15.1
Aug. 24	1	14.0		9	13.6	13.0-14.0
Aug. 25				11	13.0	11.6-14.2
Aug. 28				5	14.5	13.4-16.8
Aug. 29	2	21.1	20.2-22.0	6	14.0	8.5-16.0
Aug. 30				8	16.0	13.8-18.6
Aug. 31	1	12.6		6	14.7	14.0-15.0
No. of samples	204			73		
Average of moisture content		14.5 ± .15			13.9 ± .15	

Table 2 gives the average moisture content of samples of combined and binder-cut wheat delivered at different dates in 1928. Tables 3 and 4 show the distribution and variations in the moisture content of these samples.

Table 3—Distribution of moisture content of samples of combined wheat delivered at local elevators at different dates in 1928.

	Moisture contents in percent																
Date	8.0 - 8.9	9.0 - 9.9	10.0 - 10.9	11.0 - 11.9	12.0 - 12.9	13.0 - 13.9	14.0 - 14.9	15.0 - 15.9	16.0 - 16.9	17.0 - 17.9	18.0 - 18.9	19.0 - 19.9	20.0 - 20.9	21.0 - 21.9	22.0 - 22.9	23.0 - 23.9	No. of samples or Frequency
Aug. 1									1				1				2
Aug. 2											1		2				3
Aug. 3							2	1	5	2	3		1			1	15
Aug. 4						1	7	6	6	2		3					25
Aug. 5							4	2	1								7
Aug. 6						1		3									4
Aug. 7				1					1								2
Aug. 8		1		2	2	1	1										7
Aug. 9	1	3	4	8	7	4	4	1									32
Aug. 10			3	2	8	2	1	3									19
Aug. 11	1		1	1	1	1											5
Aug. 12				1													1
Aug. 13	3	6	3	1		1											14
Aug. 14				2	1												3
Aug. 15				2	1	2		1									6
Aug. 17							2	3	3	1	3	2	1	1	1		17
Aug. 18			2		3	4	2	8	6	3	3	2	2				35
Aug. 19				1		1											[illegible]
Aug. 22									1								1
Aug. 24							1										1
Aug. 29													1		1		2
Aug. 31					1												1
Frequency	5	10	13	21	24	18	24	28	24	8	10	7	8	1	2	1	204

Average 14.5±.15
Standard Deviation 3.14±.10

Graphs are presented in Figs. 3 and 4 to serve as an aid in the interpretation of the data contained in Tables 3 and 4 respectively. These figures show the variations in the moisture contents of the combined and binder-harvester samples as delivered to local elevators throughout the month of August, 1928.

Table 4—Distribution of moisture content of samples of binder cut wheat delivered at local elevators at different dates in 1928.

Date	Moisture content in percent											
	8.0 - 8.9	9.0 - 9.9	10.0 - 10.9	11.0 - 11.9	12.0 - 12.9	13.0 - 13.9	14.0 - 14.9	15.0 - 15.9	16.0 - 16.9	17.0 - 17.9	18.0 - 18.9	No. of samples or Frequency
Aug. 1						1						1
Aug. 4						1						1
Aug. 6					1		1					2
Aug. 7								1				1
Aug. 10			1	2								3
Aug. 11		1	2	1								4
Aug. 13		1	1									2
Aug. 15						1			1			2
Aug. 18							1	4				5
Aug. 22						1						1
Aug. 23						2	3	1				6
Aug. 24						7	2					9
Aug. 25				2	3	4	2					11
Aug. 28						2	1	1	1			5
Aug. 29	1						2	2	1			6
Aug. 30						1	1	3	1		2	8
Aug. 31							5	1				6
Frequency	1	2	4	5	4	20	18	13	4	0	2	73

Average 13.9 ± .15
Standard deviation 1.89 ± .11

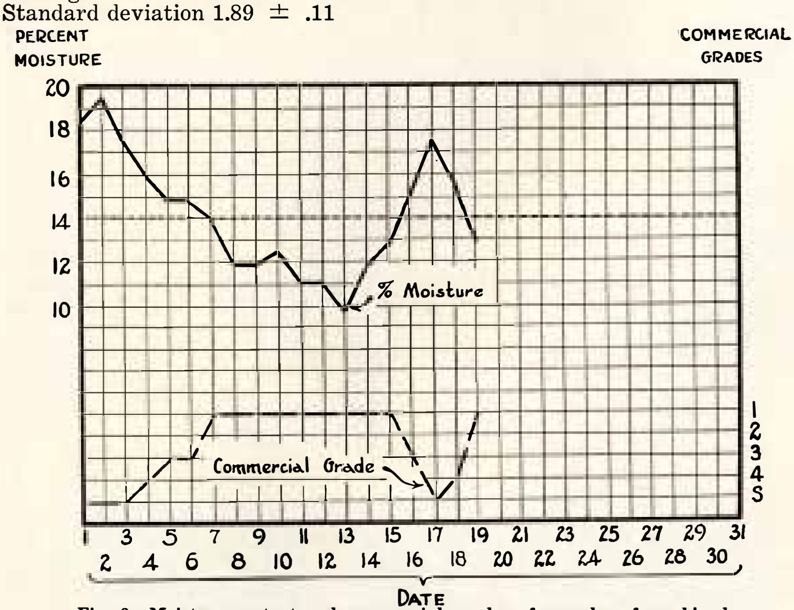


Fig. 3—Moisture content and commercial grades of samples of combined wheat delivered at different dates in 1928
(Based on Table 3)

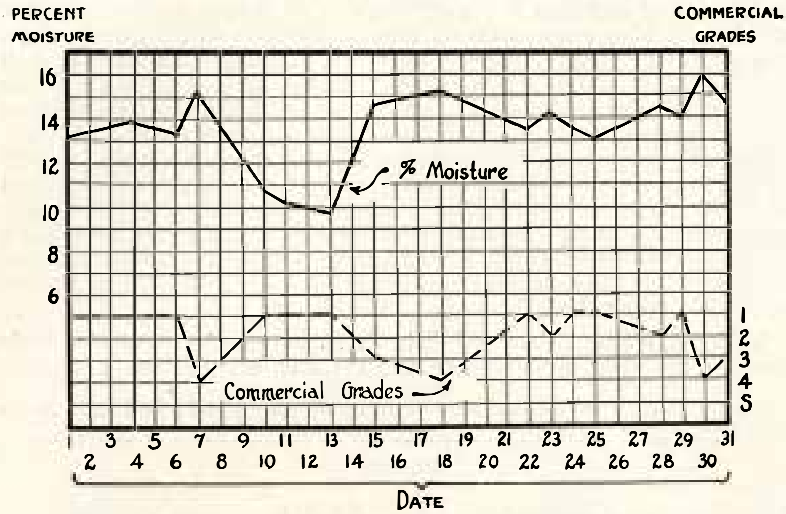


Fig. 4—Moisture content and commercial grades of binder-cut wheat delivered at different dates in 1928.
(Based on Table 4)

Variations in the moisture content of the samples of combined and binder cut wheat delivered throughout the month of August are brought out in Tables 3 and 4. The averages as well as the distributions of the moisture contents show that there was a decided tendency to start harvesting operations too early in the season, that, is, before the grain was sufficiently dry to be handled and stored with safety.

Table 5 gives a summary of the climatic conditions at the towns of Highmore, Onida and Pierre. The precipitation reported at the respective places resulted mostly from local thunderstorms. The first few days of August had a moderate amount of precipitation. With the exception of a few local showers it was dry and hot from the fifth to the 16th. As may be seen from Tables 2, 3 and 4, and Figures 2 and 3 the moisture content of the samples decreased rapidly during this period. The moisture content of the samples delivered the 17th was again high, following cloudy weather on the 15th and rain on the 16th. This shows that there was too much of a tendency to resume harvesting operations before the grain had dried out sufficiently after the rainy period.

One reason for the tendency of combined grain to contain excessive moisture after a wet period may be found in the manner in which changes take place in the moisture content of the individual kernels. The kernels of dry mature wheat standing in the field give off and absorb moisture as the humidity of the surrounding air varies. During dry periods, especially during a dry and hot period such as encountered in the ten days from August 6 to 15, wheat kernels dry out rapidly. But should the humidity of the air, that is the amount of moisture in the air, increase as it did on the 16th these dry kernels absorb moisture readily. As they absorb moisture, the moisture penetrates from the outside of the kernels and as a result they feel moist and cool. On the other hand should

the amount of moisture in the air decrease as it does after a rain, and especially if higher temperatures prevail, then the wheat kernels again give off the moisture previously absorbed. During the time that such kernels give off moisture the outsides of the kernels may feel quite dry to the touch while the interiors will still contain a high percentage of moisture. It is at this point that many combine operators are misled. From a superficial examination, the grain seems dry; it can be threshed, but still contains an excessive amount of moisture. After such grain is threshed the movement of the moisture for a time continues from the inside to the outside and collects on the outside of the kernels, but since the kernels are now not exposed to the air as previous to threshing, such moisture cannot be removed. If the moisture content of the grain is high it starts to heat and rapidly goes out of condition.

Tables 2, 3 and 4 show definitely that many producers started their combines too early in the season and too soon after rains. The grain

Table 5—Summary of climatic conditions at Highmore, Onida and Pierre, S. D., at different dates in 1928.

Date	Highmore			Onida			Pierre		
	Precipitation in in.	Maximum Temp.	Minimum Temp.	Precipitation in in.	Maximum Temp.	Minimum Temp.	Precipitation in in.	Maximum Temp.	Minimum Temp
Aug. 1	.41	87	61	.26	84	59	.28	91	66
Aug. 2	.05	78	57	.27	77	59	.01	78	64
Aug. 3		80	56		80	55		80	60
Aug. 4		82	53		84	57	.04	85	60
Aug. 5	.30	87	54		81	60		84	65
Aug. 6		87	53		89	58		91	59
Aug. 7		95	59		97	55		97	60
Aug. 8		98	58		101	68		104	62
Aug. 9		101	62		104	60	.34	104	68
Aug. 10		91	57		89	65		90	66
Aug. 11		101	64		104	67		104	68
Aug. 12		104	59		105	61		108	76
Aug. 13		104	59		105	65	T	104	68
Aug. 14		101	76	.46	94	67		95	65
Aug. 15		101	60		95	65	.28	101	66
Aug. 16	.49	77	61	.32	80	60		70	61
Aug. 17		80	47		82	49		82	55
Aug. 18		96	58		96	55	.08	100	63
Aug. 19		90	58		92	53	T	93	60
Aug. 20	.31	83	57	.29	77	58	.25	79	60
Aug. 21		87	55		80	54	.11	91	56
Aug. 22	.31	84	61	.11	88	61	T	88	65
Aug. 23		73	43		69	45		69	49
Aug. 24		81	40		84	59		84	46
Aug. 25		78	54		—	—		81	58
Aug. 26		87	50	T	89	50	T	90	57
Aug. 27		84	58		79	51		75	56
Aug. 28	.02	77	47	.17	75	47	.04	79	52
Aug. 29	.41	73	49	.04	72	61	.11	73	58
Aug. 30		68	44		67	49		70	51
Aug. 31	.02	74	46		77	44	.18	78	52
Total	2.32			1.92			1.72		

must be dry if it is to be handled with safety. The hard red spring and durum wheats in order to grade number 1 cannot contain more than 14.0 percent of moisture; 14.5 percent is the maximum for number 2, and 15.0 percent for grade number 3.

By referring to table 2 it will be seen that the average moisture content of combined wheat is 14.5 ± .15 as compared to 13.9 ± .15 for the binder cut samples. The difference between these figures as such is not great enough to be significant. When however, the moisture content of the two lots is regarded in the light of the degree of variability it shows a significant difference, as may be observed from Tables 3 and 4. The variations in the moisture content of the combined samples is significantly greater than that of the binder cut samples as is brought out by the two respective standard deviations, 3.14 ± .10 for the combined and 1.89 ± .11 for the binder cut samples. When Tables 3 and 4 are compared the greater degree of variation in the moisture content of the combined wheat is quite evident. Even though the means or averages of the moisture content of the two lots do not differ greatly it will be seen that the mode, that is the class of greatest frequency, for the combined samples falls at 15.5 percent while the mode for the binder cut samples falls at 13.5 percent of moisture. In Table 6 the variations in the modes and the distribution of the moisture content of the two respective lots are brought on a comparative basis by reducing the summations of the variates of the separate classes to a percentage basis. It will be seen that 27.4 percent of the samples of the binder cut wheat fall in the modal class of 13.5 while only 13.7 percent of the samples of the combined wheat fall into its modal class of 15.5 percent of moisture. The two moisture classes 13.0 to 13.9, and 14.0 to 14.9 contain in the binder cut wheat 52.1 percent of all samples. These same two classes in the combined wheat contain only 20.6 percent of the samples. These factors are shown graphically in Fig. 5.

Table 6—Comparison of binder cut and combined wheat as to percentages of samples in different moisture groups

Standard deviation	Average*	Mode**	Limits of moisture classes. 8.0 - 8.9	9.0 - 9.9	10.0 - 10.9	11.0 - 11.9	12.0 - 12.9	13.0 - 13.9	14.0 - 14.9	15.0 - 15.9	16.0 - 16.9	17.0 - 17.9	18.0 - 18.9	19.0 - 19.9	20.0 - 20.9	21.0 - 21.9	22.0 - 22.9	23.0 - 23.9
Combined Wheat																		
3.14± .10	14.5±.15	15.5	2.4	4.9	6.4	10.3	11.8	8.8	11.8	13.7	11.8	3.9	4.9	3.4	3.9	0.5	1.0	0.5
Binder cut wheat																		
1.89± .11	13.9±.15	13.5	1.4	2.8	5.5	6.3	5.5	27.4	24.7	17.8	5.5	0.0	2.8					

**Class having most samples

*Mean

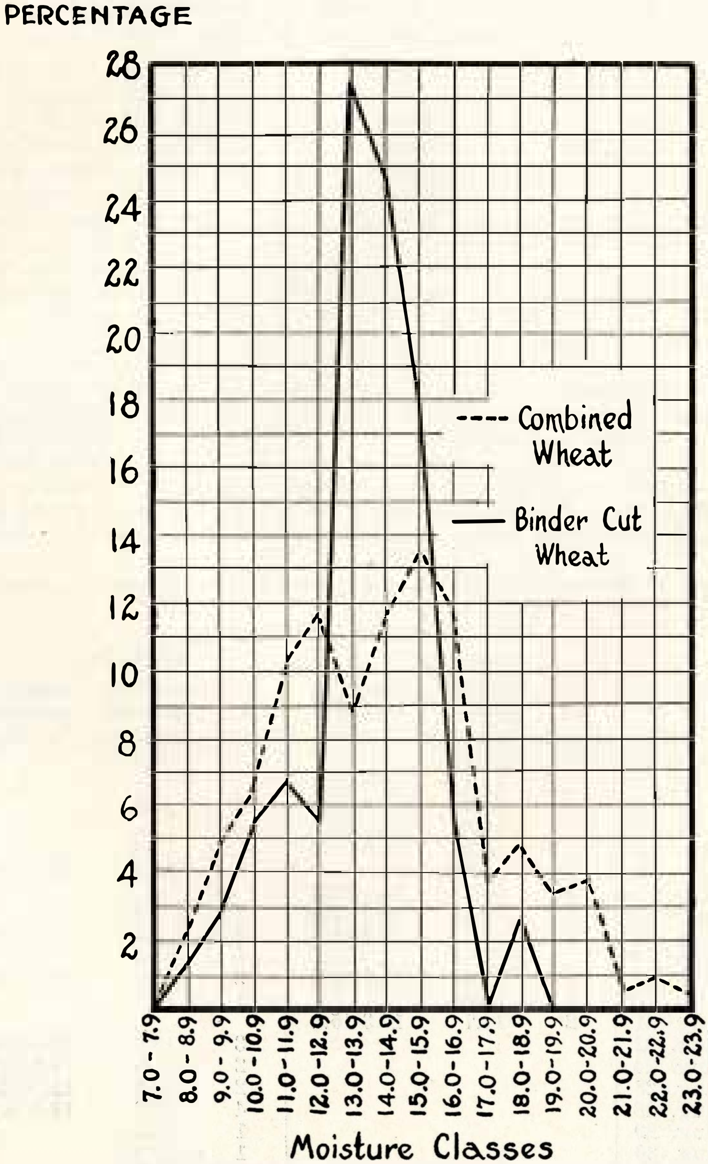


Fig. 5—Comparison of binder-cut and combined wheat as to percentages of samples in different moisture groups.
(Based on Table 6)

Moisture Content of Combined and Binder-cut Barley and Oats in 1928

Table 7 and Figs. 6 and 7 show the moisture content of samples of combined and binder-cut barley and oats delivered in 1928. The same factors brought out in Tables, 2, 3 and 4 on wheat are in evidence. As in the case of wheat, the moisture content of the binder-cut samples was lower than that of the combined samples. The means or averages were 16.0 ± .42 and 13.4 ± .30 for the combined and binder-cut samples respectively.

The differences were far more significant than in the case of wheat. Variability of moisture content was, as in wheat, less for the binder-cut than for the combined samples. The variations, as may be seen from Tables 8 and 9 were high. The standard deviation for the binder-cut samples was 2.32 ± .21 as compared to 3.93 ± .30 for the combined samples.

Attention is called to the fact that a rather high percentage of the combined samples contain a low to medium percentage of moisture, while on the other hand a fairly large percentage of the samples contain an exceedingly high percentage of moisture. Likewise a high percentage of binder-cut samples contained an excess of 15.0 percent of moisture. The the fact that 59.0 percent of the combined and 35.7 percent of the binder-cut samples contain 15.0 percent or a greater amount, of moisture is outstanding. These figures show very definitely that growers should give more attention to the moisture content of cereals at the time of threshing.

Table 7.—Moisture content of samples of combined and binder-cut barley and oats delivered at local elevators in 1928.

Moisture content in percentages

	Combined			Binder-cut		
Date of delivery	No. of samples	Average percent moisture	Range in moisture content	No. of samples	Average percent moisture	Range in moisture content
July 28	1	14.0				
Aug. 1	2	15.0	13.6-16.4			
Aug. 2	4	22.0	20.4-24.0	1	14.0	
Aug. 3	11	17.1	12.6-22.0			
Aug. 4	4	15.2	12.0-17.8			
Aug. 6	1	15.0		3	14.9	14.0-15.6
Aug. 8	2	14.1	14.1-14.2			
Aug. 11	3	8.5	8.0- 9.4	1	9.0	
Aug. 13	2	9.7	8.4-11.4	4	9.4	8.0-10.6
Aug. 15				1	12.2	
Aug. 17	6	16.5	13.0-19.8	3	15.6	15.2-16.0
Aug. 18	1	18.2		1	15.7	
Aug. 21	2	14.7	14.3-15.1			
Aug. 22				3	13.8	12.5-15.8
Aug. 24				2	11.5	10.8-12.2
Aug. 25				2	12.3	12.2-12.4
Aug. 28				4	14.3	13.8-15.0
Aug. 29				1	13.2	
Aug. 30				1	15.0	
Aug 31				1	16.8	
No. of samples	39			28		
Average of moisture content		16.0 ± .42			13.4 ± .21	

Table 8—Distribution of moisture content of samples of combined barley and oats delivered at local elevators at different dates in 1928.

