EFFECT OF GRAIN MOISTURE ON EFFICIENCY OF HARVESTING MACHINERY FOR OATS AND CORN

by

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INTRODUCTION

The corn and oat crops play an important role in the agriculture of many parts of the world. In the United States (22) the corn and oat crops occupied 83,302,000 and 42,027,000 acres, respectively, in 1950. In terms of the volume of grain, corn and oats are the first and second largest crops. In 1950 the total production of corn and oats was 3,131,009,000 bushels and 1,465,134,000 bushels, respectively.

Corn and oats are also the leading feed crops and hence are important to the great livestock, dairy, and poultry industries in this country. Due to their importance it is necessary that the mechanical means of harvesting should be efficient to produce the highest possible yield and economy. Improvements in harvesting machinery and the introduction of new varieties have increased the average yield of corn from 25.0 bushels per acre in 1930 to 37.6 bushels per acre in 1950, and that of oats from 29.5 bushels per acre in 1930 to 34.9 bushels per acre in 1950. Although some of the problems have been solved by developing new and better harvesting machinery and breeding new varieties of corn and oats with desirable characteristics, there are still problems which have not been solved.

Before harvesting machinery was introduced harvesting could be begun at a somewhat higher moisture content and, as the harvesting period was much longer, the grains were not piled up very rapidly, thereby allowing more ventilation which reduced the moisture content. Now, with the introduction of harvesting machinery, the period of harvesting has been reduced to such an extent that grains are piled up in the cribs very rapidly. In order to reduce the loss due to spoilage to a minimum it is considered necessary that harvesting should not be started until the crop has attained the correct moisture for safe storage.

Another fact needing serious consideration is that after the crop reaches maturity the adaptability of the crop for harvesting changes quite rapidly, which considerably affects the efficiency of harvesting machinery. For this reason, at times it is necessary to harvest the crop at an early date to avoid high losses.

Another factor to take into consideration at time of harvesting is the weather. It is possible that the weather conditions may be unfavorable for attaining the correct moisture content and it might become necessary to harvest when the moisture content is high, in order to avoid excess losses and working in muddy or snow covered ground.

Of late there has been a trend toward early harvesting and the use of driers on farms in order to make harvesting independent of grain moisture and the weather conditions and thus save as much of the grain as possible.

So far very little work has been done to study the effect of grain moisture on the efficiency of harvesting machinery for corn and oats and this is the objective of the present study.

REVIEW OF LITERATURE

Historical

Development of oat harvesting machinery

In the last century and a half enormous work has been done towards the improvement and development of farm machines, which has made farming methods what they are today and which has made modern society possible through the release of men from the farms. The development of harvesting machinery is an important part of the overall development as harvesting used to be one of the most time and labor consuming operations.

The most extensively used machine for the harvesting of oats at the present time is the combined harvester and thresher commonly known as the combine.

The first combine was built in 1834-1835, by H. Moore and J. Hascall of Kalamazoo, Michigan (5), who secured a patent on a machine for harvesting, threshing, cleaning and bagging the grain. In principle it was very similar to the present-day combine and was fairly successful. According to Mr. Moore's figures, with their combine it cost only 85 cents per acre whereas by reaping and threshing the cost was 3.125 dollars per acre.

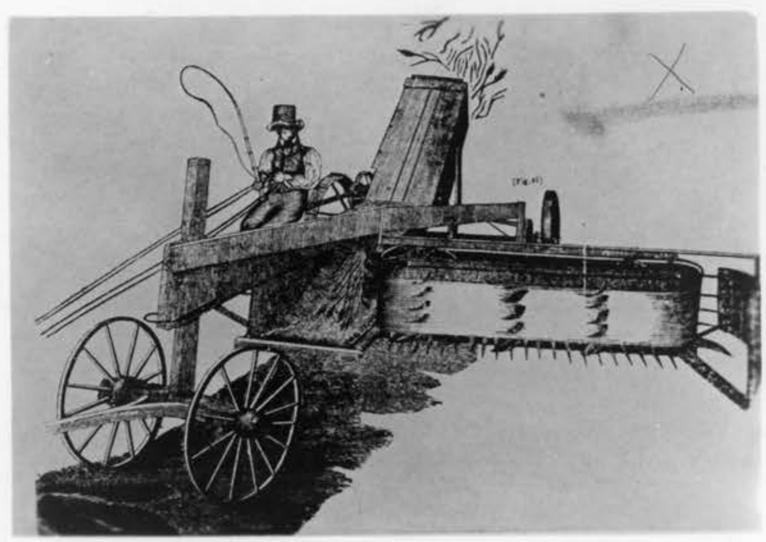

Fig. 1. The Briggs-Carpenter Combine Invented at Ft. Covington, Kentucky, in 1836

In 1836 E. Briggs and C. G. Carpenter invented a combine and obtained a patent. It was demonstrated in New York the same year and proved to be satisfactory.

It was in the Pacific Northwest section of the United States that the combine was rapidly developed and improved in the 1870's and 1880's where the conditions were particularly favorable for the use of such machines. Patents were secured by different inventors on various features of the combine and by 1890 a number of manufacturers were making combines. Some of the combines (16) used on the Pacific coast cut a swath as wide as 40 feet and required a crew of 5 men and as many as 36 horses or mules. Some of the later models were equipped with an engine which propelled the machine and furnished power for the threshing unit. Because of their size the use of combines was not considered practicable for the farms of the Great Plains. The first small combine put on the market was manufactured in 1905 in Idaho. It cut a 7-foot swath and was horse-driven. But it was not till 1918 that a small prairie-type combine equipped with auxiliary engine and pulled by horses or a tractor, was introduced in the Great Plains. Later on in the early 1930's (1) to answer the demand for soybean and small grain harvesting machinery, the small power-take-off operated combine, with usually 6 feet or less cutting width, was developed for use in the Corn Belt,