Date	Moisture contents in percentages																	
	8.0 - 8.9	9.0 - 9.9	10.0 - 10.9	11.0 - 11.9	12.0 - 12.9	13.0 - 13.9	14.0 - 14.9	15.0 - 15.9	16.0 - 16.9	17.0 - 17.9	18.0 - 18.9	19.0 - 19.9	20.0 - 20.9	21.0 - 21.9	22.0 - 22.9	23.0 - 23.9	24.0 - 24.9	No. of samples or Frequency
July 28							1											1
Aug. 1						1			1									2
Aug. 2													1	1	1		1	4
Aug. 3					3				1	2	1	1	2		1			11
Aug. 4					1		1			2								4
Aug. 6								1										1
Aug. 8							2											2
Aug. 11	2	1																3
Aug. 13	1			1														2
Aug. 17						1		1	2	1		1						6
Aug. 18											1							1
Aug. 21							1	1										2
Frequency	3	1	0	1	4	2	5	3	4	5	2	2	3	1	2	0	1	39

Average M 16.0 ± .42

Standard deviation 3.93 ± .30

Table 9—Distribution of moisture content of samples of binder-barley and oats delivered at local elevators at different dates in 1928.

Date	Moisture in percentages									
	8.0 - 8.9	9.0 - 9.9	10.0 - 10.9	11.0 - 11.9	12.0 - 12.9	13.0 - 13.9	14.0 - 14.9	15.0 - 15.9	16.0 - 16.9	Frequency
August 2							1			1
August 6							1	2		3
August 11		1								1
August 13	1	2	1							4
August 15					1					1
August 17								2	1	3
August 18								1		1
August 22					1	1		1		3
August 24			1		1					2
August 25					2					2
August 28						1	2	1		4
August 29						1				1
August 30								1		1
August 31									1	1
Number of samples or frequency	1	3	2	0	5	3	4	8	2	28

Average 13.4 ± .30

Standard deviation 2.32 ± .21

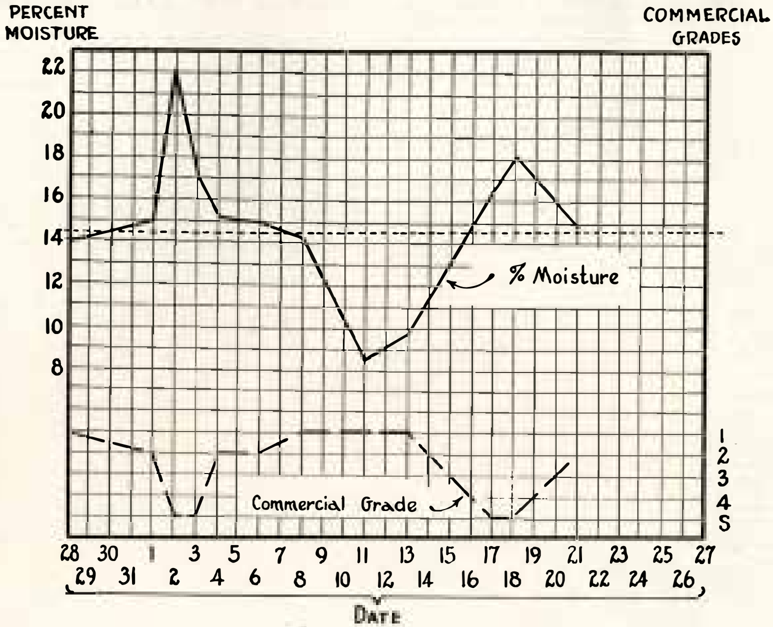


Fig. 6—Moisture content and commercial grades of samples of combined barley and oats delivered at local elevators in 1928.
(Based on Table 7)

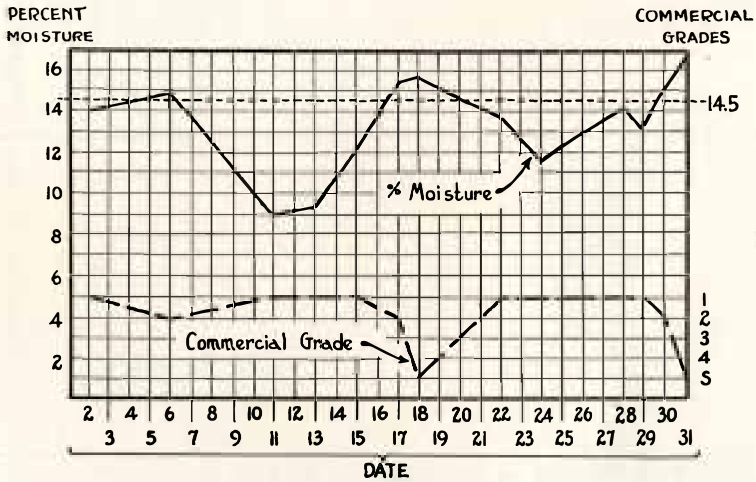


Fig. 7—Moisture content and commercial grades of samples of binder cut barley and oats delivered at local elevators in 1928.
(Based on Table 7)

Moisture Content of Combined and Binder-cut Flax in 1928.

Table 10 gives the moisture content of samples of combined and binder cut flax. The moisture content of the two lots were practically alike, the means being 10.1 ± .30 and 10.0 ± .60 for the combined and binder-cut samples respectively. The degree of variability was about the same for the two lots, the standard deviation being 2.17 ± .24 and 2.22 ± .43 respectively. While grade number 1 of the hard red spring wheats may contain 14.0 percent of moisture, flax in order to be handled and stored with safety should not contain in excess 11.0 percent of moisture. It will be seen from Table 10 that a fair percentage of the samples of both the combined and the binder-cut flax contain 11.0 percent or more of moisture

Table 10—Moisture content of samples of combined and binder-cut flax delivered at different dates in 1928.

	COMBINED FLAX			BINDER CUT FLAX		
Date of delivery	No. of samples	Av. percent of moisture	Ranges in moisture cont.	No. of samples	Av. percent of moisture	Ranges in moisture cont.
Aug. 14	2	7.4	6.4- 8.4			
Aug. 17	1	10.6				
Aug. 18	5	8.4	7.0- 9.6			
Aug. 22	2	9.2	8.6- 9.8			
Aug. 24				2	7.2	7.2- 7.2
Aug. 25	1	10.5				
Aug. 29	6	12.6	10.8-14.4	1	12.0	
Aug. 30				2	11.8	11.2-12.4
Aug. 31	1	9.0		1	8.6	
No. of samples	18			6		
Mean Moisture		10.2 ± .30			10.0 ± .60	
Standard deviation		2.17 ± .24			2.22 ± .43	

Moisture Content of Grain Threshed Immediately after Heading and of Grain Threshed from Small Stacks Two to Four Weeks after Heading

The threshing of cereals immediately after heading corresponds, for sake of comparison, to combining. The interval of time from heading to threshing is not great enough to allow for much drying out of the heads. When, on the other hand, the headed material is put up in small stacks there may be some drying depending on the weather conditions. Table 11 gives the moisture contents of samples of wheat and barley threshed immediately after heading and of samples from small stacks threshed from two to four weeks after heading. The average moisture content of the former was 16.2 as compared to 15.4 percent for the latter.

It will be noticed that the moisture content of the material threshed immediately after heading decreased from 18.0 to 14.7 percent from August 1 to August 15. The average moisture content of the stacked material is high due to the excessive moisture in the samples taken on August 17. Threshing operations were no doubt started too soon after the rain on the previous day.

Table 11—Moisture content of samples of wheat and barley cut by headers threshed immediately heading, and threshed after being in small stacks from two to four weeks.

	GRAIN HEADED AND THRESHED IMMEDIATELY			GRAIN HEADED AND STACKED PRIOR TO THRESHING		
Date of threshing and deivery	No. of samples	Av. percent of moisture	Ranges in moisture cont.	No. of samples	Av. percent of moisture	Ranges in moisture cont.
Aug. 2	1	18.0				
Aug. 3	3	16.5	14.4-17.8			
Aug. 4	2	15.4	14.8-16.0			
Aug. 8	2	16.4	14.6-18.2			
Aug. 15	1	14.7				
Aug. 17				3	17.7	15.8-20.0
Aug. 18				5	15.1	13.7-16.2
Aug. 29				3	13.9	13.6-14.2
Aug. 30				1	14.6	
Total No. of samples	9			12		
Average moisture content		16.2			15.3	

Replies from Growers Regarding the Stage of Maturity at which to Harvest Grain

In connection with what the previous data on the moisture content of combined grain tells us regarding the importance of the time of combining it is interesting to note what the farmers themselves have to say on this subject. The combine operator naturally wants to know how long he should delay combining after the usual time to begin the binder harvest.

For the purpose of determining the normal difference in time for harvesting by various methods the Department of Farm Economics of South Dakota State College in October, 1928, sent out a questionaire on this subject to about 250 farmers in the area from Blunt to Gettysburg. About 110 of these farmers were combine owners. Replies were received from about 30 percent of those solicited, and almost one-half of the answers were from owners of combines.

A number of those who replied called attention to the fact that the answers would naturally vary with amount of rain and drying weather during the harvest season. Uneven ripening of the grain and weeds in the fields would also cause variations in the best time for some of these operations.

A copy of the questions together with summaries or averages of the answers follow:

No. of Replies

Q. 1. After the grain is ripe for the binder, how much longer must it stand before it is dry enough to combine direct and dry enough to store without danger of heating in the bin?

60 Ans. 50% of the answers ranged between 10 and 14 days. The average is 14 days and the most frequent answer was 14 days. All the answers ranged between a minimum of 4-5 days, and a maximum of 3-6 weeks.

Q. 2. How soon after the grain is fit for binder harvesting would you windrow it?

62 Ans. 53% of those who replied said it could be windrowed at the same time. The average of all answers is 2.57 days. The extremes were zero and 14 days.

Q. 3. How long should the grain lie in the windrow before it is sufficiently dry to combine with the pick-up attachment?

63 Ans. 79% of the answere range between 3 and 7 days inclusive. The average of all answers is 5.69 days. All answers ranged between a minimum of 2-3 days and a maximum of 2 weeks.

Question 4: (a) About what date did binder-harvesting begin for each crop in your vicinity?

(b) About what date did direct combining of each of these crops begin in your locality?

Kind of Grain	(a) No of Reports	(a) Average date (1928)	(a) Range of Bulk of ans. and % of total: Range	%	(b) No of Reports	(b) Average date (1928)	No. of Days difference a to b	(b) Range of bulk of answers and % of total: Range	%
Spring Wheat	50	July 27	7-20 8-1	72	39	Aug. 7	11	8-1 8-15	79
Durum	36	July 29	7-20 8-1	61	24	Aug. 4	6	8-1 8-15	75
Winter Wheat	10		7-15 7-20	70	5				4
Barley	54	July 22	7-15 7-25	70	38	July 30	8	7-20 8-10	80
Rye	35	July 14	7-5 7-20	85	27	Aug. 1	18	7-20 8-10	78
Oats	45	July 26	7-15 8-1	78	12	Aug. 8	13	8-5 8-10	75
Flax	30	Aug. 23	8-1 9-1	90	29	Aug. 27	4	8-15 9-1	62

Question 4 (c) When did windrowing begin in your locality

(d) When did combining with the pick-up attachment begin?

Kind of Grain	(c) No of Reports	(c) Average date (1928)	No of days diff. a to c	(c) Range of bulk of answers and % of total: Range	%	(d) No of Reports	(d) Average date (1928	No of days diff c to d	(d) Range of bulk of answers and % of total: Range	%
Spring Wheat	37	July 29	2	7-24 8-2	57	35	Aug 6	8	7-30 8-10	60
Durum	23	July 27	2	7-20 8-1	61	23	Aug 5	9	7-30 8-10	57
Winter Wheat	4					3				
Barley	40	July 22	0	7-10 8-1	80	34	July 29	7	7-18 8-5	70
Rye	18	July 18	4	7-10 7-20	61	16	July 25	7	7-15 7-30	69
Oats	17	July 30	4	7-20 8-1	53	16	Aug 7	8	7-20 8-10	62
Flax	13	Aug 18	5	8-15 9-1	46	14	Aug 24	6	too scat- ed	

Q. 5. What difference is there in the time for binder harvesting and header harvesting, or how much later does the header harvest come.

66 Ans. 76% of the answers ranged between 7 and 10 days. The most frequent answer is 7 days; the average of all answers is 8.2 days, while the extreme range of all answers is from zero to 20 days.

Under "Remarks" a few made aditional comments calling attention to variations in climate, rainfall, evenness of ripening, weeds, differences in varieties, etc., which might affect the optimum date and the method of harvesting.

Since there has been a tendency for combine owners to cut such a large acreage as to lead them to get into the field before the grain was ripe and too soon after dew and rain it is interesting to note that one large operator says that a twenty-foot combine should harvest no more than 320 acres of wheat and in addition not over that acreage of flax. Since this operator has cut over 2000 acres with a 16-foot combine in one season his remarks would seem to indicate that there are some undesirable consequences in connection with attempting to combine more than the size of the machine and the climatic conditions would permit of harvesting in dry condition.

Being based on the experience or observation of a rather limited number of individuals and some of them for only one season in only one general area of the state, these replies are not necessarily correct for every year nor for all parts of the state. It is, of course, evident that it is the condition of the crop that determines the date for harvesting. Other years with dissimiliar conditions affecting the ripening of the grain might bring different results both as to the dates of harvesting and the spread in time between binder-cutting and combining.

Effects of Combining at Different Times of the Day on Moisture Content and Commercial Grade

It has already been mentioned that dry grain absorbs moisture from the surrounding air when the humidity of the atmosphere increases. The relative humidity of the air increases toward evening and is generally high early in the morning. During such times ripe kernels absorb moisture. The fact already mentioned relative to the movement of moisture in the grain during the drying process following the lowering of the humidity during the day must be kept in mind. The moisture in the kernel moves from the inside out, and evaporates from the surface so that the exterior portions of the kernel may feel quite dry to the touch at a time when it still contains an abundance of moisture.

In order to find how moisture content of the cereals varies during the different parts of the day, fields of barley, oats, and wheat were cut with a combine at Brookings. Samples were taken at intervals of one hour throughout the day and moisture content determined.

Table 12 and Fig. 8 shows the effects of combining oats during different hours of the day. It will be noticed that the oats was sufficiently dry to grade number 1 on August 6 from the time the combine was started at two in the afternoon until eight at night. There was a noticeable increase in the moisture content of the oats from 7:00 to 8:00 p. m. At 8:00 the next morning, August 7, the relative humidity was up to 93 percent and the moisture content of the oats was 20.4 percent. The mois-

ture content decreased rapidly with the decrease in humidity yet the oats was not dry enough to be combined with safety until 11:00 a. m. Table 12 shows definitely that the combine should not be started too early in the morning.

Table 13 shows the same factors as above on barley. The barley in this particular field was extremely short, the heads protruded only a few inches over a dense growth of Russian thistles. As in the case of the oats reported on in Table 12 the moisture content of barley was low enough to have it fall into grade number 1 on the two consecutive afternoons. The moisture content was entirely too high to obtain grain safe for storage from the material combined during the forenoons.

Table 14 gives data on the moisture content of wheat as affected by cutting at different dates and by cutting at different hours of the day. It will be noticed that the moisture content of the wheat decreased 6.6 percent in the course of four days, from August 7 to 11. It will also be noticed on examining Table 14 that the moisture content at 2:30 p. m., August 11, was lower than at any hour two days later. This was due to the fact that the wheat was slightly lodged on the 13th, making it necessary to cut lower. Consequently more of a green weedy growth was picked up. On the 11th the wheat stood up well so that the green weeds could be avoided by setting the cutter bar high enough. Due to the presence of green succulent weeds it was not until 3:00 p. m. that even fairly dry grain was obtained. At 7:00 p. m. with the increase in humidity the moisture content of the wheat began to increase materially. The variations in moisture content of wheat cut during different hours of the day are shown graphically in Fig. 9.

It is obvious, of course, that humidity may vary from day to day and also at different hours of the day. Hence, it naturally follows that other days with dissimilar atmospheric conditions would result in moisture tests somewhat unlike those shown in figures 8 and 9. The proper hour to begin combining might thus vary from day to day. These figures do, however, indicate a commonly observed tendency for grain to dry out from morning to late afternoon on normally dry days.

Table 12—Effect on moisture content and commercial grades of cutting oats with combine, at different times of the day.*

Date (1928)	Time of day	Weather	Relative humidity	Percent moisture	Commercial grade
August 6	2:00 p. m.	Clear	23	14.0	No. 1
August 6	3:00 p. m.	Clear	21	14.0	No. 1
August 6	4:00 p. m.	Clear	46	13.2	No. 1
August 6	5:00 p. m.	Clear	51	12.8	No. 1
August 6	6:00 p. m.	Clear	51	13.2	No. 1
August 6	7:00 p. m.	Clear	54	12.8	No. 1
August 6	8:00 p. m.	Clear	60	14.0	No. 1
August 7	8:00 a. m.	Clear	93	20.4	Sample grade
August 7	9:00 a. m.	Clear	82	18.0	Sample grade
August 7	10:00 a. m.	Clear	66	16.0	Sample grade
August 7	11:00 a. m.	Clear	47	14.4	No. 1
August 7	12.00 a. m.	Clear	30	12.2	No. 1
August 7	1:00 p. m.	Clear	21	11.2	No. 1
August 7	2:00 p. m.	Clear	20	11.3	No. 1

* College farm Brookings, S. D.

Table 13—Effect on moisture content and commercial grades of cutting barley* a different times of the day.

Date (1928)	Time of day	Weather	Relative humidity	Percent moisture	Commercial grade
July 30	4:00 p. m.	Cloudy	70	14.0	No. 1
July 30	5:15 p. m.	Cloudy	80	13.2	No. 1
Jply 30	8:00 p. m.	Clear	92	14.0	No. 1
July 31	7:15 a. m.	Cloudy	98	18.0	Sample grade
July 31	9:45 a. m.	Cloudy	93	18.4	Sample grade
July 31	10.45 a. m.	Clear	51	16.8	Sample grade
July 31	1:15 p. m.	Clear	53	15.2	No. 3
July 31	2:30 p. m.	Clear	33	12.4	No. 1
July 31	3:30 p. m.	Clear	44	13.2	No. 1
July 31	4:30 p. m.	Clear	41	13.2	No. 1
July 31	5:30 p. m.	Clear	49	14.2	No. 1
July 31	6:30 p. m.	Clear	55	12.0	No. 1
August 1	10:15 a. m.	Cloudy	93	20.8	Sample grade

* J. H. Heilig farm, Brookings, S. D.

Table 14—Effect on moisture content and commercial grades of cutting Durum wheat* at different times of the day.

Date (1928)	Time of day	Weather	Relative humidity	Percent moisture	Commercial grade
August 7	3:45 p. m.	Clear	34	19.6	Sample grade
August 9	2:35 p. m.	Clear	30	17.2	Sample grade
August 11	2:30 p. m.	Clear	37	13.0	No. 1 (1)
August 13	8:00 a. m.	Clear	90	19.0	Sample grade
August 13	9:00 a. m.	Clear	78	17.0	Sample grade
August 13	10:00 a. m.	Clear	75	16.6	Sample grade
August 13	11:00 a. m.	Clear	56	17.0	Sample grade
August 13	12:00 m.	Clear	50	16.8	Sample grade
August 13	2:00 p. m.	Clear	40	16.0	No. 4
August 13	3:00 p. m.	Clear	36	15.0	No. 3
August 13	4:00 p. m.	Clear	34	14.0	No. 1
August 13	5:00 p. m.	Clear	36	13.6	No. 1
August 13	6:00 p. m.	Clear	44	13.8	No. 1
August 13	7:00 p. m.	Clear	65	14.4	No. 2

(1) The grain stood up well August 11. By Apgust 13 it was slightly lodged. This made it necessary to run more of the green weeds through the machine at the later date.

* Morris farm, Brookings, S. D.

Tables 12, 13 and 14 show that the moisture content of standing, ripe grain varies directly with the amount of moisture in the air. This is true also but to lesser degree with shocked grain, as is shown in Table 15. In the case of grain in the shock, variations in moisture content of the grain are less pronounced than with standing grain due mainly to the differences in exposure.

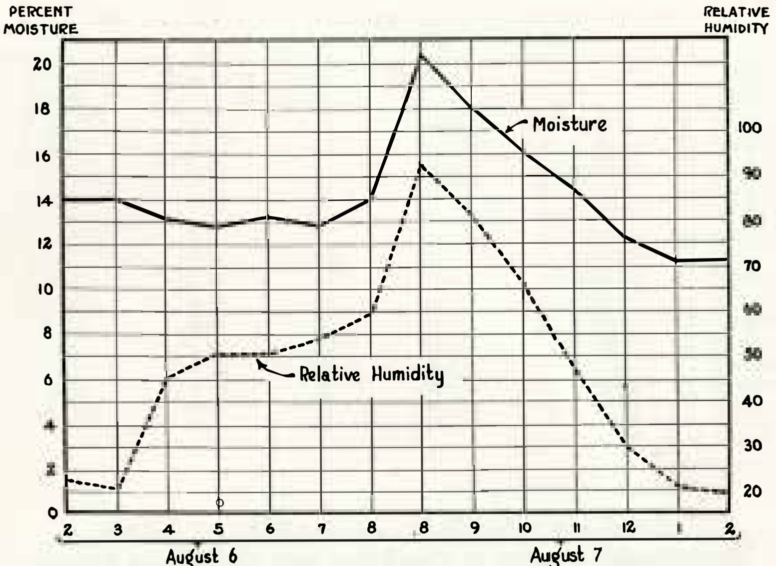


Fig. 8—Effect on the moisture content of cutting oats with combine at different times of the day.
(Based on Table 12)

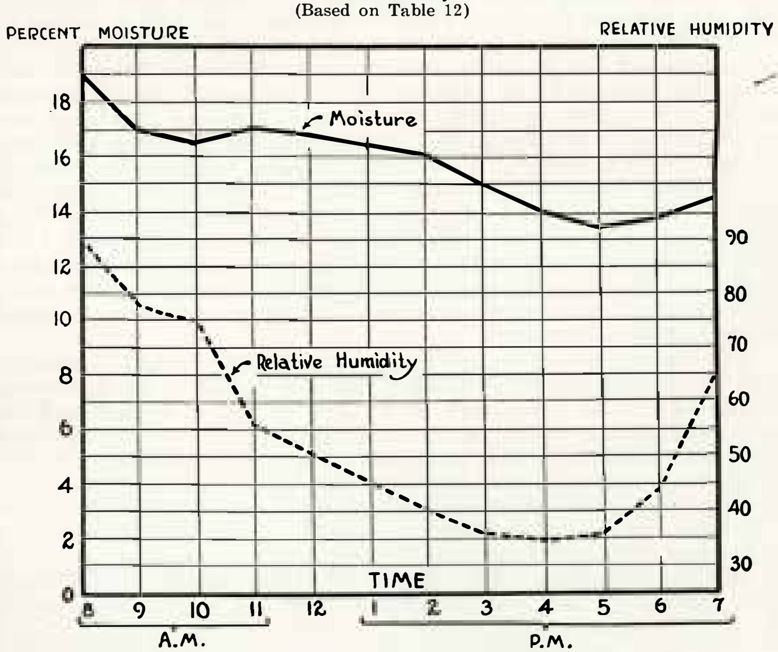


Fig. 9—Effect on the moisture content of cutting wheat with combine at different times of the day.
(Based on Table 14)

Table 15—Moisture content and commercial grades of shocked oats* threshed at different times of the day.

Date (1928)	Time of day	Weather	Relative Humidity	Percent moisture	Commercial garde
August 10	3:00 p. m.	Clear	29	10.0	No. 1
August 10	4:00 p. m.	Clear	35	11.0	No. 1
August 10	5:00 p. m.	Clear	35	11.0	No. 1
August 10	6:00 p. m.	Clear	40	10.4	No. 1
August 10	7:00 p. m.	Clear	45	11.4	No. 1
August 11	7:00 a. m.	Clear	90	12.0	No. 1
August 11	8:00 a. m.	Clear	80	12.8	No. 1
August 11	9:00 a. m.	Clear	70	13.0	No. 1
August 11	10:00 a. m.	Clear	60	13.4	No. 1
August 11	11:00 a. m.	Clear	56	12.0	No. 1
August 11	12:00 m.	Clear	50	13.0	No. 1
August 11	1:00 p. m.	Clear	45	13.0	No. 1
August 11	2:00 p. m.	Clear	45	11.2	No. 1
August 11	3:00 p. m.	Clear	41	11.0	No. 1

(1) On load during night
(2) Loaded 7 a. m.
* College Farm, Brookings, S. Dak.

Moisture Contents and Grades of Grain

Commercial Grades of Combined and Binder-cut Wheat

The main grading factor encountered in the samples under consideration was moisture content. This is apparent from Tables 16 and 17 showing the commercial grades of samples of combined and binder-cut wheat collected. These tables show the same factors as Tables 3 and 4 on moisture content for the separate days of the season. During the early portion of the season and again after the rain on August 16 a large number of samples of combined wheat graded sample grade due to excessively high moisture content. None of the samples in either the combined or binder-cut wheat fall in grade number 5. This is due to the fact that the maximum limits of moisture are the same for both of these grades, namely 16 percent. Much of the wheat grading number 4 and some grading number 3 would upon storage, due to the effects produced by high moisture content, grade either number 5 or sample grade within a comparatively short period of time unless steps were taken to reduce the percentage of moisture.

The rate at which grain carrying an abundant percentage of moisture goes out of condition is influenced by climatic conditions, by the method of storing, by the percentage of cracked or injured kernels and the amount and kind of dockage it contains. The samples of combined wheat contained an average of 4.90 ± .19 percent of cracked and injured kernels while the binder cut wheat contained only 1.86 ± .14 percent of such kernels. The figures for cracked and injured kernels were obtained after the removal of the dockage from the samples. The combined wheat had an average of 3.66 ± .15 and the binder cut wheat an average of 2.53 ± .14 percent of dockage. The dockage consisted mainly of weed seeds, often green weed seeds and small pieces of cracked kernels. Two samples of combined wheat contained 20 and 21 percent of cracked kernels. Out of 204 samples of combined wheat 24 contained 10 percent or more of cracked kernels. Cracked kernels will lead to a more rapid rate of respiration

Table 16—Commercial grades of samples of combined wheat delivered at local elevators at different dates in 1928

Date of Delivery	No. of Samples	Commercial grade					
		No. 1	No. 2	No. 3	No. 4	No. 5	Sample grade
Aug. 1	2						2
Aug. 2	3						3
Aug. 3	15			2	2		11
Aug. 4	25	1	4	5	6		9
Aug. 5	7	2	1	2	2		
Aug. 6	4			2	2		
Aug. 7	2	1					1
Aug. 8	7	6	1				
Aug. 9	32	26	4	1	1		
Aug. 10	19	14	1	2	2		
Aug. 11	5	5					
Aug. 12	1	1					
Aug. 13	14	13	1				
Aug. 14	3	2	1				
Aug. 15	6	4		1	1		
Aug. 17	17		1	2	2		12
Aug. 18	35		6	6	9		14
Aug. 19	2	1		1			
Aug. 22	1			1			
Aug. 24	1	1					
Aug. 29	2						2
Aug. 31	1		1				
Total	204	77	21	25	27	0	54
Distribution on a percentage basis		37.7	10.3	12.3	13.2	0.0	26.5

Table 17—Commercial grade of samples of binder cut wheat delivered at local elevators at differents dates in 1928

Date of Delivery	No. of Samples	Commercial grade					
		No. 1	No. 2	No. 3	No. 4	No. 5	Sample grade
Aug. 1	1			1			
Aug. 4	1	1					
Aug. 6	2	2					
Aug. 7	1				1		
Aug. 10	3	2			1		
Aug. 11	4	4					
Aug. 13	2	2					
Aug. 15	2	1					1
Aug. 18	5			2	3		
Aug. 22	1			1			
Aug. 23	6	2	3	1			
Aug. 24	9	9					
Aug. 25	11	9	2				
Aug. 28	5	2	1	1			1
Aug. 29	6	1	1	2	2		
Aug. 30	8		1		5		2
Aug. 31	6		1	4	1		
Total	73	35	9	12	13	0	4
Distribution on a percentage basis		48.0	12.3	16.4	17.8	0.0	5.5

and in that way cause grain to heat quicker. This shows the importance of proper adjustment of the machine.

The percentage distribution of the commercial grades of the samples of combined and binder cut wheat are shown graphically in Fig. 10. It is interesting to note that 37.7 percent of the samples of combined wheat grade number 1, while 48.0 percent of the binder-cut samples grade number 1. These figures speak well for the utilization of the combine. When, however, the relative percentages of samples falling into sample grade, namely 26.5 for the combined and only 5.5 for the binder-cut wheat are regarded, the same factor, excessive moisture during the early part of the season and following the rain of August 16, comes again into evidence. These figures do not condemn the employment of the combine but they do point out the necessity for caution and judgment on the part of the producer and user of the combine.

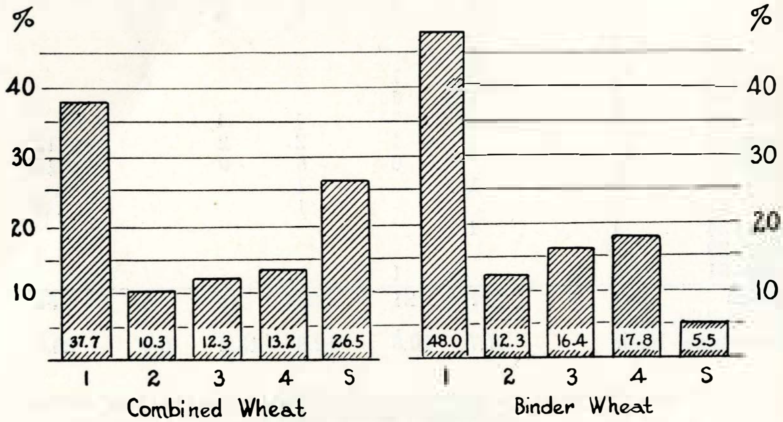


Fig. 10—Percentage distribution of commercial grades of combined and binder cut wheat.
(Based on Tables 16 and 17)

Commercial Grades of Combined and Binder-cut Barley and Oats

Tables 18 and 19 give the commercial grades of samples of combined and binder-cut barley and oats delivered at different dates throughout the harvest season. The percentage distribution of the grades of combined and binder-cut samples is shown graphically in Fig. 11. The main grading factor in barley is color. Number 1 barley may contain 14.5 percent of moisture while grades No. 2, No. 3, and No. 4 may contain not in excess of 15.5 percent of moisture. A high percentage of the samples delivered during the early part of the season and again after the 16th fell into sample grade for the reason that they contained more than 15.5 percent of moisture. This condition resulted in 51.3 percent of the combined barley samples falling in sample grade as compared to 17.9 percent for the binder-cut. It is interesting to note that 42.9 percent of the binder-cut samples graded number 2 as compared to only 12.8 percent for the combined samples. This shows that the color of the binder-harvested barley was generally superior to that of the combined. On

the other hand 10.7 percent of the binder-cut barley fell into grade number 4, due to the presence of stained and weathered kernels. Number 1 barley may be slightly stained; number 2 may be stained; number 3 may be stained or slightly weathered, while grade number 4 may be badly stained or weathered.

Table 18—Commercial grades of samples of combined barley and oats delivered at local elevators at different dates in 1928

		Commercial grade				
Date of Delivery	No. of Samples	No. 1	No. 2	No. 3	No. 4	Sample grade
July 28	1			1		
Aug. 1	2			1		1
Aug. 2	4					4
Aug. 3	11		1	2		8
Aug. 4	4			2		2
Aug. 6	1		1			
Aug. 8	2		1	1		
Aug. 11	3	1		2		
Aug. 13	2	1	1			
Aug. 17	6			2		4
Aug. 18	1					1
Aug. 21	2		1	1		
Total	39	2	5	12	0	20
Distribution on a percentage basis		5.1	12.8	30.8	0.0	51.3

Table 19—Commercial grades of samples of binder cut barley and oats delivered at local elevators at different dates in 1928.

		Commercial grade				
Date of Delivery	No. of Samples	No. 1	No. 2	No. 3	No. 4	Sample grade
Aug. 2	1		1			
Aug. 6	3			2		1
Aug. 11	1				1	
Aug. 13	4		3		1	
Aug. 15	1		1			
Aug. 17	3			1	1	1
Aug. 18	1					1
Aug. 22	3	1	1			1
Aug. 24	2	1	1			
Aug. 25	2		2			
Aug. 28	4	1	2	1		
Aug. 29	1		1			
Aug. 30	1			1		
Aug. 31	1					1
Total	28	3	12	5	3	5
Dstribution on a percentage basis		10.7	42.9	17.9	10.7	17.9

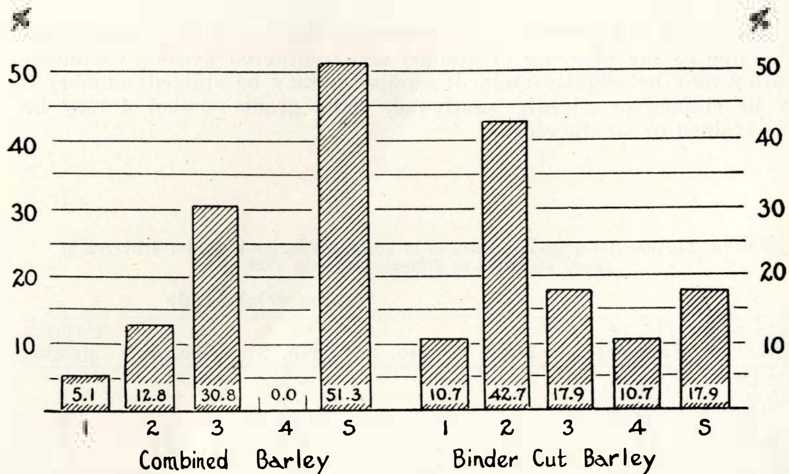


Fig. 11—Percentage distribution of commercial grades of samples of combined and binder-cut barley.
(Based on Tables 18 and 19)

Moisture Content in Relation to Market Price In August, 1928

Method of Sampling, and Source of the 1928 Moisture Samples

As previously mentioned the work was carried on during August, 1928, in Hughes, Sully and Potter counties. Samples of the grain were taken at the local elevators at the time of delivery by farmers. That is, while the grain was being run out of the farmer's wagon or truck into the pit of the grain elevator, a representative sample was taken by now and then dipping into the flowing grain here and there. An eight-ounce sample was taken in an air-tight tin can for the moisture test. A two-quart sample was also taken in a cotton bag. This larger sample was needed for determining the commercial grade of the grain. Both parts of the samples were placed in the same cotton bag, together with a sheet of information regarding that sample. The samples were mailed daily to the Agronomy Department at Brookings for moisture determination and grading. About 400 samples were secured. Sometimes a rain that temporarily terminated all field operations at one place made it necessary to go to another town in order to get samples. There was not, however, any attempt to avoid taking moist samples. In fact samples were taken just as soon as combining was resumed after a rain in order to see what tendency there might be to attempt to market grain containing excessive moisture. In a few cases such grain was refused by some elevators.

Moisture and Price Relationships

The moisture content of grain becomes important only insofar as it involves economic consequences, such as extra risk of spoiling in storage,

or extra cost of conditioning, reduced quality, etc., resulting in lower price. The writer has no evidence of discrimination against combined grain as such on the part of the grain trade. But all good grain men object to handling grain containing excessive moisture. Grain that is so wet as to be certain to heat in the bin will be discriminated against whether is comes from a combine or from a stationary separator. Because of the fact that the combine is a rather recent introduction in the spring wheat area it is perhaps inevitable that some inexperienced operators should have delivered grain of high moisture content. The reaction of the men in the grain trade in connection with the problems created by the increased use of the combine has made it desirable to study the quality of the combined grain in relation to the price paid. Since the outstanding difference between combined grain and grain from stationary threshers seems to be the higher moisture content of the former, the following price discussion will be limited to consideration of variations in price due solely to differences in moisture content.