Fig. 2. The Hiram Moore Combine in West Michigan about 1850

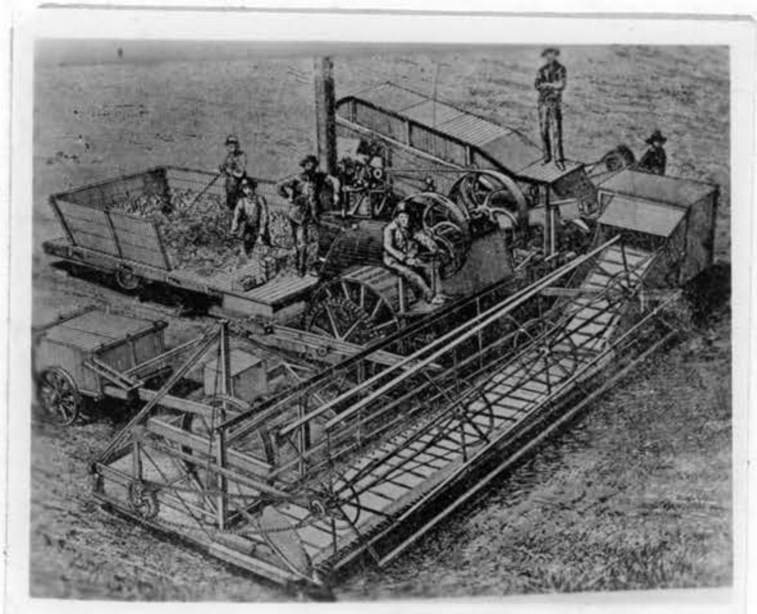

Fig. 3. Berry's Self-Propelled Combine, 1887

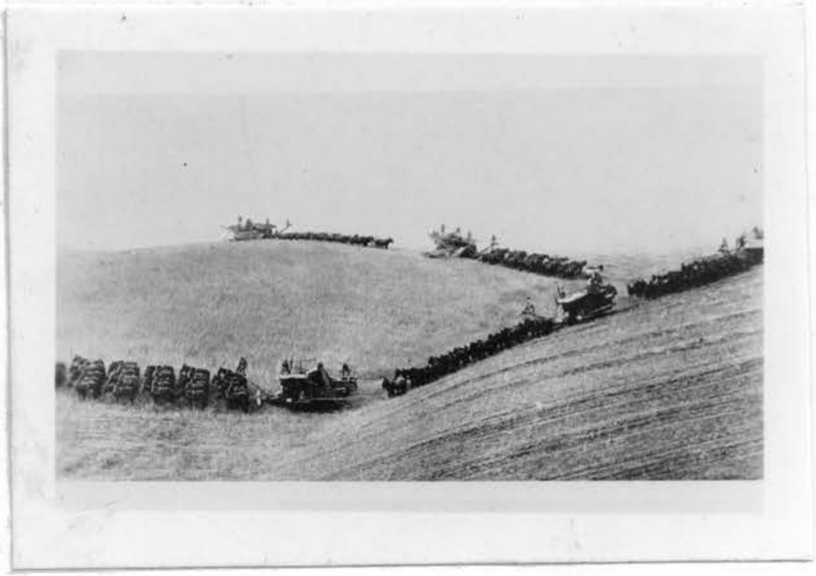

Fig. 4. Five Holt Combines near Walla Walla, Washington, 1890's

Fig. 5. Holt Self-Propelled Combine in Washington about 1909

the Northeast and the Southeast, where the acreage of small grains per farm was small.

While the pull-type combine was being developed on the Pacific coast, the first self-propelled unit was built by G. S. Berry of Tulare County, California in 1887 (3). This combine had a 6-horsepower Westinghouse engine for providing power for the threshing mechanism and a 25-horsepower Mitchell-Fisher steam engine for traction power. About 1909 (5) the Holt Company of Stockton, California, developed a self-propelled combine, which was reported to be quite satisfactory. During the period 1915-1925 a number of other models were developed but due to their high cost were not manufactured in large numbers.

Recently, due to changed conditions, the self-propelled combine has gained considerable acceptance and at present five major agricultural machinery manufacturers are making a number of different models. In 1949 (4), out of 104,888 combines produced, 13,671 were self-propelled.

Development of corn harvesting machinery

As early as 1820 (3) attempts were made to build mechanical corn harvesters and during the period 1820 to 1829 a number of machines were developed. These machines were either of the sled-type or of the mower and reaper-type for harvesting the whole corn plant. In 1850 Edmund W.

Quincy of Illinois obtained the first patent on a corn harvesting machine. This machine was essentially a field picker. During the period 1880-1885 (25) Patrick J. Lawler and John F. Barry of Wall Lake, Iowa, developed a machine which was very similar in principle to the present-day pickers and obtained a patent on April 15, 1890. It is reported that this machine worked satisfactorily but was not manufactured as there were very few customers. In 1892 (3) A. S. Peck of Geneva, Illinois, received a patent on a machine that he invented. This machine consisted of a corn harvester with the two dividers passing one on each side of a row of corn, which was cut and carried back in a vertical position to the binder attachment by means of chains and gathering arms.

For a number of years the idea of pickers was given up and it was not till about 1900 that, when the demand for such a machine became so apparent in the Corn Belt, farm machinery manufacturers again turned their attention to pickers. The ideas of Lawler (25) and Peck (3) were incorporated in one machine and after several changes and improvements, corn pickers were put in the field. The first machines were horse-drawn but later on as tractors were developed pickers with power-take-off drives were built. In recent years numerous changes have been made and at present pickers of three main types are available; the trailing, integral mounted, and mounted type.

The most recent development that has been brought about in corn harvesting machinery due to high wages and labor shortage is the picker-sheller. It did not receive much acceptance in the beginning due to storage difficulty of grain with high moisture content, but now with the use of driers it has more possibilities. O'Brien (15) in his article "Corn Combines Speed the Harvest" has listed the following advantages in using picker-shellers.

1. Labor-saving. It can be a complete power job, and one man can do it all, if he does his own hauling as well as running the picker-sheller.
2. Harvesting can be done earlier and in less time, ahead of bad weather. No packing of wet soil.
3. Cobs left right in the field, well distributed, and no chaff flying around the barnyard.
4. Quicker marketing if crop is to be sold, or a loan can be obtained sooner.
5. Better-quality grain and safer storage.
6. Less storage space.
7. Reduced harvesting and handling costs, including saving the wages of one man.
8. Earlier wheat seeding following corn.

Use and Performance

Oats

Hurst and Humphries (7) have reported the results of an experiment to secure the average losses in harvesting oats with the 5-foot, 6-foot, 8-foot and larger combines in Illinois and Indiana in 1935. The losses for the 8-foot and larger combines were as follows:

Cutter-bar - 0.51 bushels per acre representing 1.38 per cent of the total yield.

Straw loss - 0.12 bushels per acre representing 0.36 per cent of the total yield.

Chaff loss - 1.43 bushels per acre representing 3.86 per cent of the total yield.

Total loss of 1.55 bushels per acre or 4.22 per cent of the total yield.

The average moisture of the grain was 9.6 per cent.