It is obvious that local prices do not reflect minor variations in the quality of grain as accurately as do terminal market prices. Hence, in order to get data on the relationships between the moisture content and price of grain on the Minneapolis market this matter was taken up with Mr. W. R. Kuehn, marketing specialist of the United States Department of Agriculture, Bureau of Agricultural Economics, Minneapolis, Minnesota. Request was made that the price quotations furnished be such as would disregard every other factor except variations in moisture. Mr. Kuehn very kindly submitted certain price information, based on a "study of prices which prevailed during the month of August, 1928," and on interviews with men in the grain trade. Unless otherwise specified all the following price discussions will be based on these price spreads reported by Mr. Kuehn. On the basis of these premiums and discounts, for grain of low or high moisture content respectively, the results reported in Tables 20 and 22, and Fig. 12, have been worked out.

Table 20—Average relationship betwen moisture content in wheat and the spread in price per bushel on the Minneapolis market during August, 1928.*

Percentage of Moisture	Cents per bushel discount for high moisture contents.		Percentage of Moisture	Cents per bushel premium for low moisture contents	
	Spread	Average		Spread	Average
18%	9c to 12c	10.5c	13-13½%	Base Price	0.0
17	6c to 8c	7.0c	12%	0c to 1c	0.5c
16	4c to 5c	4.5c	11	0c to 2c	1.0c
15	2c to 3c	2.5c	10	1c to 2c	1.5c
14	0c to 1c	0.5c	9	1c to 2c	1.5c
13-13½%	Base Price	0.0	8	1c to 3c	2.0c

* As reported by W. R. Kuehn of the U. S. D. A. Marketing Service.

"The price range has been given only up to 18 percent moisture content as very little wheat arrived showing a higher moisture content. In fact, wheat coming in over 19 percent moisture would be so badly sprouted that it would have very little commercial value.

In arriving at the above table, the matter of grade changes with different moisture contents was also taken into consideration. For instance, the maximum for No. 1 spring wheat is 14 percent; No. 2, 14.5 percent; No. 3, 15 percent; and No. 4, 16 percent."

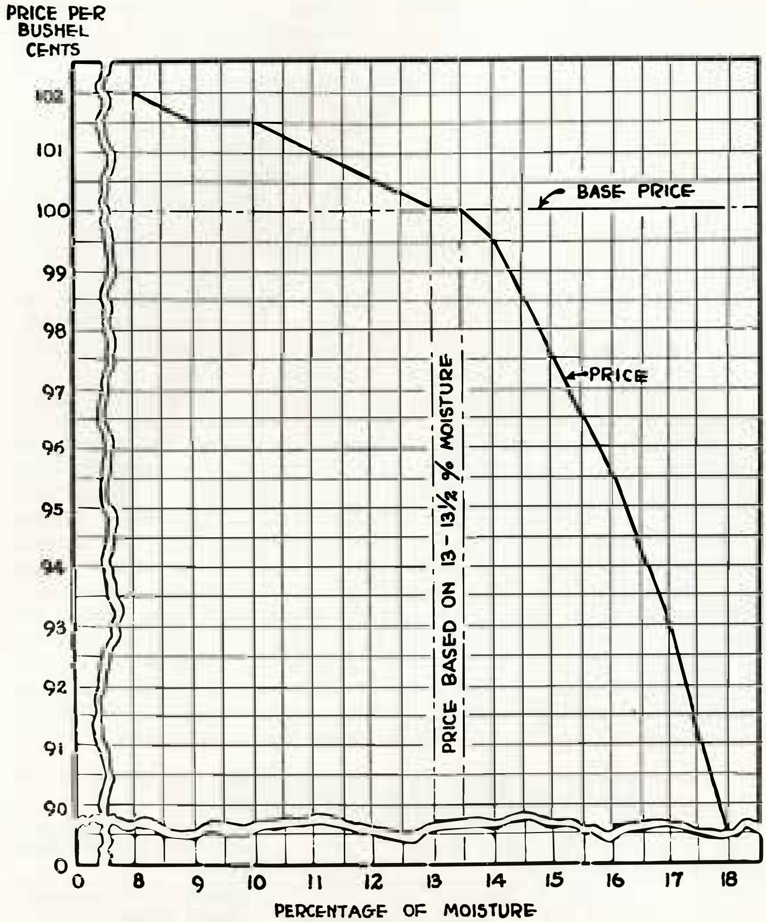


Fig. 12—Relationship between moisture content and price of wheat based on the Minneapolis price spreads, August 1928. $1.00 per bushel assumed as the base price.
(Based on Table 20)

As indicated in Table 20 above and in Fig. 12 and the upper section of Fig. 14, it will be seen that the premium for grain of lower moisture content than the base, 13 to 13.5 percent is porportionally smaller than the discount on grains having a moisture content an equal number of degrees above the base, 13.5 percent. That is, the extra dry wheat was not rewarded to the same extent that the overly damp grain was penalized. It is, of course, obvious that there are certain risks and expenses involved in connection with the storing and handling of wheat having a moisture content considerably above 14 percent and these are naturally reflected in a correspondingly lower price.

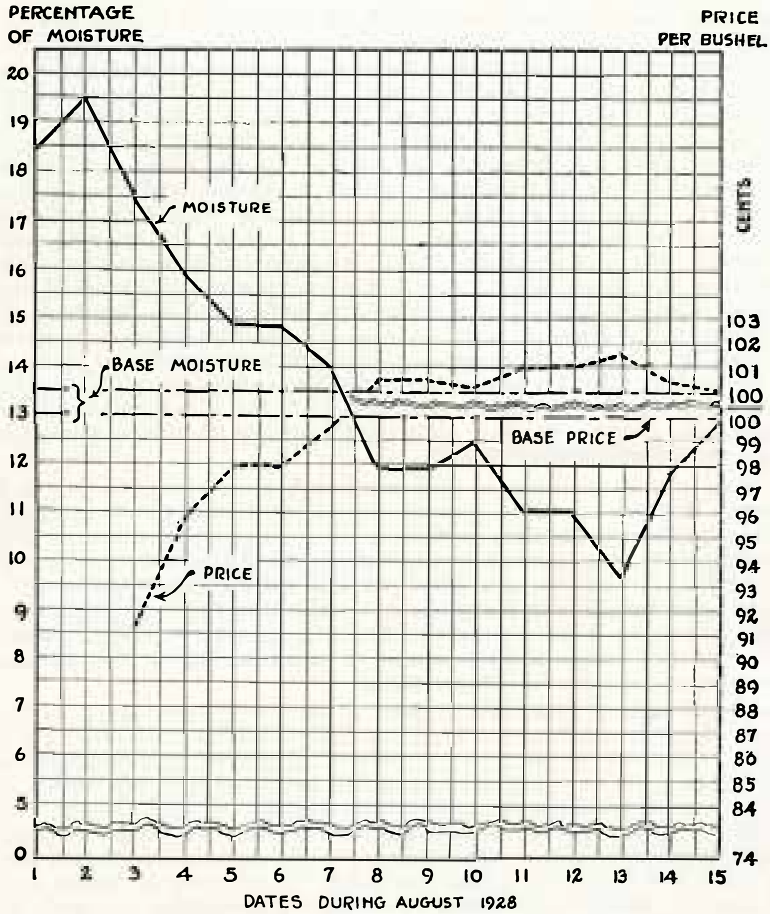


Fig. 13—Variations in the price of wheat combined at different dates in August, 1928, caused by average daily variations in moisture content. $1.00 per bushel assumed as the base price.
(Based on Tables 2 and 20)

In Fig. 13 there is a comparison between the average moisture content of samples of combined wheat collected each day during the first half of August, 1928, with an assumed market price. That is, if the base price had been $1.00 for grain of the base moisture content, 13 to 13½ percent, and the premiums and discounts previously mentioned were used, Fig. 13 like Table No. 20 and Figs. 12 and 14, illustrate the fact that the penalty for very moist grain is larger than the premium for correspondingly dry grain. It also indicates that a loss in price was sustained on wheat that was combined early in the season before the grain had become sufficiently dry.

The foregoing tables and figures, however, do not give a sufficient basis for decision as to what time to combine wheat. In Table 21 are

presented some additional data showing hypothetically the net gain or loss from marketing wheat containing different degrees of moisture. Let us assume that the uncut grain is found to contain 18 perecent moisture, and that the question to decide is when to combine. Disregarding here the question of whether the local elevator would take this grain or not, let us see what price the farmer would get. We will base our price spread on Table No. 20 but we will assume that the base price is $1.00 per bushel for wheat containing between 13 percent and 13.5 percent moisture. Thus, for example, wheat containing 18 percent moisture would sell for $0.89½ per bushel, and if the moisture content were only 8 percent the price would be $1.02. Superficially it would seem that the drier the wheat the more desirable and profitable because of the higher price received. The market price per bushel on the basis of moisture, taken alone, however, may be a misleading guide as to when to combine. According to agronomists there is no growth or increase in dry weight after the wheat has reached a maturity stage of 18 percent moisture. Hence the computations in Table 21 are based on the assumption that the standing grain does not grow after having reached that stage af maturity.

Sixty pounds of wheat of 18 percent moisture content contains 10.8 pounds of moisture. 13½ percent wheat has 8.1 pounds of moisture. Hence, in drying the sixty pounds of 18 percent wheat down to 13.5 percent the loss of moisture is 10.8 pounds less 8.1 pounds or a loss of 2.7 pounds. That is, the quantity of wheat which formerly weighed sixty pounds now weighs only 57.3 pounds. It will, therefore, be necessary to add 2.7 pounds of other wheat containing 13½ perecent moisture in order to have a full bushel of sixty pounds of wheat containing 13½ percent moistune, and selling at $1.00 per bushel.

The 18 percent wheat had a price of 89½ cents per bushel so the farmer is getting 10½ cents more per bushel for his 13½ percent dry wheat. However, to the sixty pounds of 18 percent wheat, which he dried down to 57.3 pounds, he must add 2.7 pounds of 13½ percent wheat from some other source in order to get a bushel of sixty pounds. At $1.00 per bushel these 2.7 pounds are worth or cost 4½ cents. In other words, the farmer gained 10½ cents per bushel in price but it cost him 4½ cents per bushel to replace the weight of the moisture which was evaporated. Hence the net gain as a result of permitting the grain to dry from an 18 percent moisture content to a 13½ percent moisture content is 10½ cents minus 4½ cents or 6 cents per bushel.

It will be noted in Table 21 that, at $1.25 per bushel base price and using the same discounts for high moisture content, it apparently does not pay to dry the wheat much below a 14 percent moisture content. It is obvious that it becomes less profitable, at these price spreads, to dry the grain when the price is high. On the other hand it is also quite certain that these premiums and discounts for moisture will vary with changes in the market price. They could, perhaps, best be expressed as a certain percentage deviation from the base price.

If the grain is to be dried below the base, 13 percent moisture, the loss of weight from evaporating the moisture must be replaced by grain of the same moisture content as that at which the grain is to be sold. Table 21 shows that drying wheat from a 13 percent to an 8 percent moisture content results in a loss of three pounds. This has to be replaced with

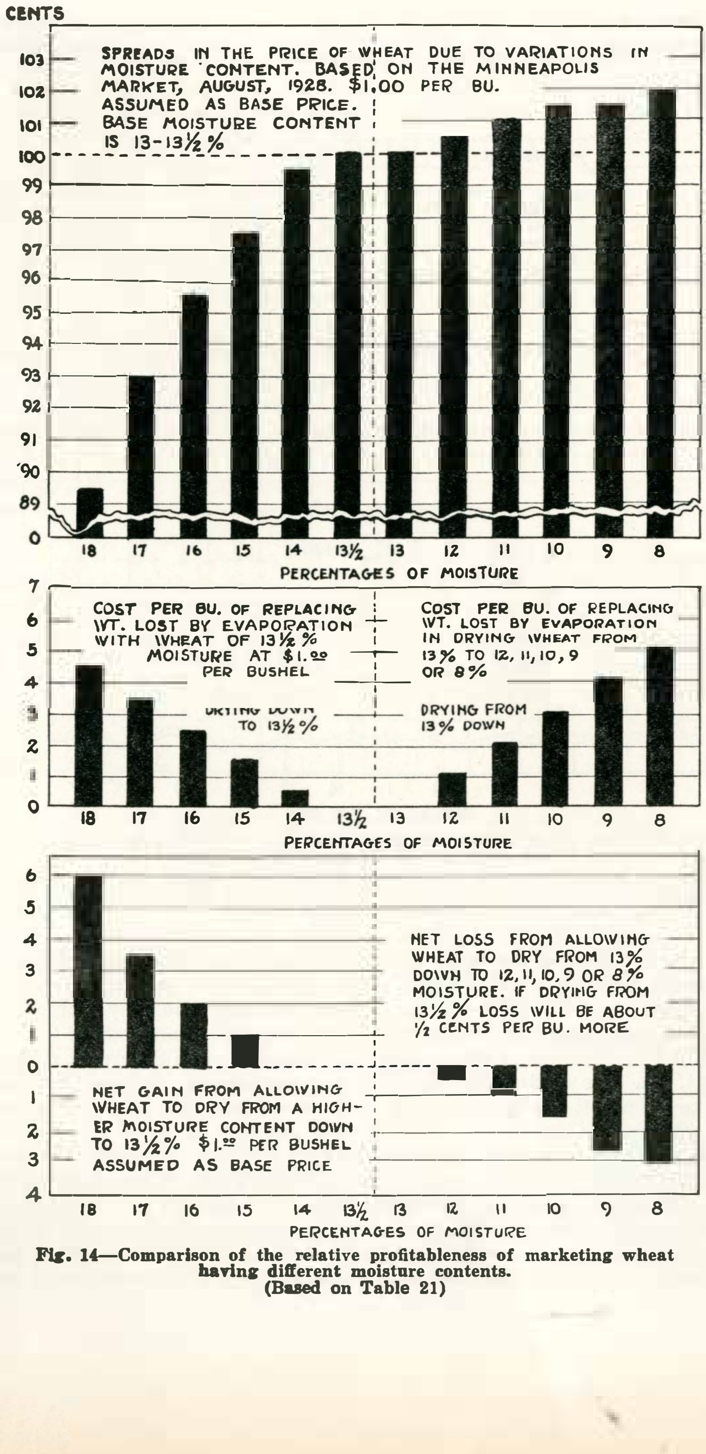


Fig. 14—Comparison of the relative profitableness of marketing wheat having different moisture contents. (Based on Table 21)

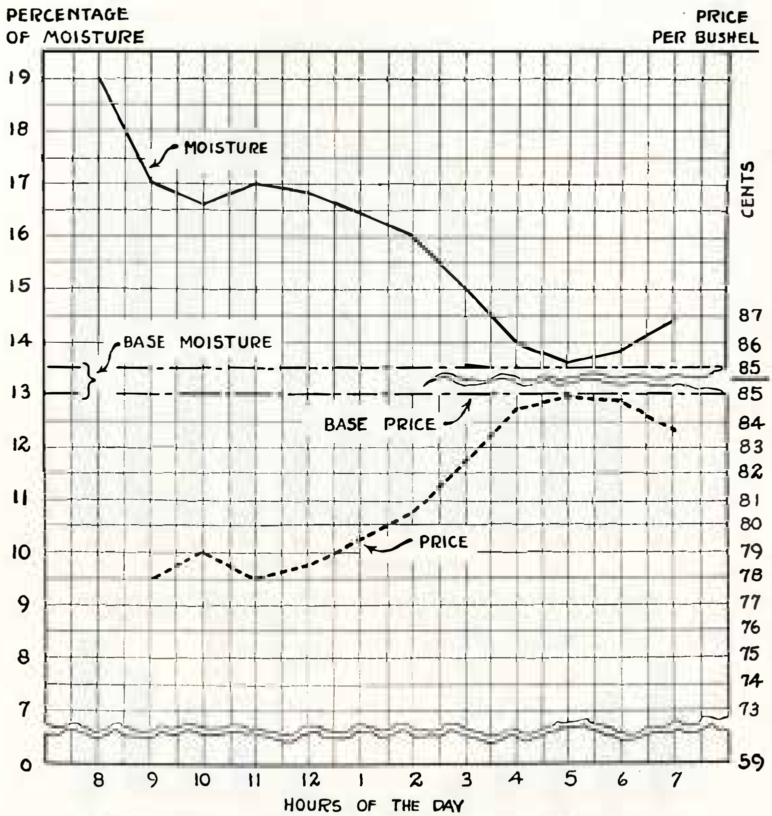


Fig. 15—Comparison of moisture content and price of durum wheat combined at different hours of the day, August 13, 1928.*

* The base price, 85 cents per bushel, was the price at Brookings for No.1. Amber Durum that date, but the spreads for moisture are based on the Minneapolis market for August, 1928, as shown in Table 20. Moisture from Table 14.

grain worth $1.02 per bushel, assuming a base price of $1.00 per bushel or 1.7 cents per pound. The farmer would gain 2 cents per bushel in price, but it would cost him 5.1 cents to replace the weight lost by evaporation. Hence he sustains a loss of 5.1 cents less 2 cents or a net loss of 3.1 cents per bushel in drying this wheat from a 13 percent to an 8 percent moisture content. In case of drying from 13½ percent instead of from 13 percent down to 8 percent the loss would be about one-half cent per bushel more at the $1.00 base price.

The conclusion to be drawn from the data in Table 21 would seem to be that the spreads in the price of wheat in Minneapolis during August 1928 due to difference in moisture content were such that it did not pay the farmers to allow the wheat to become any dryer than just enough to make it safe for storage. It also seems to show that the loss due to selling moist grain was less than the difference in price per bushel between moist grain

Table 21—Comparison of the net gain or loss from marketing wheat having different percentages of moisture.
(Indicated base price used with the average discounts which prevailed on the August, 1928, Minneapolis market for moisture contents above the 13.5% base and premiums for moisture content below 13%)*.