Bottum, Rothenberger and Mayer (2) have made a study of the cost of combining, efficiency of cutting and threshing, and time of cutting for the small combine in Indiana. Losses by different methods of harvesting oats are reported as follows:

Combined direct

Harvesting loss - 1.5 per cent of yield

Threshing loss - 3.25 per cent of yield

Windrowed

Harvesting loss - 2.0 per cent of yield

Threshing loss - 1.75 per cent of yield

Jones and Beasley (11) after making a study of combine harvesters in Missouri have reported the cost of combining with combines of different sizes and have also compared the same with the cost of binding and threshing.

McCuen and Silver (13) after making investigations regarding the harvesting losses, costs, and capacities of combine-harvesters in Ohio have made recommendations for their adaptability.

Richey (17) in Ohio has developed a simple method for measuring the combine loss in the field. This method consists in catching the losses on a sampling pan. The dimensions of the pan are determined by the width of cut of the combine. The number of tablespoonfuls of grain in the sampling pan indicates the bushels lost per acre.

Corn

Johnston and Myers (10) made a study of the relative costs of different methods of harvesting corn, especially in terms of quantity of labor, power, equipment and materials, and the relative advantages of different methods under different conditions. They also expressed the opinion that machine harvesting could be started from a week to 10 days earlier than hand picking.

Young (24) while discussing the status of mechanical corn picking in 1931 has emphasized the need to make the machines more reliable and durable with lesser losses. He has also stated that the corn picker does its best work when operating early in the season, when the stalks are still tough and the corn is not easily shelled.

Hobson and Wileman (6) after a study of mechanical corn pickers in Indiana in 1929, 1930 and 1931 have reported the cost, capacity, and losses of one and two-row pickers. The average loss in the case of one-row pickers was 7.70 per cent and in the case of two-row pickers the average loss was 9.90 per cent.

The Iowa Corn Research Institute (9, p. 23) in the Sixth Annual Report on Agricultural Research reported the field losses in testing five hybrids and one open-pollinated variety as follows:

> On October 16, total loss ranged from 1.37 to 2.68 per cent of the yield for the five hybrids and the loss was 6.35 per cent for the open-pollinated variety; on November 30, the total losses were 4.27 to 11.8 per cent of the yield for the hybrids, and 16.95 per cent for the open-pollinated variety.

Smith and Sorenson (21) in 1948 reported the results of investigations for determining the harvesting characteristics and performance of the conventional-type corn picker operating under Texas climatic and farming practices. Their results indicate that the machine efficiency decreased as the season advanced and the average percentage of ear corn lost by the machine increased as the season advanced. Their results also show that there appears to be a definite relation between the machine efficiency on one hand and the ear corn loss and the percentage of lodged and down stalks on the other.

Smith, Lyness and Kiesselbach (20) made a study of factors affecting the efficiency of the mechanical corn picker in 1949 and reported that the picker operated most efficiently at a kernel moisture content of 20 to 24 per cent. As this exceeds somewhat the upper limit of moisture for safe storage, they suggested that the crop should be picked when the moisture is from 17 to 20 per cent. They have also reported that, as an average, corn harvested on October 19, November 30, and December 22, respectively, suffered total picker losses of 4.4, 6.5, and 9.1 per cent of the entire crop produced. Total amounts shelled by the picker were 5.8, 13.7 and 15.0 per cent. The shelled grain loss was reported to be relatively low and constant at moistures above 20 per cent, and increased materially as the moisture declined to 16 per cent, and became very serious with a thorough drying of the grain to 14 per cent.

McKibben (14) in an article has reported that in December 1928 an attempt was made at Iowa State College to harvest corn with a 10-foot combine. The results of this trial were somewhat unsatisfactory as many of the conditions were unfavorable and the combine was in no way intended by the manufacturer for combining corn.

Logan (12) in 1931 reported on the Baldwin combine which could be used for combining corn by replacing the harvester cylinder unit. In a test at Stratton, Nebraska, on May 23, 1930, the operating cost was estimated to be $1.15 per acre and the cost per bushel .0322 cents. The losses were from 10 to 15 per cent. The success of the combine was doubted because shelled corn with high moisture content could not be stored.

Skelton and Bateman (19) in an article in April 1942 presented the results of tests on a picker-sheller. A comparison of the various methods of harvesting was made and it was reported that for areas greater than 45 acres the field shelling method had a lower cost as compared to other methods. Eighty-seven per cent of the total average loss was reported to occur in picking and the remaining 13 per cent in shelling.

Shedd (18) in an article "Corn Picker-Sheller and Shelled Corn Drier" has reported the picker ear loss as 7.4 bushels, the shelled corn loss as 2.4 bushels when the grain moisture was 25.4 per cent and the net yield 71.0 bushels per acre.

From this review of literature it is evident that considerable work has been done in different parts of the country in connection with cost, efficiency and adaptability of harvesting machinery for oats and corn. Little or no work has been done to investigate the possibility of early harvesting as till lately it was not considered feasible due to the storage problems involved. In recent years considerable work, however, has been done in connection with drying agricultural products for safe storage. This work is likely to influence the time and period of harvesting because of the possibility of making it independent of moisture content and weather. It was with this in view that this investigation was undertaken to determine the efficiency of harvesting equipment in effect of grain moisture and crop condition on the various harvest losses.

EXPERIMENTAL

Objectives of This Investigation

As the most commonly used index of the crop in regard to suitability of harvesting and indication of its maturity is the moisture content, this study was undertaken with the following objectives.

1. To determine the effect of grain moisture on efficiency of the combining operation by measuring the

   (a) shatter losses

   (b) separating losses

   (c) cutter-bar losses

2. To compare the two common practices of harvesting oats,

   (a) windrowing and combining

   (b) direct combining

at different grain moisture levels.

The second part of this study which is related to the harvesting of corn was undertaken with the following objective:

1. To determine the effect of grain moisture on efficiency of the picking and shelling operation in the field and determination of the

(a) loose ear loss

(b) picker ear loss

(c) picker shelled corn loss

(d) sheller corn loss

PROCEDURE

Equipment Used for Harvesting

The machine selected for this experimental work was a Massey-Harris No. 26 self-propelled combine. This machine has a 10-foot cutter-bar for direct combining. For windrow combining the cutter-bar arrangement is replaced by a pick-up attachment. All necessary adjustments were made according to the operator's manual for maximum efficiency.

For windrowing an 8-foot Oliver windrower was used.

Experimental lay-out

Test plots were laid out as shown on Fig. 6. Plots I, II and III were windrowed on the day when the first direct combining tests were made.

Direct combining and picking of windrowed crop was repeated as the moisture in the grain decreased.