Percentage of Moisture	Weight of moisture per 60-lb. bushel of wheat	Result of drying a bu. down to 13.5% moisture and below 13 percent.		Price per bushel at indicated base prices.			Price per pound for replacing weight lost by evaporation			Cost of replacing the weight of evaporated moisture with grain of 13.5% moisture at the following prices per bushel:			Average variation from base price due to moisture.	Net gain or loss in cents per bushel from drying the wheat to 13.5 percent at the following prices per bushel.**		
		Lbs. remaining.	Lbs. Lost by drying	Base Prices $1.25	$1.00	$0.75	Prices per bushel $1.25	$1.00	$0.75	$1.25	$1.00	$0.75		$1.25	$1.00	$0.75
%	Lbs.	Lbs.	Lbs.	$	$	$	¢	¢	¢	¢	¢	¢	¢ per bu.	¢	¢	¢
18	10.80	57.30	2.70	1.14½	.89½	.64½	1.908	1.491	1.075	5.62	4.5	3.375	-10.5	4.9	6.0	7.13
17	10.20	57.90	2.10	1.18	.93	.68	1.966	1.550	1.133	4.37	3.5	2.625	- 7.0	2.63	3.5	4.4
16	9.60	58.50	1.50	1.20½	.95½	.70½	2.008	1.591	1.191	3.12	2.5	1.875	- 4.5	1.38	2.0	2.625
15	9.00	59.10	0.90	1.22½	.97½	.72½	2.041	1.625	1.208	1.87	1.5	1.125	- 2.5	0.63	1.0	1.375
14	8.40	59.70	0.30	1.24½	.99½	.74½	2.075	1.658	1.241	0.625	0.5	0.375	- 0.5	-.125	0	.125
13.5	8.10			$1.25	$1.00	$.75	2.083	1.666	1.250	Cost of replacement with grain below 13%.				Loss due to drying wheat from 13 percent down to indicated dryness.***		
13.0	7.80															
12	7.20	59.30	0.60	1.25½	1.00½	.75½	2.091	1.675	1.258	1.25	1.01	0.75	0.5	-0.75	-0.51	-0.25
11	6.60	58.80	1.20	1.26	1.01	.76	2.100	1.683	1.266	2.52	2.02	1.52	1.0	-1.52	-1.02	-0.25
10	6.00	58.20	1.80	1.26½	1.01½	.76½	2.108	1.691	1.275	3.79	3.04	2.30	1.5	-2.29	-1.54	-0.80
9	5.40	57.60	2.40	1.26½	1.01½	.76½	2.108	1.691	1.275	5.06	4.06	3.06	1.5	-3.56	-2.56	-1.56
8	4.80	57.00	3.00	1.27	1.02	.77	2.117	1.700	1.283	6.35	5.10	3.85	2.0	-4.35	-3.10	-1.85

* Based on discounts in Table 20.
** Disregards possible gain in weight from growth, and assumes no cost for drying.
***The loss due to drying from 13½ percent to 13 percent has not been considered here, but would amount to about one-half cent per bushel at the $1.00 base price. Hence the losses given in this table would be about one-half cent per bushel more if drying from the 13½ percent base down. Discounts and losses are preceded by minus (-) signs.

and very dry grain. This data is shown graphically in Fig. 14.

In Fig. 15 is shown the change in moisture content of durum wheat due to being combined at different hours of the day, August 13, 1928. The price per bushel for the corresponding hour and moisture content is also shown. This price was the local price in Brookings of No. 1 Amber Durum that day. The same base, 13 to 13½ percent moisture is used, and the premiums and discounts are the same as those previously discussed. It will be noticed that on this particular day it was not until 4:00 p. m. that the grain was sufficiently dry to be safe for storage. This was not necessarily a typical day as regards the hour when the grain became sufficiently dry to be safe for storage. However, there normally is a tendancy for the moisture content of standing grain to decline from morning until late afternoon. The extent of this drying process will vary with the climatic conditions. A heavy dew or a rain during the night followed by good drying weather will result in a very marked decline in moisture content. During a period of dry, hot weather, such as prevailed between the 6th and the 15th of August, 1928, in the central part of the state, the grain will have a safe moisture content even quite early in the forenoon. After some experience in combining, and with a knowledge of the keeping qualities of the grain and the price discounts for moisture, each operator can judge for his own situation how long he can afford to wait for the grain to dry.

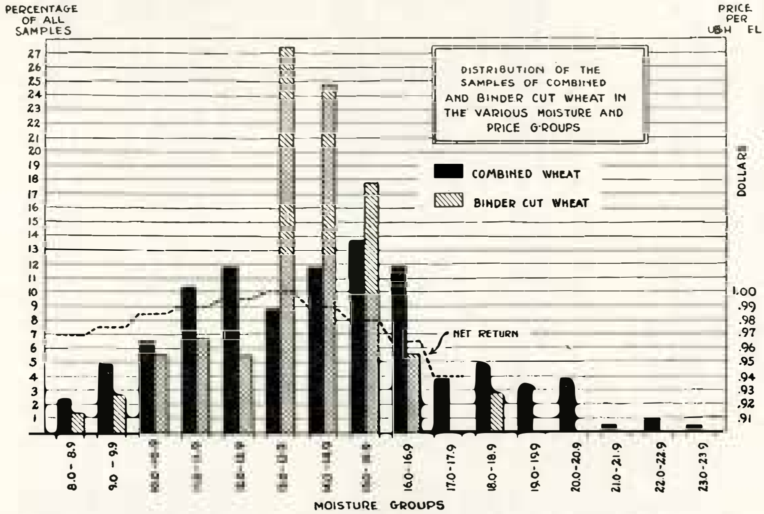


Fig. 16—Comparison of binder-cut and combined wheat as to the percentage of the samples falling in different moisture groups, and as to the net returns from the high and low moisture groups in comparison with the base price.*

* $1.00 assumed as the base price for grain of 13 to 13½ percent moisture. The spreads in price are based on the Minneapolis market for August, 1928, as shown in Tables 20 and 21. Moisture from Tables 3 and 4.

Fig. 16 shows graphically the difference in the proportion of combined wheat and of binder-cut wheat falling in the various moisture groups. It also shows the relative profitableness of marketing wheat containing different percentages of moisture, on the basis of the price spreads previously discussed. The curve of net return indicates, as does Table 21 and Fig.

14, that a loss was sustained, on the basis of the price spreads used, from marketing grain both below and above the base moisture content. In the extra dry grain the loss in weight due to loss of moisture was not entirely compensated by the higher price. The loss from marketing moist grain was not as great as the difference in the market price between wheat at the base moisture content and wheat of higher moisture contents, up to 18 percent. This is due to the fact that the discount for excess moisture was not quite large enough to offset the weight of moisture. This Fig. 16 also visualizes the comparative moisture condition of the combined and binder-cut wheat samples. It will be seen that, of the two kinds of samples secured, a much larger proportion of the binder-cut samples falls in or near the base moisture class. In other words, a larger percentage of the binder-cut samples falls in or near the group netting the farmers the highest return. Furthermore in the case of the samples of combined wheat a larger percentage fell in the extra moist class group for which no price quotations were secured. Naturally the price for this wet grain would be still lower. It is also seen that a larger proportion of the combined wheat falls in the moisture group below 13 percent. In the case of extremely dry grains this was a disadvantage rather than an advantage, because the premuims were not large enough to compensate for the weight lost through evaporation.

Thus far the binder-cut grain has averaged of better quality. The farmer will naturally consider the cost of field operations as well as the quality and price of the grain before making a choice of harvesting methods.

Table 22 shows the discounts below the base price for flax, barley and oats in cases of moisture contents above the base. No premiums were quoted for extra dryness in any of these grains.

Table22.—Price discounts in cents per bushel of flax, barley and oats due to excess moisture content. Average for August, 1928, on the Minneapolis market.*

FLAX Relationship between price and moisture content.		BARLEY Discount in price per bushel due to excess moisture content.		OATS Discount in price per bushel due to excess moisture content.	
Moisture Percent	Discount Per Bu.	Moisture Percent	Discount Per. Bu.	Moisture Percent	Discount Per Bu.
13	11c	18	5-7c	16	1-2c
12	7c	17	3-5c	14½	base
11	4c	16	2-3c		
10	2c	15	1-2c		
9	1c	14	base	The base, 14½, is the maximum allowed in grades, 1, 2 and 3.	
8)					
7) base		Av. of feed and malting grades			
6)					
5.4)					

FLAX: "Moisture did not show up as a factor until a content of over 8 percent was reached As 11 percent moisture is the maximum allowed in No. 1 flax, anything over that percentage would throw it into Sample Grade and discounts, therefore would be greater after the 11 percent mark was passed.

BARLEY: "Up to 14 percent moisture content, moisture would not be a factor . . . This range is made on the average for feed and malting grades. If barley was malting type, the discounts for heavier moisture content would be somewhat more than the above table, while discounts on strictly feed grades would be less."

OATS: "Moisture content has been of little importance in determining price of oats on this crop."*

*** According to information furnished by Mr. W. R. Kuehn, U. S. D. A.**

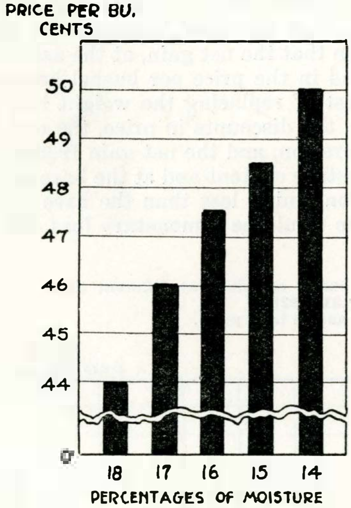
Table 23—Comparison of the net gain or loss from marketing barley having different amounts of moisture.
(Indicated base prices used with average discounts which prevailed on the August, 1928, Minneapolis market for moisture content above the 14 percent base)*

Percentage of moisture	Weight of moisture per 48-lb. bushel of barley.	Result of drying a bushel down to 14 percent moisture.		Price per pound of 14% barley for replacing weight lost by evaporation.				Cost of replacing the weight of evaporated moisture with grain of 14% moisture at following prices per bushel				Av. discount in price per bushel for moisture in excess of 14%.	Net gain (cents per bushel) from drying the grain to 14% moisture at following prices per bushel.**			
		Lbs. remaining.	Lbs. lost by drying	Prices per bushel $0.40	$0.50	$0.60	$0.70	$0.40	$0.50	$0.60	$0.70		$0.40	$0.50	$0.60	$0.70
%	Lbs.	Lbs.	Lbs.					c	c	c	c	c	c	c	c	c
18	8.64	46.08	1.92					1.60	2.00	2.40	2.80	6	4.40	4.00	3.60	3.20
17	8.16	46.56	1.44					1.20	1.50	1.80	2.10	4	2.80	2.50	2.20	1.90
16	7.68	47.04	0.96	Prices per pound				0.80	1.00	1.20	1.40	2½	1.70	1.50	1.30	1.10
15	7.20	47.52	0.48	c	c	c	c	0.40	0.50	0.60	0.70	1½	1.10	1.00	0.90	0.80
14=base	6.72	48.00		0.833	1.04	1.25	1.46									

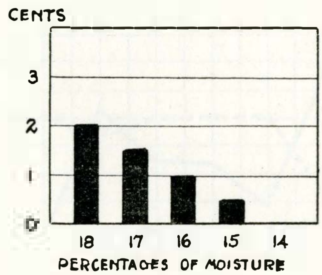
Since no premiums were quoted for barley of less than the 14 per cent base moisture content it is obvious that the loss due to drying below the base would be greater. The loss in weight due to evaporation would have to be replaced by dry grain, but there would be no added reward for this extra dryness.

* Based on the discounts for barley in Table 22.
** Disregards possible gain in weight from growth, and assumes no cost for drying.

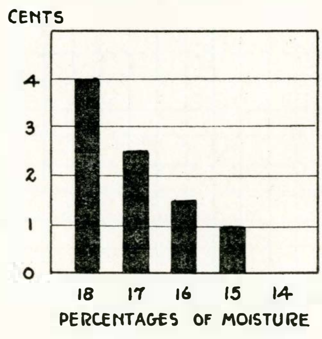
Fig. 17—Comparison of the relative profitableness of marketing barley having different moisture contents.*



Spreads in the price of barley due to variations in moisture content.*



Cost per bushel of replacing with barley the weight of evaporated moisture in drying down to 14 percent moisture content.

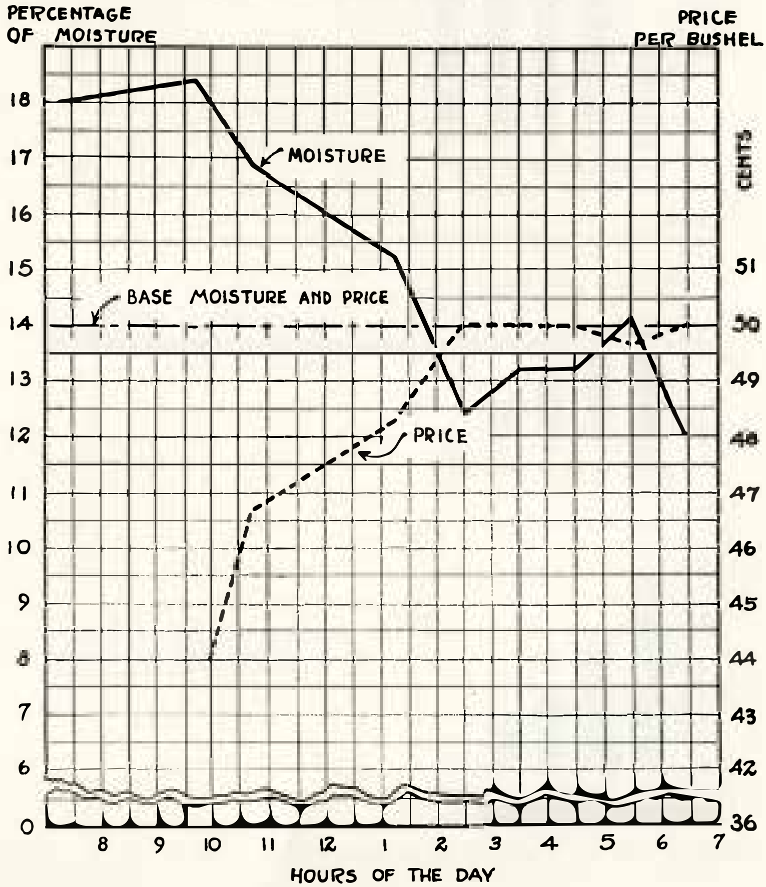


Net gain per bushel from allowing barley to dry from the indicated moisture content down to 14 percent.

* Based on Table 23 ; 50 cents per bushel assumed as the base price.

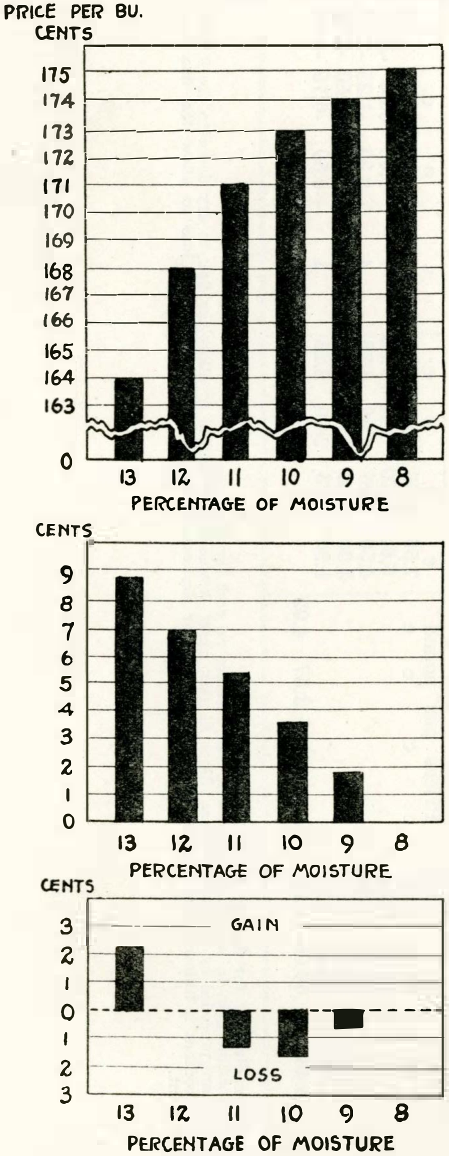
In Table 23 is presented the data necessary for computing the net gain as a result of drying the barley to base dryness from some higher moisture content. The method is the same as that discussed in connection with wheat, in Table 21. Here also it is shown that the net gain, at the assumed base prices is not as great as the spread in the price per bushel between moist and dry barley because of the cost of replacing the weight lost by evaporation. Fig. 17 shows graphically the discounts in price, the cost of replacing the weight lost through evaporation, and the net gain from drying barley so as to sell it at the base moisture content and at the base price. No premuims were quoted for barley containing less than the base moisture content of 14 percent. Hence there would be a monetary loss due to drying below this point.

Fig. 18—Moisture content and price of barley combined at different times of the day, July 31, 1928.*
50c per bushel assumed as the base price.



*Discounts for moisture based on Table 23.

Fig. 19.—Comparative returns from marketing flax having different moisture content*.
$1.75 per bushel assumed as the base price.



Spreads in the price of flax due to the variations in moisture content.*

Cost per bushel of replacing with flax the weight lost by evaporation in drying down to the 8 percent moisture content.

Net gain or loss per bushel from allowing flax to dry from the indicated moisture content to the 8 percent base.

* Based on Table 24.

Table 24—Comparison of the net gain or loss from marketing flax having different percentages of moisture.
(Indicated base prices used with the above discounts which prevailed on the August, 1928, Minneapolis market for moisture content above the 8% base)*

Percentage of moisture	Weight of moisture per 56-lb. bushel of flax	Result of drying a bushel down to 8 percent moisture		Price per pound of 8% flax for replacing weight lost by evaporation.				Cost of replacing the weight of evaporated moisture with 8% flax at following prices per bushel.				Discount in in price per bu. for moisture in excess of 8%	Net gain or loss (cents per bushel) from drying the flax to 8% moisture content at following prices per bushel.**			
		Lbs. re-maining	Lbs. Lost by drying	Prices per bushel $1.50	$1.75	$2.00	$2.25	$1.50	$1.75	$2.00	$2.25		$1.50	$1.75	$2.00	$2.25
%	Lbs.	Lbs.	Lbs.	Prices per pound				c	c	c	c	c	c	c	c	c
13	7.28	53.20	2.80	c	c	c	c	7.50	8.75	10.00	11.26	11	3.50	2.25	1.00	-0.26
12	6.72	53.76	2.24					6.00	7.00	8.00	9.00	7	1.00	0.00	-1.00	-2.00
11	6.16	54.32	1.68					4.50	5.25	6.00	6.75	4	-0.50	-1.25	-2.00	-2.75
10	5.60	54.88	1.12					3.00	3.50	4.00	4.50	2	-1.00	-1.50	-2.00	-2.50
9	5.04	55.44	0.56					1.50	1.75	2.00	2.25	1	-0.50	-0.75	-1.00	-1.25
8% to 5.4= base.	4.48	56.00	0.00	2.68	3.125	3.57	4.02									

* Based on the discount for flax in Table 22.
** Disregards possible gain in weight from growth, and assumes no cost for drying.
The net losses are preceded by minus (-) signs. Since in most cases it was not profitable to allow the flax to dry down to the 8 percent base moisture content it follows that, with no premiums for greater dryness, it would involve additional loss to allow the flax to dry below this point.

Fig. 18 shows that the barley cut in the morning had a higher moisture content, and consequently a lower price, than that which was combined in the afternoon.