Samples taken

Shatter loss. This loss which is due to wind, rain and other forces was picked from each plot before the harvesting operation was started. Each sample was from an area 1/2000 of an acre. A frame 1/10,000 of an acre was

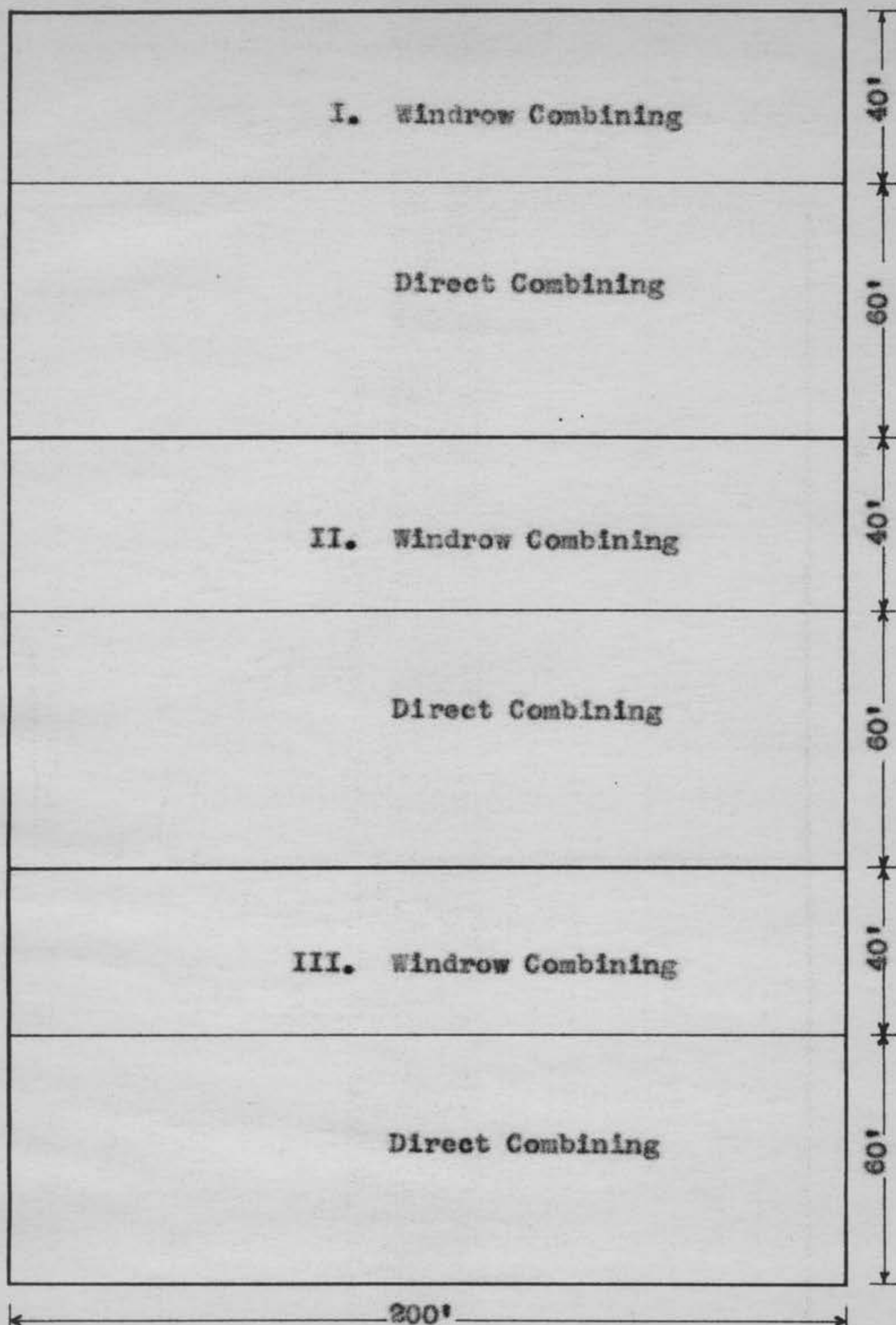

Fig. 6. Plot Lay-out for Oats

used and the grain was picked from five areas in the plot. The areas were distributed over the whole plot.

Windrower loss. The grain lost due to the windrowing operation was picked from an area 1/2000 of an acre. A frame 1/10,000 of an acre was used and the sample was picked from five areas that were distributed over the whole plot.

Net yield. Net yield samples were taken for an area 500 sq. ft. In the latter half of the plot a distance of 50 ft. was marked by stakes and all the grain coming out of the spout between these stakes was collected in a sack. To insure that the machine was working at normal load, the net yield samples were taken in the second half of the plot.

Separating and threshing loss. The grain that passes through the separating and threshing mechanism and is blown over with the straw constitutes this loss. Samples for this loss were collected by laying a canvas 0.0006125 of an acre at the end of the plot so that as the machine passed over it, the straw that was being blown out fell on it. One sample was taken in every plot.

Cutter-bar loss. This loss is due to the action of the cutter-bar and the reel while combining standing grain. After the combining operation, the combined shatter loss, cutter-bar loss and the separating loss were picked up from 1/2000 of an acre. From this the shatter loss and the separating loss were subtracted to determine the cutter-bar loss.

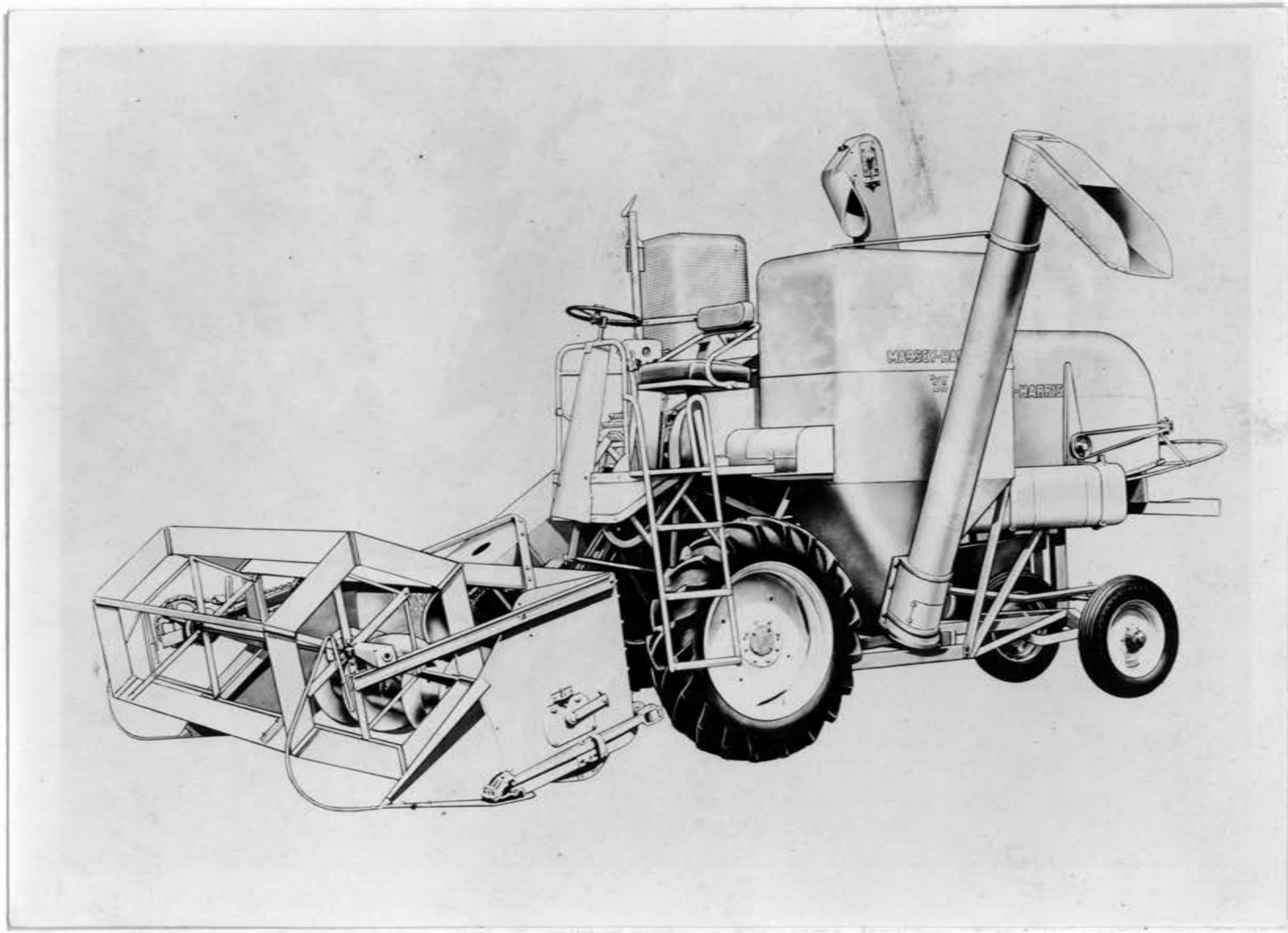

Fig. 7. Massey-Harris No. 26 Self-Propelled Combine with Cutter-Bar Attachment

Pickup loss. After harvesting the windrowed grain, the combined windrower loss, shatter loss and separating loss were picked from 1/2000 of an acre. From this, the windrower loss, shatter loss and the separating loss which were determined separately were subtracted to obtain the pickup loss.

Samples were collected in paper sacks. The date, kind of loss, and plot number were noted on each sack for identification. The samples were cleaned and weighed. A Toledo balance was used for the weighing of loss samples.

Grain sample for moisture. A sample was taken from every plot by picking heads from different parts of the plot.

Grain moisture determination

For moisture determination, the Brown-Duvel moisture tester was used. This tester operates on the principle of heating whole grains of oats in an oil bath to a temperature of 190° Centigrade, or nearly twice the boiling point of water. The water in the grain is thus driven off in the form of water vapour, which is condensed by passing through tubes immersed in cold water. The distillate is caught in graduates calibrated to one-fifth cubic centimeter. One hundred grams are used for the test; and as one cubic centimeter of water weighs one gram, the moisture percentage is read directly from the graduates.

Table 1. Direct Combining Losses - Massey Harris Self-Propelled Combine No. 26

July 23, 1951

Test no.	Grain moisture per cent	Gross yield lbs/ acre	Net yield lbs/ acre	Shatter loss lbs/ acre	Shatter loss per cent	Separating loss lbs/ acre	Separating loss per cent	Cutter-bar loss lbs/ acre	Cutter-bar loss per cent	Total loss lbs/ acre	Total loss per cent	Grain saved per cent
I		1878	1760	0.0	0.0	102.90	5.48	15.10	0.805	118.0	6.29	93.71
II	23.85	1834	1748	0.0	0.0	68.94	3.75	17.06	0.928	86.0	4.68	95.32
III		1824	1728	0.0	0.0	81.60	4.44	14.40	0.788	96.0	5.23	94.77
Avg.	23.85	1845	~~1778~~ 1745	0.0	0.0	84.48	4.56	15.52	0.80	100.0	5.40	94.60

1745 DAL May, 15, 1958

Table 2. Direct Combining Losses - Massey Harris Self-Propelled Combine No. 26

July 25, 1951

Test no.	Grain moisture per cent	Gross yield lbs/ acre	Net yield lbs/ acre	Shatter loss lbs/ acre	Shatter loss per cent	Separating loss lbs/ acre	Separating loss per cent	Cutter-bar loss lbs/ acre	Cutter-bar loss per cent	Total loss lbs/ acre	Total loss per cent	Grain saved per cent
I		1768	1672	6.0	0.34	68.4	3.60	21.6	1.22	96.0	5.16	94.86
II	16.10	1903	1783	10.0	0.53	90.0	4.73	20.0	1.05	120.0	6.31	93.69
III		1476	1407	8.0	0.53	45.66	3.10	15.2	1.03	68.9	4.67	95.33
Avg.	16.10	1716	1620	8.0	0.48	68.02	3.81	18.93	1.10	94.96	5.38	94.62

Table 3. Direct Combining Losses - Massey Harris Self-Propelled Combine No. 26

July 28, 1951

Test no.	Grain moisture per cent	Gross yield lbs/ acre	Net yield lbs/ acre	Shatter loss lbs/ acre	Shatter loss per cent	Separating loss lbs/ acre	Separating loss per cent	Cutter-bar loss lbs/ acre	Cutter-bar loss per cent	Total loss lbs/ acre	Total loss per cent	Grain saved per cent
I		1872	1780	8.0	0.43	61.95	3.32	22.05	1.18	92.0	4.93	95.07
II	12.45	1607	1513	14.0	0.87	53.82	3.36	26.18	1.63	94.0	5.86	94.14
III		1617	1543	8.0	0.50	45.66	2.82	20.34	1.26	74.0	4.58	95.42
Avg.	12.45	1698	1612	10.0	0.60	53.81	3.17	22.86	1.36	86.66	5.13	94.87