Table 24 shows in detail the discounts for moist flax, the cost of replacing with dry flax the weight lost through evaporation of moisture, and the net gain or loss from drying flax down to the base moisture content. The prices per bushel used are assumed, but the spreads in price for the various moisture content are the discounts in effect on the Minneapolis market during August, 1928, as reported by Mr. W. R. Kuehn, Marketing Specialist of the U. S. Department of Agriculture. Fig. 19 shows the same data graphically. At the price spreads reported, and assuming $1.75 as the base price per bushel, it was not profitable to dry the flax down to the 8 percent base, except in the case of 13 percent moisture. Since no premuims were quoted for extra dry flax it would have involved added loss to have dried it below the 8 percent base.

Comparative Costs of Harvesting and Threshing By Different Methods

Although the data on the cost of combining, secured from the South Dakota operators in October, 1927 apparently were based on estimates rather than on exact records it may be of interest to see what they indicate, bearing in mind that they may be only approximately correct. Interest and depreciation costs, on a per acre basis, will naturally vary with the acreage cut each year. For this reason Table 25 following, is presented showing the acreage cut by each machine on which such information was secured.

Table 25—Acres Reported Combined in 1927

Operator	Size of Machine	Year Purchased	Acres cut 1927
1	16'	1925	1420
2	16'	1925	1500
3	16'	1926	935
4	16'	1926	1000
5	15'	1926	660
6	16'	1927	1470
7	20'	1927	890
8	16'	1927	2040
9	16'	1927	1100
10	15'Two Machines	1927	3000
11	12'	1927	160
12	12'	1927	175
13	12'	1927	210
14	9'	1927	350

The seven 16 ft. and the three 15 ft. combines averaged 1312 acres each during 1927 according to above reports. This is a much larger acreage per combine than can be expected as an annual average. All the combines were equipped with auxiliary motors. All used tractors for motive power, and trucks for hauling the grain.

The detailed figures on costs of operation each separate combine on which fairly complete data were secured are given in Table 26. These costs are all based on direct combining; no windrowing or pick-up devices were used.

Table 26.—Cost of combining, as reported by nine South Dakota operators in 1927.

Operator	Size of machine	Year Purchased	WAGES PER DAY $ Truck Driver	Tractor Operator	Combine Operator	Days worked 1927	Cost of Repairs & Labor $	Gallons of Gas per acre Tractor	Combine	Gallons oil per day Tractor	Combine	lbs grease per day Tractor	Combine	Estimated life of Combine in years	Acres cut 1927
1	16'	1925	$3.50	$3.50	$		$125.00 #10.50	.75	.75	.75	1.25	.		7.5	1420
2	16'	1925	6.00	6.00	4.00		#12.00 100.00	.75	.75	2.50	2.50	1.0	1.0	7	1500
3	16'	1926	4.00 5.00	4.00	3.00 3.00		75.00 #20.00	1.00	1.00	1.50	1.00	.5	.5	10	650
4	16'	1926	5.00	4.00		40	50.00 # 1.00	.50	.50	.25	.25			11	1000
5	15'	1926	6.00	4.00		18	30.00 # 6.00	.93	.73	1.25	1.00	1.0	2.0	9	660
6	16'	1927	5.00	4.00	4.00	40	25.00 # 5.00	.61	.41	.62	.37	.25	.25		1470
7	20'	1927	5.00	4.50			25.00 #18.00	1.75	1.25	1.50	1.00			7.50	890
8	16'	1927	10.00	4.50	3.00		10.00 # 5.00	.45	.45	1.00	1.00	.4	.6	[illegible]	2040
9	16'	1927	5.00* 5.00	4.00		40	8.00 # 2.00	.83	.50	.75	1.00	1.0	1.5	[illegible]	1100
Average			6.61	4.28		34.5	49.22 # 8.83	.84	.70	1.12	1.04	.69	.98	7.87	1192

* Unpaid labor of farmer operator.
# Labor cost of making repairs.

Gas is figured at 15 cents per gallon, lubricating oil at 75 cents per gallon, and grease at 10 cents per pound. It is possible that for most years gas would cost more than 15 cents per gallon even after the state gas tax has been refunded.

Taking 34.5 days as the average length of the combine season and dividing this into the 1192 acreage we get 34.55 as the average number of acres cut per day. This is perhaps a larger daily acreage than the average actually cut considering the short days late in the season, and the delyas caused by morning dews, rains, etc. Eight hours of actual work as the average day would result in about 30 acres as the average daily acreage cut. This is perhaps about right and the following cost will be computed on that basis. N. Dak. Bul. 220 COMBINE HARVESTING IN NORTH DAKOTA, page 10 gives 7.1 hours as the actual hours worked per day. Table 14, page 18, U. S. D. A. Technical Bul. No. 70 THE COMBINED HARVESTER-THRESHER IN THE GREAT PLANS gives the acreages cut per hour per foot of width as .22 to .24 acres for machines of the size here considered.

It will be seen that there were quite wide variations in the cost of some items as reported by the various operators.

Computing the daily and per acre cost of combining on the foregoing basis, and distributing the annual depreciation and interest charges over 1192 acres, the results presented in Table 27 are obtained.

Table 27—Cost of Operating Combine

	Cost Per Day	Cost Per Acre
Wages of Combine operator	$6.61	$0.22
Wages of Tractor operator	4.28	.14
Repairs, parts (1927 season $49.22)		
Repairs, wages (1927 season $8.83) combine	1.46	.05
Repairs and upkeep of Tractor[1]	1.16	.04
Gas for tractor	3.78	.13
Gas for auxiliary motor	3.15	.10
Oil for Tractor	.84	.03
Oil for auxiliary and combine	.78	.03
Grease for tractor	.07	.00
Grease for auxiliary and combine	.10	.00

Depreciation on combine 1-7 of $2300 each year equals $328.57 per year, or per acre	.28
Interest on combine, 6% on ½ of $2300 each year equals $69 per year, or per acre	.06
Depreciation on Tractor ⅛ of $1300 each year equals $162.50 per year	
Interest on Tractor, 6% on ½ of $1300 equals $39 per year	
Annual Tractor Cost equals $201.50	
Charging ½ of the annual tractor cost to the combine operation—$100.75, or per acre	.09
Total per acre cost of combining in 1927 as reported by 9 South Dakota operators.	$1.17

1* From Table 4, U. S. D. A. Farmers Bulletin No. 1297, Cost of Using Tractors on Corn Belt Farms.

Since no information was secured showing how much other work was performed by the tractor an estimate had to be made. In justification of the assumption that pulling the combine during the harvest was only one-half of the total work performed by the tractor, the following data in Table 28 are submitted.

Table 28—Acreage Operated and Power Owned

Operator	Acres Operated	Tractor	Work Horses
1	480	2	
2	700	1	
3	1500	1	10
4	640	3	5
5	800	3	23
6	1700	2	
7	900	1	
8	620	3	
9	450	1	
Totals	7790	17	38

It appears from the foregoing figures that most of these combine owners are tractor farmers. Plowing would require about 4½ times the power required for pulling the combine. In addition, discing, harrowing and seeding would require considerable tractor power. From this it would seem that the tractor may have been used for other work fully as much as for combining, and hence only one-half of the annual charges for tractor use should be computed as a part of the cost of harvesting with the combine.

Because of the fact that the 1927 South Dakota figures on the cost of operating the combine are based on such a small number of reports from users, it may be desirable to make comparison with data based on more extensive investigations. Table 29 partly adapted from U. S. D. A. Technical Bulletin 70, "The Combined Harvester-Thresher in the Great Plains", makes it possible to make such comparison.

Table 29—Comparative Costs of Harvesting and Threshing vs. Combining

Item of Cost	Per Acre Charges							
	U. S. D. A. Figures						S. D. FIG.	
	7 ft. Binder		12 Foot. Header		15 ft. Com.		16 ft. Com.	
	Quantity	Cost	Qu.	Cost	Qu.	Cost	Qu.	Cost
Man labor 2 man hours	3.6	1.80	2.8	1.40	0.65	0.39	.53	.36
Horse labor 3 horse hours	5.9	.59	4.1	.41				
Tractor Repairs 4						.04		.04
Fuel5 gallons					1.43	.36	1.54	0.23
Oil5 gallons					.05	.04	.07	.05
Grease pounds					.05	.01	.06	.01
Twine 6 pounds	2.00	.28						
Repairs on Combine, etc.		.05		.05		.10		.05
Threshing 7		1.50		1.50				
Variable Costs		4.22		3.36		.94		.74
	Per Acre Cost of Annual charges, pro-rated on given acreages.							
	An'u'l Ch'ge	Cost per A 250A	An'u'l Ch'ge	Cost per A 480A	An'u'l Ch'ge	Cost per A 574A	An'u'l Ch'ge	Cost per A 1192A
Depreciation 8	22.50	.09	13.33	.03	251.00	.44	328.57	.28
Interest 9	6.75	.03	6.00	.01	62.52	.11	69.00	.06
Depreciation on Trac. 10					81.25	.14	81.25	.07
Interest on Tractor 11					18.50	.03	18.50	.02
Annual cost per acre		.12		.04		.72		.43
Sum of variable and Annual cost per acre		4.34		3.40		1.66		1.17
Cost per bushel at 15 bushels per acre		.29		.23		.11		.08

1 Adapted from Table 26, p. 33, U. S. D. A. Technical Bulletin 70, "The Combined Harvester-Thresher in the Great Plains."

2 Labor on combines charged at 60c per hour; on binder and header 50c per hour for U. S.

3 Horse labor charged at 10c per hour.

4 The tractor might be rented at a rental of from 50 to 75 cents per acre and would then be a variable cost. However, it is here assumed that the farmer owns a tractor and that pulling the cmbine is only one-half of the work done by that machine. Here the tractor cost is an annual charge, and only one-half of such cost is here charged to the combine operation. While it is not known how much the repair cost will be, it seems reasonable that the tractor will require fewer repairs than the combine. The repair charge of 4 cents per acre is computed from data in Table 4, U. S. D. A. Farmers Bulletin 1297, "Cost of Using Tractors on Corn Belt Farms".

5 Fuel charged at 25 cents, oil at 75 cents per gallon in U. S. D. A. data. S. D. figures are 15c for gas, and 75c for oil per gallon.

6 Twine charged at 14c per pound.

7 Threshing charged at 10c per bushel; 15 bushel yield assumed.

8 U. S. D. A. figures based on 8.3 years life of combine, 10 years for binder, 15 years for header. The S. D. figures are b ased on 7 years life of combine, 1-7 of $2300.00 each year.

9 Annual charge per machine based on one-half the first cost at 6 per cent.

10 Based on 8 years life of tractor; 1-8 of $1300 each year. Only one-half of annual depreciation and interest on tractor are charged to combining.

11 One-half of $1300 at 6 per cent.

Although the quantity of man labor per acre is lower in the South Dakota data than in the U. S. D. A. report, it is not believed to be too low. One man on the tractor and one on the combine is usually considered sufficient. By reference to Table 26 it will be seen that seven reported this amount of help, and two operators reported an additional man. It is not known whether two men were needed on the combine, or if the owner reported his time as manager. The annual tractor cost is listed as a variable cost in the original U. S. D. A. Table. The tractor cost is there entered at 60 cents per acre rental. But because of the fact that all the South Dakota combine operators included in this cost study owned their own tractors they would not hire the use of a tractor and hence the rental is out of place. Tractors can possibly be rented for from 50 cents to 75 cents per acre for pulling the combine. The charge of four cents per acre for tractor repairs is based on Table 4, of U. S. D. A. Farmers' Bulletin No. 1297, COST OF USING TRACORS ON CORN BELT FARMS. Repairs and upkeep is there given as $1.16 per acre day for three-bottom tractors. Distributed over 30 acres per day this would be slightly less than four cents per acre for combining.

The estimate of 1.54 gallons of gas or fuel, per acre is slightly larger than the U. S. D. A. figures, but the cost is lower. The reason is that the U. S. D. A. cost is based on gas at 25 cents per gallon. The South Dakota farmers reported 15 cents per gallon as the average price paid. Normally the price will perhaps be slightly higher. Gas at 16½ per gallon would increase the per acre gas cost 10 percent; 18 cent gas would add 1-5 to the cost of gas. The variation reported in the use of oil is not important.

The lower per acre cost of repairs on combines as reported by the South Dakota operators may be explained by the fact that the total expenditure for repairs is distributed over about twice the acreage used in the U. S. D. A. data, and perhaps the machines were newer. In both cases, however, the machines were relatively new. That the cost of repairs will increase rapidly with the age of the machine is to be expected, and is indicated in Table 26. There seems to be a marked direct correlation between the age of the combine and the annual cost of repairs. Naturally as the combines become older this item of cost will increase.

The annual charges are composed of depreciation and interest on the combine and on the tractor. The per acre cost of these charges depends on the number of acres on which the machines are used each year. The figures for the annual charges on the binder, and header, are taken from U. S. D. A. Technical Bulletin 70. The acreages over which these annual charges have been distributed were, however, assumed in order to be able to compute the total cost per acre in each case. Any farmer can divide his own acreage into these annual charges and get the cost per acre for his own farm. The tractor-drawn 15 foot machines equipped with auxiliary engines used in the U. S. D. A. investigation averaged 574 acres each, and the cost per acre for repairs is perphaps based on that acreage. In the computation of the per acre cost of interest and depreciation on the 15 foot combines, the same acreage has been used. The South Dakota figures are based on 1192 acres, since this was the average reported by the owners.

There are some differences between the U. S. D. A. and the South Dakota figures on the depreciation charges for the combine. The former

seem to be based on a price of about $2084 for the combine and an expected life of 8.3 years. The South Dakota computations are based on a cost of $2300 for the 16 foot combines. Although the expected life, as reported by eight owners is 7.87 years, the depreciation cost for these South Dakota combines is here based on seven years. With the large acreage being cut this is, perhaps, as long as they can be expected to last without excessive expenditures for repairs.

In the case of the annual charges for depreciation and interest on the tractor both the U. S. D. A. and South Dakota figures are here based on a cost of $1300 for one of 15-30 Horse Power and a life of eight years. Also, in both cases the per acre costs are based on the assumption that pulling the combine is only one half of the work done by tractor: hence, if a farmer has no other use for his tractor he would divide the entire annual charge by his acreage.

No figures were secured from the South Dakota operators for the repair costs on the tractor. It is quite certain, however, that the annual and per acre cost of repairs for the tractor will average lower than for the combine. Using data from Farmers' Bulletin 1297 it would seem that four cents per acre should cover all the repair cost and upkeep on the tractor chargeable to the combine operation.

The South Dakota costs are lower because of lower fuel cost, and lower labor requirements. The per acre cost of repairs is also lower. This may be due to newer machines and to large acreage. The annual depreciation charge on the combine is larger for the South Dakota data, but, like the other annual charges, on a per acre basis, it is lower because of the larger acreage cut by the South Dakota operators. It is not to be expected that this large acreage can be maintained in later years when combines become more numerous. It is also likely that gas may cost more, and it is quite certain that repair costs on the combines will increase with the age of the machines. For these reasons farmers can expect, on an average, that their per acre cost of combining will be higher than the 1927 costs of these nine South Dakota operators.

Fig. 20 shows at a glance the relative cost of harvesting and threshing by the different methods previously discussed. It should be borne in mind that these costs of $1.66 and $1.17 per acre for combining as found by the U. S. D. A. and South Dakota investigations respectively, include only one half of the interest and depreciation on the tractor. It is assumed that other work would be chargeable with one-half the annual tractor cost. The same applies to the costs per bushel as shown in Figure 20.

In comparing the costs of harvesting and threshing by different methods as presented in Table 29 and in Fig. 20, it should be borne in mind that some of these figures may not be applicable to South Dakota conditions. The labor costs for binder and header used in this table apparently include some threshing labor.

The cost per bushel by the different methods considered would of course vary with the yields. Also the per acre threshing cost with binder and header will naturally vary with the yield per acre. Assuming a yield of ten bushels per acre the costs would be as follows: 7 foot binder 38 cents, 12 foot header 29 cents; 15 foot combine 16 cents. The South Dakota figures on the combine would be about 12 cents per bushel. With a yield of 6 bushels the cost would be 57, 42, 28 and 19 cents respectively. If combined grain is delivered in wet condition there may be such a discount in price as

to seriously offset some of the gain from lower cost of harvesting and threshing. But where the conditions are right, and where the farmers have a sufficiently large acreage of small grains, perhaps about 600-800 acres for a 16 foot machine, the combine is unquestionably the most economical means of harvesting and threshing.

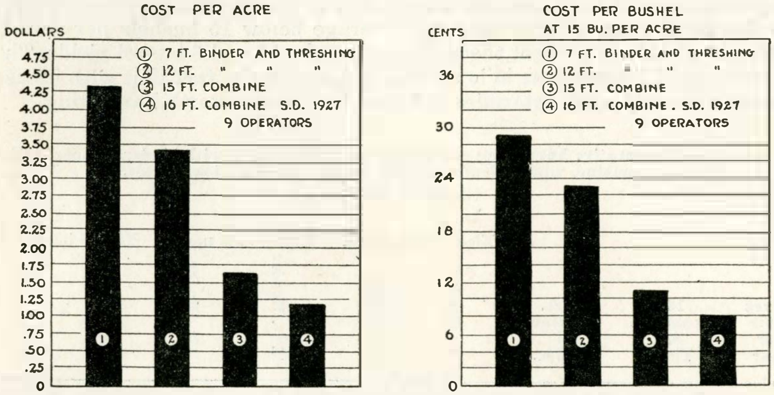


Fig. 20—Comparative costs of harvesting and threshing by different methods*
(Based on Table 29)

* Only one half of the interest and depreciation on the tractor is charged to the cost of combining.

The relationship between the acreage cut per year and the cost per acre is presented in Table 30, and in Fig. 21 This figure and the table are built up from Table 29 in the following manner:

The sum of the annual interest and depreciation for the various machines used is divided by the number of acres to be considered. To the resulting figures of the annual cost per acre is added the total variable cost per acre for each method of harvesting and threshing. This gives the total cost per acre for each method of harvesting with the different annual acreages cut. There is some inaccuracy in the use of this manner of computing the cost and that is the assumption that the annual depreciation will remain the same irrespective of the acreage harvested each year. Naturally any harvesting machinery will wear out faster if used on a larger acreage. It is not known, however, just how long these machines would last if used on the respective acreages assumed.

There is less possibility of reducing the cost per acre with binder and header, by increasing the acreage, than with the combine. The reason for this is that the bulk of all cost is variable, such as man and horse labor, twine and threshing costs. In the case of the combine the interest and depreciation are large items, while the variable costs are relatively small. It is thus possible to get a low total cost per acre of combining if the ananual charges can be spread over several hundred acres. As indicated in both Table 30 and part A of Figure 21, on the basis of the cost data presented, the binder and the header are more economical on acreages up to 125 and 175 respectively when the yield is 15 bushels per acre. Beyond 200 acres per year the combine will do the work at a lower cost.