Table 4. Direct Combining Losses - Massey Harris Self-Propelled Combine No. 26

August 7, 1951

After 0.76 inches Rainfall on August 2, 1951

Test no.	Grain moisture per cent	Gross yield lbs/acre	Net yield lbs/acre	Shatter loss		Separating loss		Cutter-bar loss		Total loss		Grain saved per cent
				lbs/acre	per cent	lbs/acre	per cent	lbs/acre	per cent	lbs/acre	per cent	
I		1482	1340	66.0	4.46	52.20	3.52	23.80	1.61	142.0	9.59	90.41
II	12.9	1533	1387	60.0	3.92	60.30	3.93	25.70	1.67	146.0	9.45	90.55
III		1562	1428	72.0	4.61	39.15	2.51	22.85	1.46	134.0	8.57	91.43
Avg.	12.9	1525	1385	66.0	4.33	50.55	3.32	24.11	1.58	141.33	9.20	90.80

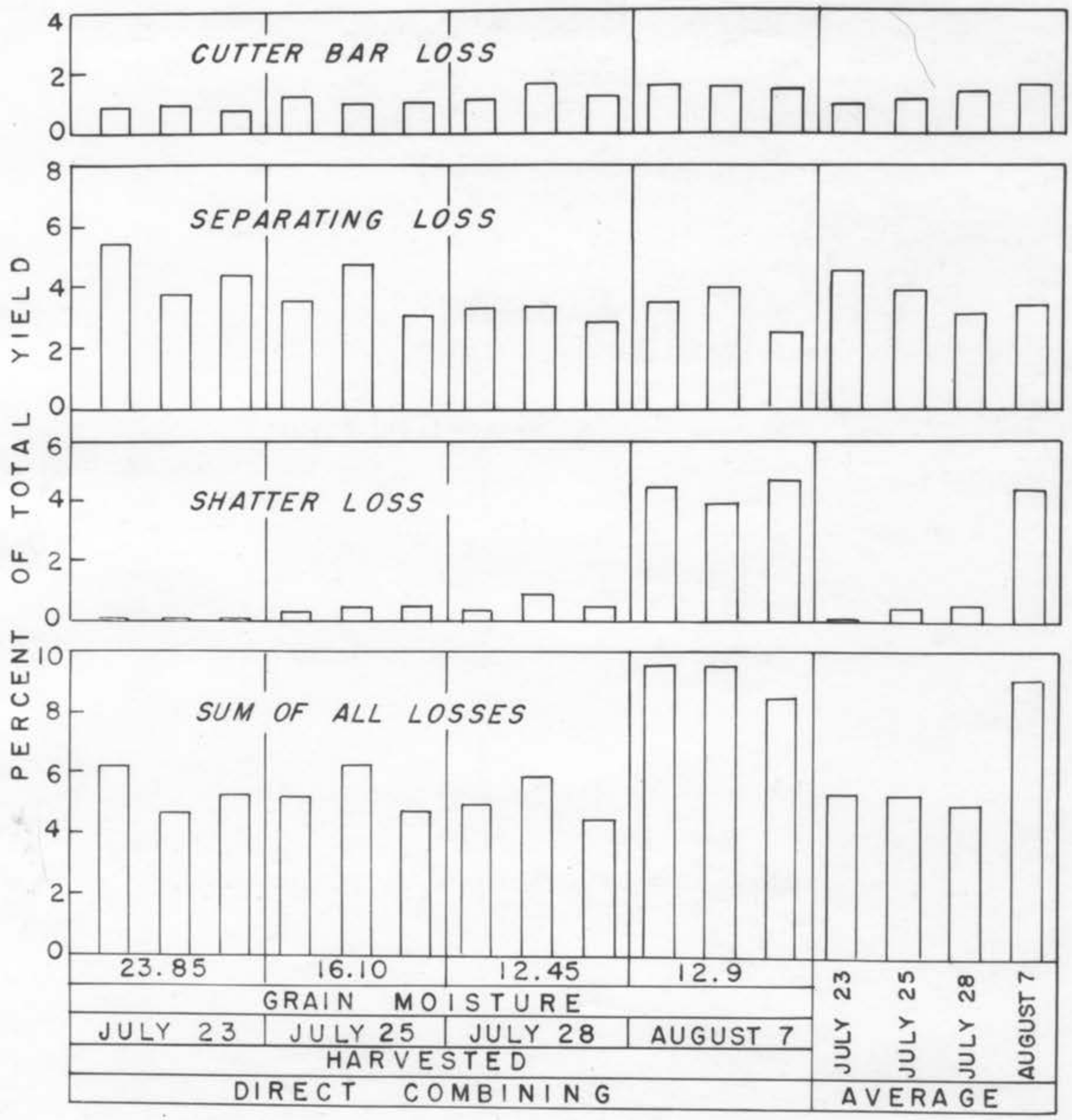

Fig. 8. Various Losses Resulting from the Direct Combining of Clinton Oats at Four Different Dates. On August 2 there was a rainfall of 0.76 inch. (23)

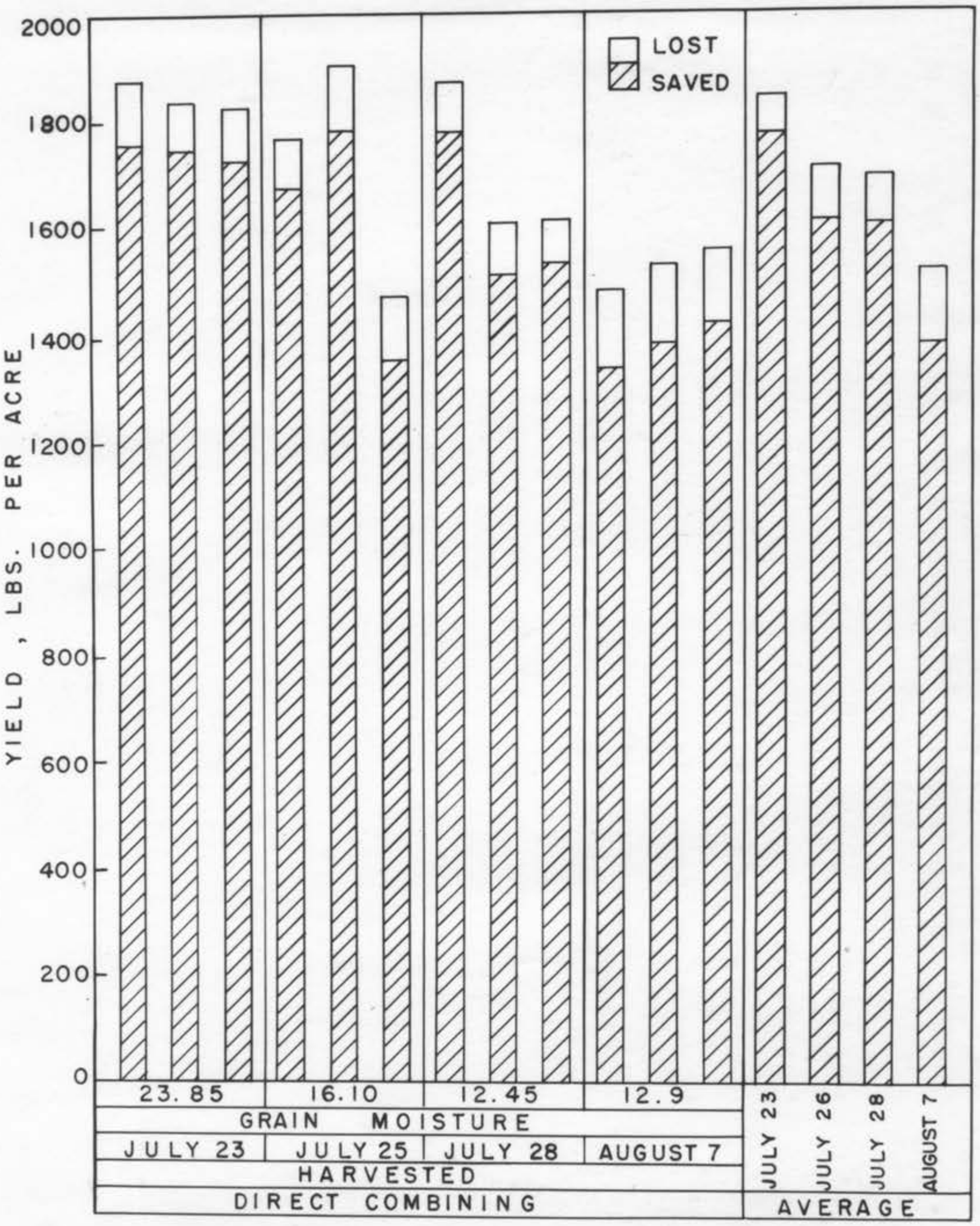

Fig. 9. Grain Saved and Lost from the Direct Combining of Clinton Oats at Four Different Dates. On August 2 there was a rainfall of 0.76 inch (23).

Fig. 10. Massey-Harris No. 26 Self-Propelled Combine with Pickup Attachment

Table 5. Windrow Combining Losses - Massey Harris Self-Propelled Combine No. 26

July 30, 1951

Test no.	Grain moisture	Gross yield	Net yield	Windrower loss		Shatter loss		Separating loss		Pickup loss		Total loss		Grain saved
	per cent	lbs/ acre	lbs/ acre	lbs/ acre	per cent	lbs/ acre	per cent	lbs/ acre	per cent	lbs/ acre	per cent	lbs/ acre	per cent	per cent
I		1726	1658	16.0	0.81	6.0	0.35	32.67	1.90	15.33	0.89	68.0	3.06	96.94
II	15.6	1720	1640	18.0	1.05	7.0	0.41	40.80	2.38	14.20	0.83	80.0	4.67	95.33
III		1788	1710	16.0	0.90	4.0	0.22	44.10	2.47	13.90	0.78	78.0	4.37	95.63
Avg.	15.6	1744	1669.3	16.0	0.92	5.66	0.33	39.19	2.25	14.47	0.83	75.33	4.03	95.96

Table 6. Windrow Combining Losses - Massey Harris Self-Propelled Combine No. 26

August 1, 1951

Test no.	Grain moisture per cent	Gross yield lbs/acre	Net yield lbs/acre	Windrower loss lbs/acre	Windrower loss per cent	Shatter loss lbs/acre	Shatter loss per cent	Separating loss lbs/acre	Separating loss per cent	Pickup loss lbs/acre	Pickup loss per cent	Total loss lbs/acre	Total loss per cent	Grain saved per cent
I		1678	1580	14.0	0.83	16.0	0.95	45.7	2.73	22.30	1.33	98.0	5.86	94.16
II	10.6	1826	1720	18.0	0.99	19.5	1.07	40.8	2.24	25.70	1.41	104.0	5.71	94.29
III		1632	1530	16.0	0.98	9.0	0.55	50.6	3.10	26.60	1.62	102.0	6.25	93.75
Avg.	10.6	1712	1610	16.0	0.93	14.83	0.85	45.70	2.69	24.86	1.45	101.33	5.94	94.06

Table 7. Windrow Combining Losses - Massey Harris Self-Propelled Combine No. 26

August 7, 1951

Test no.	Grain moisture per cent	Gross yield lbs/acre	Net yield lbs/acre	Windrower loss lbs/acre	Windrower loss Per cent	Shatter loss lbs/acre	Shatter loss per cent	Separating loss lbs/acre	Separating loss per cent	Pickup loss lbs/acre	Pickup loss per cent	Total loss lbs/acre	Total loss per cent	Grain saved per cent
I		1616	1480	14.0	0.87	26.0	1.61	65.25	4.04	30.75	1.86	136.0	8.38	91.62
II	9.3	1689	1517	18.0	1.07	29.5	1.75	89.70	5.32	34.80	2.04	172.0	10.18	89.82
III		1734	1608	16.0	0.92	21.5	1.24	57.15	3.30	31.35	1.81	126.0	7.37	92.63
Avg.	9.3	1680	1535	16.0	0.95	25.66	1.53	70.70	4.22	32.30	1.90	144.66	8.64	91.35