Due to the fact that threshing is usually paid for by the bushel the cost per acre for threshing and harvesting with header or binder will vary di-

rectly with the yield. For this reason, as indicated in Table 30 and in parts B and C of Fig. 21, the binder and header can be used economically on larger acreages when yields are low. There is, of course, a slight inaccuracy in the assumption that harvesting costs remain the same irrespective of yields. Somewhat more power would be needed and also greater wear and depreciation will take place in heavy yields. However, since wheat yields in the dryer araes of the state will average below 15 bushels per acre it seems desirable to present these figures for the 10 and 6 bushel yields. The advantage of the combine in low yields is found in the fact that with its use one can more quickly determine whether the field is worth harvesting.

Table 30—Comparative harvesting and threshing cost per acre with binder, header, and combine, with different annual acreages, and various yields.

(Based on Table 29)

			Yield 15 bu. per A		Yield 10 bu. per A		Yield 6 bu. per A	
Acres cut per Year	16 ft. combine All Yields.	15 ft. combine All Yields.	12 ft. Header	7 ft. Binder	12 ft. Header	7 ft. Binder	12 ft. Header	7 ft. Binder
1	$498.06	$414.21	$22.69	$33.47	$22.19	$32.97	$21.79	$32.57
10	50.47	42.28	5.29	7.15	4.79	6.65	4.39	6.25
30	17.32	14.72	4.00	5.20	3.50	4.70	3.10	4.30
50	10.69	9.21	3.75	4.81	3.25	4.31	2.85	3.91
75	7.36	6.45	3.62	4.61	3.12	4.11	2.72	3.71
100	5.71	5.07	3.55	4.51	3.05	4.01	2.65	3.61
125	4.72	4.25	3.51	**4.45**	3.01	**3.95**	2.61	3.55
150	4.06	3.70	**3.49**	4.42	2.99	**3.92**	2.59	**3.52**
175	3.58	3.30	**3.47**	4.39	2.97	3.89	2.57	3.49
200	3.23	3.01	3.46	4.37	**2.96**	3.87	2.56	3.47
250	2.73	2.59	3.44	4.34	**2.94**	3.84	**2.54**	3.44
300	2.40	2.32	3.42	4.32	2.92	3.82	2.52	3.42
400	1.98	1.97	3.41	4.29	2.91	3.79	2.51	3.39
500	1.73	1.77	3.40	4.28	2.90	3.78	2.50	3.38
600	1.57	1.63	3.39	4.27	2.89	3.77	2.49	3.37
700	1.45	1.53	3.39	4.26	2.89	3.76	2.49	3.36
800	1.36	1.46	3.38	4.26	2.88	3.76	2.48	3.36
900	1.29	1.40	3.38	4.25	2.88	3.75	2.48	3.35
1000	1.24	1.35	3.38	4.25	2.88	3.75	2.48	3.35
1100	1.19	1.31	3.38	4.25	2.88	3.75	2.48	3.35
1200	1.15	1.28	3.38	4.24	2.88	3.74	2.48	3.34

NOTE—The heavy faced figures indicate the cost and the approximate maximum acreage for which the header and binder are more economical than the combine.

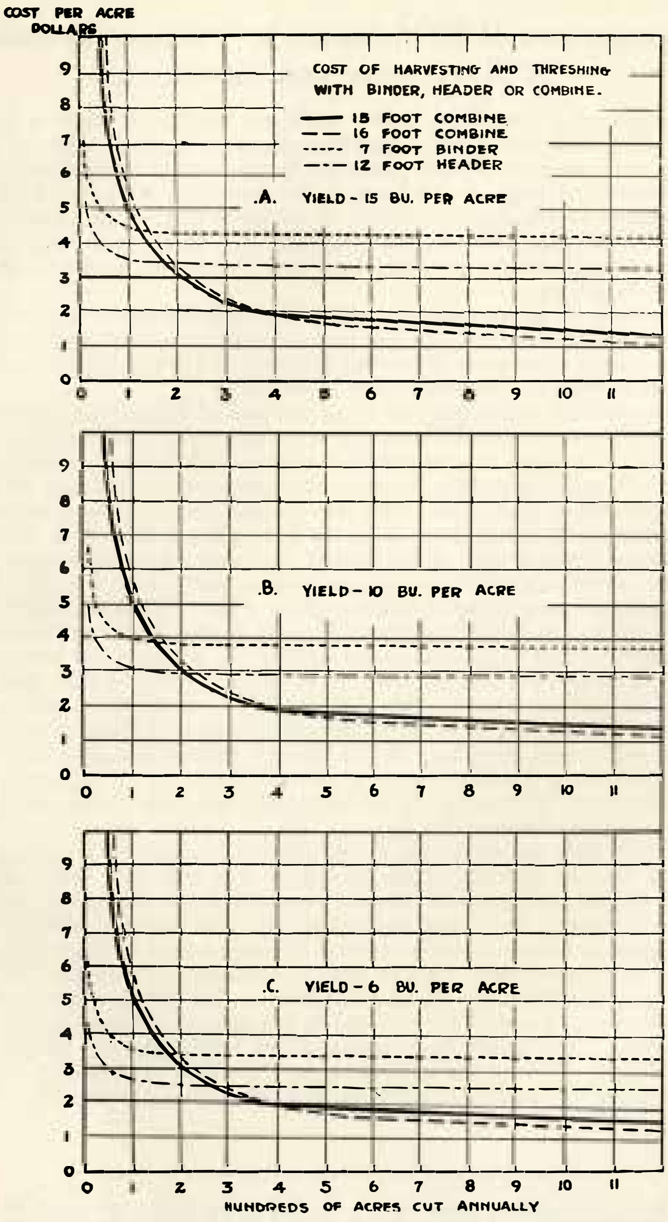


Fig. 21—Comparative harvesting and threshing cost per acre with binder, header, and combine with different annual acreages, and various yields
(Based on Table 30)

Comparison of Field Losses by Various Methods Of Harvesting and Threshing

The method of procedure in this work was briefly, as follows: In each field samples were taken from which to determine the yield. After the grain was cut separate counts were made of the heads left standing and of the heads cut off and dropped. This completed the loss counts in the fields that were headed or combined. In case of binder cut fields the losses in the shock bottoms were counted after threshing. No counts were made of losses around header stacks nor at each "setting" of the separator in the case of shock threshing.

Threshing losses were determined by the "blanket test". This test was made by holding a 16 foot x 20 foot canvas in such a manner as to catch all the straw as it came from either the combine or the stationary separator while 2½ bushels of grain was being threshed.

Some criticism can be made of these methods of determining the threshing losses. Some combines had straw spreaders while others did not have them. In the absence of straw spreaders the straw fell very nicely on the canvas. It was impossible, however, to determine the amount of grain lost in unthreshed heads, since with the equipment used it was possible only to separate the threshed grain from the straw; the grain left in the heads could not be threshed out. In the case of the combines equipped with straw spreaders relatively somewhat less unthreshed grain might possibly be left in the straw because of the shattering effect of the revolving spreader arms striking the straw. This might possibly also be the case with the stationary thresher where the straw was struck by the wings of the blower fan. The spreader and the blower, however, were the sources of two other, possibly more serious, errors. The straw spreader tended to impart to the kernels of grain sufficient speed to land them outside of the canvas in spite of attempts to raise the sides. It was likewise difficult to adjust the blower on the stationary threshers so as to prevent straw, chaff and grain from being blown off tarpaulin. In all cases only the grain remaining on the canvas could be accounted for.

The 1927 data on harvesting losses included losses from combines, binders and headers in fields of wheat, barley, flax and oats. However, the number of observations on the header were so few that no general conclusion can be drawn. More data were procured on the binder, but is is only with respect to wheat that the number of observations is large enough to warrant comparison with the loss data on combines. Hence the following discussion will refer to the wheat harvest only. As will be seen from Table 33, the harvesting losses were larger in the case of the binder than with the combine. The three observations on the header showed losses somewhat less than with the binder, but larger than with the combine.

Analyzing these harvesting losses as to the sources of loss, the following results are obtained.

Table 31—Kind of Binder-Harvesting Losses in Wheat

Cut heads left in the field composed	58.36%	of all binder-harvesting losses
Uncut heads left standing, composed	10.67%	of all binder-harvesting losses
Heads left in shock bottoms composed	30.97%	of all binder-harvesting losses
Total	100 %	

(Based on 9 observations)

Disregarding the binder losses in the shock bottom in order to compare only those binder and combine losses which are comparable, the following comparative percentages are obtained:

Table 32—Comparison of Sources or Kinds of Harvesting Losses in Wheat by the Use of Binders and Combines
(Binder losses in shock bottoms have been omitted)

Kind or source of loss	Binder: No. of observations	Binder: Percentage which each kind of loss constitutes of the total loss	Combine: No. of observations	Combine: Percentage which each kind of loss constitutes of the total loss
Cut heads	9	84.54%	16	60.50%
Standing heads	9	15.46%	16	39.50%
Total		100 %		100 %

It will be seen that of these two sources of loss the combine shows a higher percentage of losses in the form of standing heads. This may be due to the fact that the combine usually leaves a longer stubble and that consequently more uncut heads are likely to remain. On the other hand there seems to be proportionately more cut heads lost by the binder. This may be accounted for by the larger number of avenues of loss, such as between canvasses, binder head and bundle carrier.

Disregarding the losses in the shock bottoms, which constitute about 31 percent or almost one third of the total binder losses, the combines lost on an average 98.45 heads per square rod, and the binder last an average of 114.22 heads per square rod. In addition the binder cut fields lost an average of 51.22 heads per square rod in the shock bottoms.

Naturally the harvesting losses tell only about one half the story. Hence the following table presents both the harvesting losses and the threshing losses from binders and threshers in comparison with the combine. Because the South Dakota results for 1927 are based on a limited number of observations, comparative figures are quoted from a U. S. D. A. bulletin.

Table 33—Comparative Harvesting and Threshing Losses in Wheat.
(Expressed as a percentage of the yield)

Kind of operation	South Dakota				U. S. D. A.*			
	Combine		Binder and Thresher		Combine		Binder and Thresher	
	Number of observations	Percent lost	Number of observations	Percent lost	Number of observations	Percent lost	Number of observations	Percent lost
Harvesting	16	1.8	9	3.0	259	2.6	34	6.1
Threshing	10	.5	3	.7	33	1.9	9	1.1
Total		2.3		3.7		4.5		7.2

* Figures taken from U. S. D. A. preliminary report, "Harvesting wheat with a combined harvester-thresher in the Great Plains region, 1926".

For comparison we quote again from the above bulletin. "The average loss from harvesting winter wheat with combines was 2.6 percent. Fields cut with headers showed an average loss of 3.3 percent and fields cut with binders showed an average loss of 6.1 percent". It will be observed that the harvesting losses in South Dakota reported above were smaller than found in the larger investigation by the U. S. D. A. In the case of threshing losses the U. S. D. A. figures show a considerably higher loss with the combine than with the stationary threshers, whereas the South Dakota results indicate the combine to be less wasteful. Naturally less reliance should be placed on results based on only a few observations. It would also seem reasonable that the stationary separator, other things being equal, should do a cleaner job of threshing and separating grain than a moving combine. However, considering the sum of harvesting and threshing losses both investigations indicate the combine to be less wasteful than the binder or header and thresher. In addition to being moved about the field the combine has the disadvantages in direct combining, of having to handle straw that may be partly green in low places, but the greatest disadvantage is undoubtedly the mass of green weeds found in many fields. Such tough weeds make thorough threshing and separation difficult. In addition the green weed matter that can not be separated out and hence goes into the grain tank tends to raise the moisture content of the combined grain. Either better separating and cleaning devices or else cleaner fields are desirable.

Although the field losses due to mechanical operation may be lower in case of the combine than with the other methods of harvesting, there are certain climatic risks to which the standing grain is subjected while waiting to become thoroughly mature and dry. This risk naturally varies with the length of time the grain must stand and with the prevailing amount of high winds, rain and hail in each area. Likewise the different kinds and varieties of grain crop also vary in susceptibility to lodging, shattering and damage from wind, rain and hail.

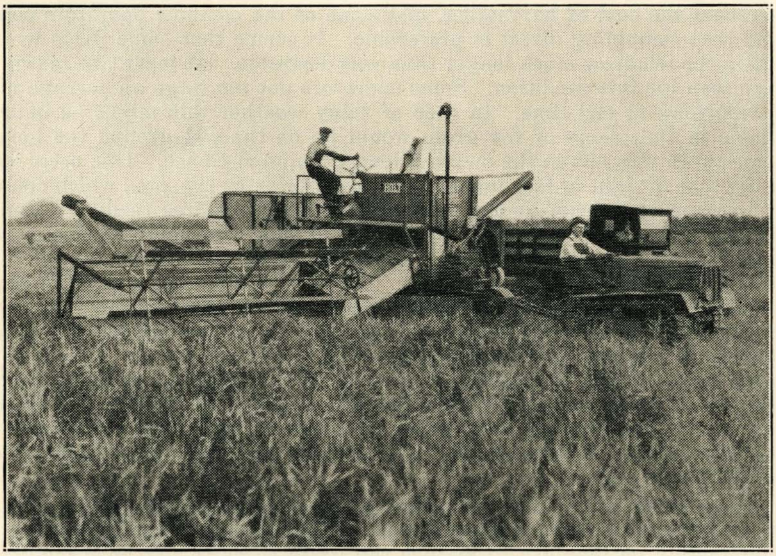
This risk to which the standing grain is subjected naturally affects the cost of combining. If one is to compare the cost of combine harvesting with the cost by the use of either binders or headers and stationary threshers this risk of field losses due to the climate is one of the elements of cost which should be considered. Since all the grain fields are subject to the same risk up to the time of the binder harvest no matter how the harvesting is to be done, the farmer who may be considering what method of harvesting to use will be interested only in the additional climatic risks involved in connection with postponement of harvesting beyond the usual time for the binder harvest.

Opinions Concerning the Use of the Combine

The moisture problem is outstanding, but may in time partly be solved by the operators themselves as they become more familiar with the requirements for producing dry grain. In this connection it is desirable to limit the acreage cut by machines of a given size to such an amount as can be combined during the time when climatic conditions are right. The continued increase in the number of machines, reduction in the acreage cut per machine, and increasing knowledge of operating requirements will help to solve this problem.

Because green weeds are difficult to separate in the case of direct combining and since their presence in the combined grain tends to increase the moisture content of such grain there is need for cleaner farming, and better separating devices in the combines. The use of the windrowing and pick-up machines may not always be the best solution to the weed problem. In order to get the full advantage of reduction in cost of harvesting it would seem that combining should be done direct. This requires clean fields that mature uniformly.

The local grain buyer faces a real problem in connection with the handling of combined grain. Most elevators were not built for handling wet grain. They may not all have facilities for cleaning out the green weed material. Satisfactory equipment for drying grain in the local elevators does not seem to have been developed, because the demand for such machinery is rather recent. As it is, the local grain buyer who tries to accommodate his combine patrons often has much extra work and worry before the



Trucks carry the grain away from the combine.

wet grain is finally sold at the terminals. The local buyer may even suffer a loss on some of this grain, if he has underestimated the moisture content at the time of buying. In many cases he must pay a small charge per bushel for conditioning damp grain. The fact that the terminal markets are equipped with dryers for reducing the moisture content of such grain does not solve the problem. The wet grain may easily heat either in the local elevator or in transit during the hot weather of the combine season. Cleaners and economical dryers would seem to be desirable even at the country points where large quantities of moist grain are being delivered.

The number of combines in use in the area studied increased greatly during 1928. Apparently a large majority of the combine users are sufficiently well satisfied to prefer this method of harvesting and threshing. The lower cost of harvesting, the reduced labor requirement and the simplification of the labor problem were mentioned by the farmers as reasons for buying and using the combine.

The windrower and the pick-up attachment were introduced in this area for the first time in 1928. Those who favored these devices said they enabled them to combine earlier. The grain could be put into windrows about the time the binder harvest would begin. After a few days of windowing that which was the first put into swaths could be combined by using the pick-up attachment. Then by the time this operation was completed the standing grain might be ripe for direct combining. It was also said that the green weed problem could partly be solved by the use of these devices. After lying in the windrow a few days the green weeds would dry out and could be separated out better by the combine. Especially in light grain, it was possible to windrow and pick-up a wider swath than the width of the combine platform would handle in direct combining. Using the windrowing and pick-up method naturally involves going over the field twice. This increases the cost of harvesting, and some of the combine operators contend that combining direct is preferable. It seems that some fields were left in the windrow much longer than was desirable. At least two reasons were seen for this condition. Some operators put too large an acreage into windrows at one time. In case of rainy weather this might be undesirable in that some of the grain would lie on the wet ground too long. Some grain was left in the swath a long time from choice. This occurred in the case of light or less important crops, barley or rye, etc., which could be windrowed just before the main crop of wheat became ready for combining. If it became necessary to use the combine continually on the more important crops, that which had been windrowed early was left on the ground until the end of the harvest. Crops of barley and rye were seen combined with the pick-up attachment after being in the windrow four and five weeks. The rye windrows were turned with a side-delivery rake and "fluffed up" shortly before combining so as to dry out better. Except for being bleached this rye appeared to be in good condition. Such long exposures in windrows may have bleached or discolored certain combined grains and thus lowered their grade as compared with binder and header harvested grain. Except in fields in poor tilth the "pick-up" seemed to do fairly clean work .

From those who did not own one, expressions came both for and against the combine. Those who opposed the use of the combine based their contentions mainly on inability to mature the grain so as to get good quality, reduction in price or deterioration in storage of damp grain, and risk con-

nected with leaving the grain stand so long in the field. A few expressed fear that combined grain might contain sufficient moisture to cause heating in the farm bin, and thus have its germination injured. A number of combine owners, however, said that after learning how to use the combine they had had satisfactory results from using combined grain for seed. Live stock farmers objected to the loss of the straw. Some farmers who raised only feed grain were also skeptical about the combine on the ground that excessive moisture might cause the grain to heat in farm storage. In Gettysburg it was said that a few landlords had entered into an agreement not to permit their tenants to use the combine on any of their lands during the following year. Their objection was said to be based on the quality of the grain. Direct combined grain might be immature or contain too much moisture and too much green weed matter. Windrowed grain might also have too much moisture if "picked-up" too soon after windrowing or after rain, or be badly bleached and lowered in grade. Much apprehension was expressed regarding possible deterioration of grain left in windrows for considerable lengths of time and exposed to wind and rain. It also seemed that newly windrowed grain before having settled down, might be badly scattered in high winds, thus entailing loss. On fields of new land with rough, uneven surface it may be impossible for the pick-up attachment to do a clean job. Some apprehension was also expressed regarding the cumulative effect from spreading weed seeds back on the fields.

The objection of the landlords may be reasonable, and even justified in some cases, without necessarily condemning the use of the combine. On a share-rent basis the landlord is naturally interested in the quantity and quality of the crop. He is not necessarily interested in the costs of field operations so long as these are all paid for by the tenant. If the tenant should buy a combine in order to reduce his cost of harvesting and threshing that does not necessarily benefit the landlord. On the other hand, if the landlord should feel that the quality of his share of the crop is poorer and the price he recieves is lower he would naturally become dissatisfied. In other words, on a share rent grain farm where the tenant furnishes all the equipment and stands all the expenses, he suffers part of the loss but receives all the benefits from the use of the combine, while the landlord also suffers part of the loss but receives none of the benefits. This is, of course, assuming that grain has been combined in immature, moist or bleached condition, etc. Cost of operation studies have indicated that the combine can reduce costs with sufficiently large acreages, when other conditions are right. Such landlords as are in favor of more livestock on their farms in order to build up the fertility of the soil may also reasonably be opposed to the use of the combine, if the combine tends to promote or perpetuate specialized grain farming. The introduction of the combine is thus giving rise to some new problems in farm organization and management.

Judging from observation, it seems that the farms having combines are more highly motorized than other farms. Near the towns where most of the combines were in operation practically all the grain was hauled to the elevator by truck, direct from the machine. The tractor and the truck seem necessary accompaniments of the combine. This possibly should be considered when comparing the costs of harvesting by different methods. The farmer would want to consider the possible use or disposition of his present equipment.

Summary

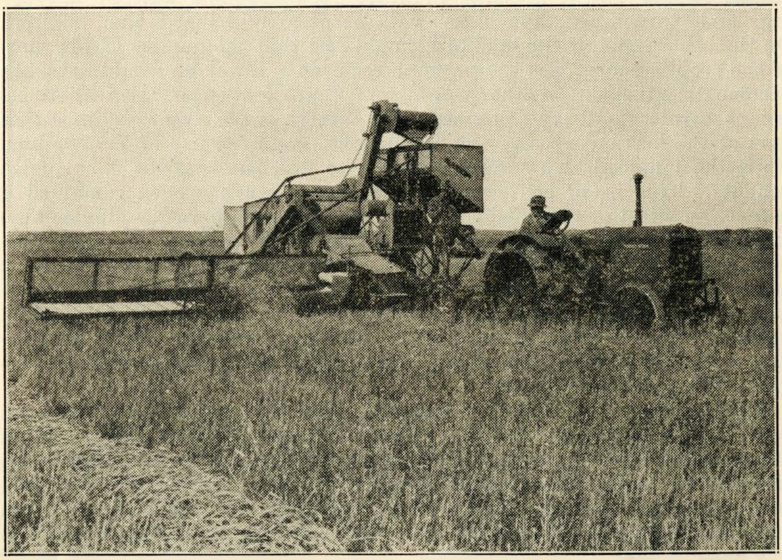
The number of combined harvester-threshers has increased rapidly especially in the central and western parts of South Dakota, 648 machines were on record in 1928.

The employment of this new method of harvesting has brought with it a number of problems such as relative cost of harvesting by different methods; the comparative quality of grain harvested by different methods; as well as the means by which the producer may effect the quality of his crop during harvesting operations.

Moisture determinations made during the harvesting season of 1927 indicated a tendency for combine operators to cover too large an acreage with one machine. This attempt to harvest extremely large areas with one machine led to the practice of harvesting too early in the season, too early in the mornings while the grain was still damp with dew or too early after rainy periods.

Samples of combined wheat, barley and oats collected in 1928 showed a greater variation in moisture content than binder harvested samples. In the case of the combined samples of wheat 43.6 percent contained 15.0 or a higher percentage of moisture as compared to 26.1 percent of the binder cut samples. On the other hand only 22.0 percent of the binder cut samples contained less than 13.0 percent of moisture while 35.8 percent of the combined samples fell into this low moisture group. This shows that wheat of low moisture content can be obtained by the use of the combine. But the facts brought out also show that judgment must be exercised in the use of this method of harvesting.

The samples collected in 1928 showed very definitely that many combine users started their machines too early in the season before the grain



Combine with pick-up attachment.

was sufficiently dry for harvesting. They also show a decided tendency for producers to resume harvesting operations too soon after rainy periods, before the grain is dry enough. The grain must be dry if it is to be handled with safety.

The high moisture content of a large percentage of the combined samples are reflected in the commercial grades of these samples. 37.7 percent of the samples of combined wheat graded number 1, as compared with 48.0 percent of the binder-cut samples. These figures speak well for the utilization of the combine, when, however, the relative percentage of samples falling into sample grade, namely 26.5 for the combined and only 5.5 for the binder-cut wheat are regarded the same factors, excessive moisture during the early part of the season and following rainy periods, come again into evidence. These figures do not condemn the employment of the combine but they do point out the necessity of caution and judgment on the part of the user of the combine.

The moisture content of mature wheat standing in the field is reduced rapidly under favorable climatic conditions. In one case a reduction in the moisture content of durum wheat of 6.6 percent, namely form 19.6 to 13.0 was observed in the course of four days.

The time of day at which grain may be cut with a combine is dependent on climatic conditions for that day, and on the condition of the grain relative to degree of ripeness, the character of the stand and on the presence or absence of the green weedy growths. On the basis of experiments performed in eastern South Dakota it is not there advisable to start combining earlier in the morning than eleven o'clock except on very dry days. In some cases, as in weedy fields it was found that grain sufficiently dry to be handled with safety could not be obtained except by delaying cutting till the middle of the afternoon. The moisture content of grains increases towards evening, but on most dry days it was found that it was safe to carry on harvesting operations until 8:00 p. m.

As regards the time of the season to begin combining direct, farmers themselves reported that this should begin between ten and fourten days later than the beginning of the binder harvest. On the other hand, windrowing could begin at the same time as the binder harvest, but the grain should dry in the windrow about five days before combining with the pick-up attachment.

The previous discussion of the moisture condition has called attention to the relatively high moisture content of considerable portions of combined grain. According to the best available estimates the average discounts for moisture in wheat, on the Minneapolis market during August, 1928, ranged from no discount for 13½ percent to 10½ cents per bushel discount for 18 percent moisture. Wheat containing 8 percent moisture was accorded a premuim of 2 cents per bushel.

The farmer, however, did not suffer as much loss as indicated by the discount for excess moisture. Neither did he gain by marketing extra dry grain at the premiums paid. The reason for this is to be found in the weight of the moisture. Although the discount was 10½ cents per bushel for wheat of 18 percent moisture content the farmer did not gain 10½ cents per bushel by allowing the wheat to dry to 13½ percent. This drying process removed 2 7-10 pounds in weight, and the cost of replacing that weight at $1.00 per bushel is 4½ cents. After deducting this cost it is seen that the net gain from drying was 6 cents per bushel instead 10½ cents. In other words the discount for 18 percent moisture was 10½ cents,

but the net loss from marketing 18 percent wheat was 6 cents per bushel.

Similiarly, because it cost 5½ cents per bushel to replace the weight of the moisture lost through evaporation in drying below 13½ percent, the farmer lost 3½ cents per bushel by letting his wheat dry down to an 8 percent moisture content in order to take advantage of the 2 cents per bushel premium for wheat containing 8 percent moisture.

The most profitable moisture condition was about 13½ to 14 percent. At this point the wheat had the greatest weight of moisture consistent with safe storage, and the price was best.

In the case of barley and flax it was also found that the gains from drying were not as large as the spread in price between wet and dry grain.

The cost of harvesting and threshing large acreages was found to be lower with the combine than with the binder or header and stationary threshers. Cost figures from an investigation by the United States Department of Agriculture covering both harvesting and threshing are as follows per acre: 7 ft. binder, $4.22; 12 ft. header, $3.36; 15ft combine, $1.66. Threshing costs are based on a yield of 15 bushels per acre. Nine South Dakota operators using 16 ft. machines and combining 1192 acres per machine, reported an average cost of $1.17 per acre. At 15 bushels per acre the cost per bushel would be 29, 23, 11, and 8 cents respectively. But the South Dakota figures are lower than can be expected as a working average. The economy in the use of the combine is confined to large acreages. The shortage of good drying weather, however, will set a limit to the acreage that can be cut with one machine if one wants dry grain. For cutting 100 acres or less the binder would be more economical.

In addition to the price of the grain, and the cost of field operations the harvesting and threshing losses must also be considered. The results available from various investigations indicate that harvesting losses are largest with the binder, lower with the header, and lowest with the combine. But it is also shown that the combine is less efficient as a thresher than the stationary separator. However, taken as a whole the losses with the combine were found to be only about six or seven tenths as great as with the binder and separator.

The risk of loss due to shattering, hail and wind while waiting for the grain to become sufficiently dry for combining should also be considered as a possible cost.

Since the combined wheat tends to have more green weed material and contain more moisture, it may be necessary for the local elevators to install better grain cleaning machinery. An efficient, economical dryer may also be necessary at certain local points, especially during wet seasons. If there is any danger of moist combined grain having its viability injured from heating in the bin a dryer at the local elevator would also be of value for conditioning seed grain.

The windrower and pick-up devices may partly overcome the green weed problem, but they increase the cost. Direct combining is cheaper, but a better separating and cleaning mechanism would be desirable.

Certain farm management problems arise since the combine fits better into a specialized grain farming system than into a livestock system where the straw is utilized. On a share-rent basis of grain farming the use of the combine may benefit the tenant more than the landlord. Where the climatic and other factors are suitable and the farms are sufficiently large the combine seems destined to become a permanent part of the grain producing equipment.

List of Publications on Combine

Compiled in the Office of Grain Investigations, Bureau of Agricultural Economics, U. S. Department of Agriculture. October, 1928.

Publications by U. S. Department of Agriculture

The combined harvester-thresher in the Great Plains. By L. A. Reynoldson, R. S. Kifer, J. H. Martin and W. R. Humphries. U. S. Dept. of Agriculture. Technical bulletin 70. 1928. 60p.

This bulletin reports the results of an exhaustive study of the use of the combine harvester in the Great Plains area, including the cost, the advantages, the harvesting, and threshing losses, climatic factors, acreages cut, quality and condition of harvester wheat, storage, effect of combines on farm organizations, etc.

Eastward march of the "combine." (In annual repart of the Secretary of Agriculture. 1927 p. 14.)

Discusses the spread of the combine eastward and the question of relation between increased efficiency of production and the price of farm products.

Preventing damage in spring wheat harvested with combines. By R. H. Black and E. G. Boener. June, 1928. 7p. A mimeographed report issued by Grain Investigations, Bureau of Agricultural Economics. U. S. Dept. of Agriculture.

The report discusses five principal sources of damage and loss in grain in connection with the operation of a combine in the spring wheat area, and gives suggestions for overcoming each of these losses. The report is illustrated with charts.

Shall I buy a combine? By L. A. Reynoldson, J. H. Martin, W. R. Humphries, U. S. Dept. of Agr. Farmers' bul. 1565. 1928. 18 p.

The bulletin treats of the crops that may be harvested with the combine, types and equipment of combines, their cost, rate of harvesting, cost of combining, weather conditions, harvesting and threshing losses, quality and condition of combined grain, acreage on which a combine will be economical.

Preliminary report on maintain satisfactory condition of wheat harvested with combines in the hard red winter wheat area, season 1928. By J. H. Cox and E. G. Boerner.

Publications Issued by State Experiment Stations and Scientific Journals

Combines in Illinois. By E. W. Lehmann and I. P. Blauser. (Illinois Agr. Exp. Sta. Circ. 316. 1927. 16 p.)

The bulletin discusses the reduction in losses in harvesting soy-beans, wheat and clover seed, the cut in threshing cost, factors influencing the acreage harvested, quality of combined grain, troubles and adjustment of the combine, its advantages and disadvantages.

Combine harvester-thresher in Indiana. By I. D. Meyer. (In Purdue Agriculturist, v. 22. March 1928. p. 149

The author reports that they have records of successful harvesting of rye, wheat, oats, timothy, millet, mammoth red clover seed, little red clover, alsike clover seed, sweet clover seed, buckwheat and soybeans

with the combine in Indiana. One of the problems is the reclaiming of straw needed for feed or bedding.

Combine-harvester operated in Michigan. By E. E. Sauve. (In Michigan Quarterly bul. Agr. Exp. Sta. v. 10, no. 3. Feb. 1928. p. 82-86)

The bulletin contains a discussion of the cost of harvesting with the combine for Michigan conditions.

Combine harvesting in North Dakota: a progress report. By R. C. Miller and A. H. Benton. No. Dak. Exp. Sta. bul. 220. 1928. 26 p.

This bulletin presents the results of investigations made in North Dakota and other states on the use of the combine. It discusses the problems on the use of the combine, types of combines, the acreage, power requirements, labor and hauling capacity, threshing efficiency, harvesting losses, the shattering with respect to wheat, rye, oats, barley and flax. Also the storage of combine grain, conditioning wet grain, marketing of combined grain, combine attachments, and other subjects.

Combines comes to Minnesota, Circular No. 30, Extension Division, University of Minnesota.

Combine studies in Missouri, Agricultural Experiment Station, Columbia, Mo.

Combine in North Dakota. By R. C. Miller (Asst. Prof. of Ag'l. Eng. No. Dak. Ag'l College) (In Ag'l Engineering, v. 8, no. 51, May 1927 p. 115)

The investigations reported were along two lines: one was a personal one, cooperating with C. D. Kinsman of the U. S. Dept. of Agriculture and the other was a questionnaire investigation.

Combine-harvester studies at the Ohio station. (In Ohio Agr. Exp. Sta. bul. 417, 1928. p. 82-83)

Combine in Ohio. By G. W. McCuen. (Prof. of Ag'l. Engineering, Ohio State Univ.) (In Ag'l Engineering, v. 8, no. 5. May 1927 p. 116)

The Combined harvester-thresher in North Dakota (May, 1929) bul. 225 N. D. Station and College in cooperation with U. S. D. A.

Combine harvester on Oklahoma farms. 1926. By J. O. Ellsworth and R. W. Baird. Oklahoma Agr. Exp. Sta. bul. 162. April 1927. 15 p.

The bulletin discusses the following subjects: cost of operating combines, price of combines, labor, power and fuel and equipment, grain losses, repairs, also its practicability for grain sorghums.

Combine Harvesting, Cleaning and Drying of Combined Grain, etc. Several articles in Apricultural Engineering magazine, Feb. 1929.

Combine in Pennsylvania and Delaware. By R. U. Blasingame (Prof. of Farm Machinery State College) (In Ag'l Engineering, v. 8, no.5, May, 1927 p. 117.)

Combine in Saskatchewan. By E. A. Hardy (Prof. of Ag'l. Eng. Univ. of Saskatchewan) (In Ag'l Engineering, v. 8, no. 8. Aug. 1927, p. 206-208)

Field test of the combine in Indiana. By R. H. Wileman. (Ext. Ag'l Engineer Purdue Univ.) (In Ag'l Eng. v. 8, no. 5. May, 1927, p. 118)

Grain handling methods in relation to combine harvesting. By E. J. Stirniman (Prof. of Ag'l. Eng. Univ. of California) (In Ag'l. Eng. v. 8, no. 8 Aug. 1927, p. 219-220)

Moisture in Combined wheat, Bulletin 183, by A. Daane, Oklahoma Experiment Station, Stillwater, Oklahoma.

Nationwide combine reports at meeting of the Power and Machinery

Division of the Society of Agricultural Engineers. Nov. 1927. (In Ag'l Eng. v. 9, no. 1. Jan. 1928. p. 9-13)

Symposium of reports by state, federal and Canadian Agricultural engineers on combine investigations in 1927.

New engineering developments in combines. (In Ag'l. Eng. v. 9, no. 1, Jan. 1928. p. 13-14)

Report made at meeting of Power and Machinery Division of Society of Agricultural Engineers, Nov. 1927. The points referred to were the pick-up attachment, future for power take-off drive, light weight construction, and standardization of combines sizes into two classes.

Results of "combining" and grain drying tests in Wisconsin. By F. W. Duffee. (Assoc. Prof. of Ag'l. Eng. Univ. of Wisc.) (In Ag'l Eng. March 1927. p. 55)

Time of cutting and storage of combine wheat. By E. A. Stokdyk. (Kans. Ag'l College, Extension Service, Marketing Notes. v. 3, no. 5. May, 1927. 2 p.)

Publications from the Press

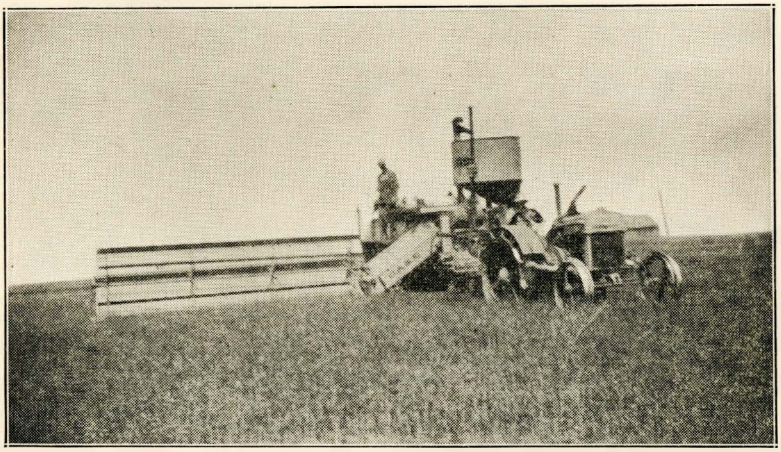
Combines and damp grain, windrowing is meeting this problem. By I. W. Dickerson. (In The Farmer, June 9, 1928)

The author says it is advisable to clean combined grain as soon as it comes from the combine or store it in ventilated bins, some farmers use home made dryers. Windrowing the grain, letting it cure for several days is another solution.

Farm storage of wheat needed with combine. Elevator proves of value in handling damp grain in early season. By C. W. Mullen (In Oklahoma Farmer-Stockman. May 15, 1928)

Author reviews tests made by government in North Dakota. Discusses affect of weeds, time of cutting on moisture content and test weight. Advises ventilated bins and use of farm elevators on farms.

Possibilities of the combine in humid areas. By G. W. McCuen. (Prof. of Ag'l. Eng. of Ohio State Univ.) (In Farm Implement News, v. 48, no. 52. December, 1927. p. 12-13)



Level fields are ideal for combines.