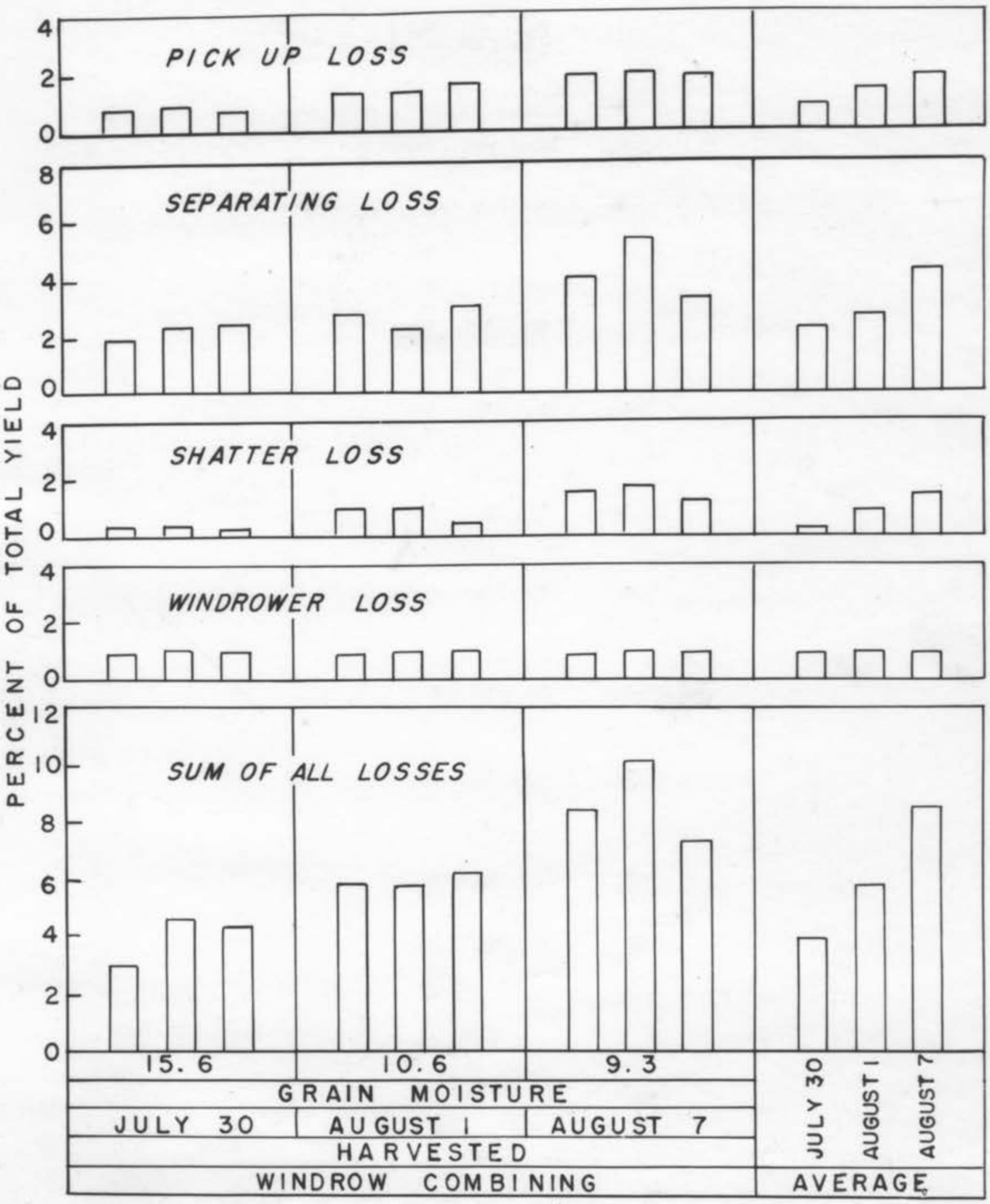

Fig. 11. Various Losses Resulting from the Windrow Combining of Clinton Oats at Three Different Dates. On August 2 there was a rainfall of 0.76 inch (23).

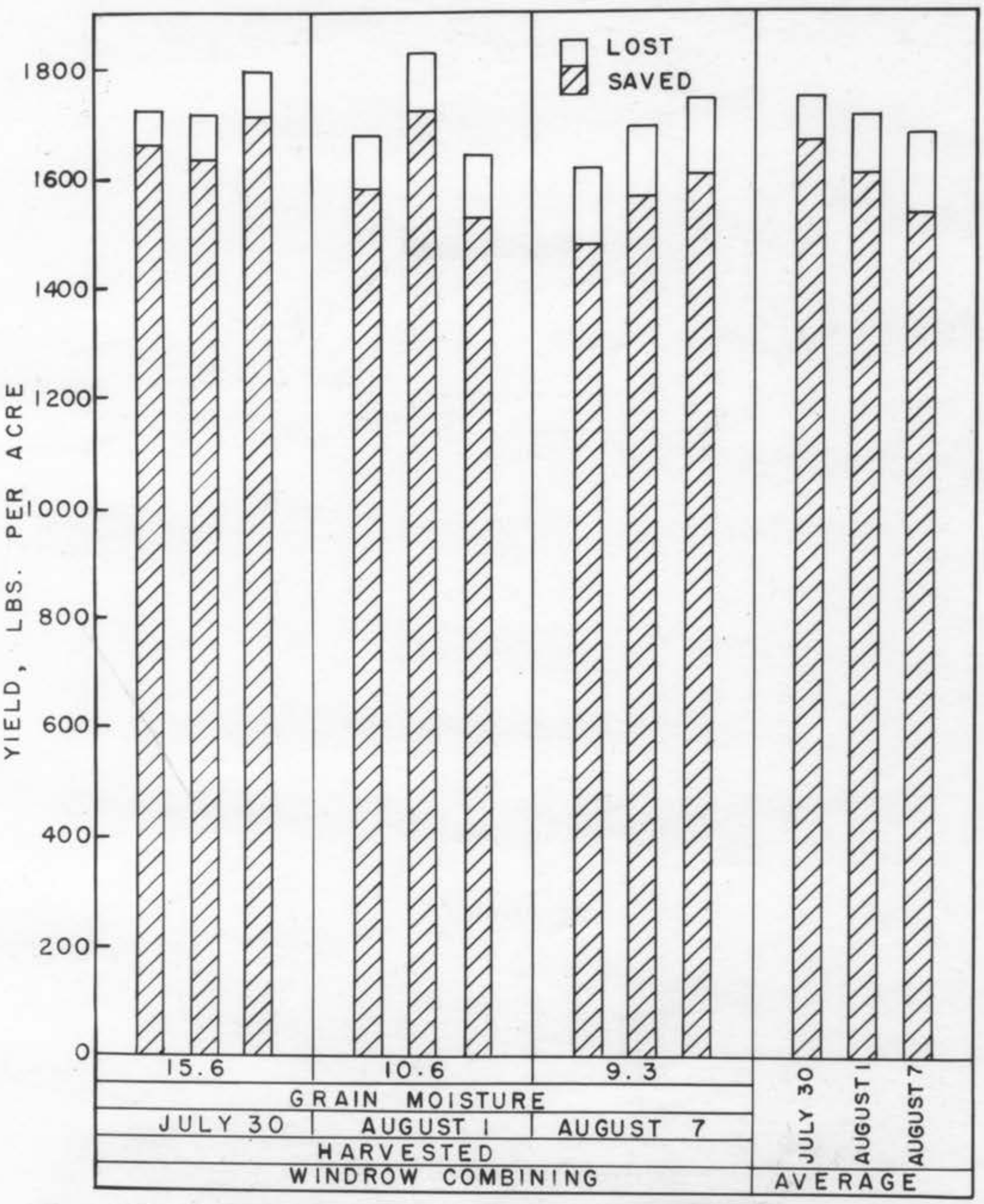

Fig. 12. Grain Saved and Lost From Windrow Combining of Clinton Oats at Three Different Dates. On August 2 there was a rainfall of 0.76 inch (23).

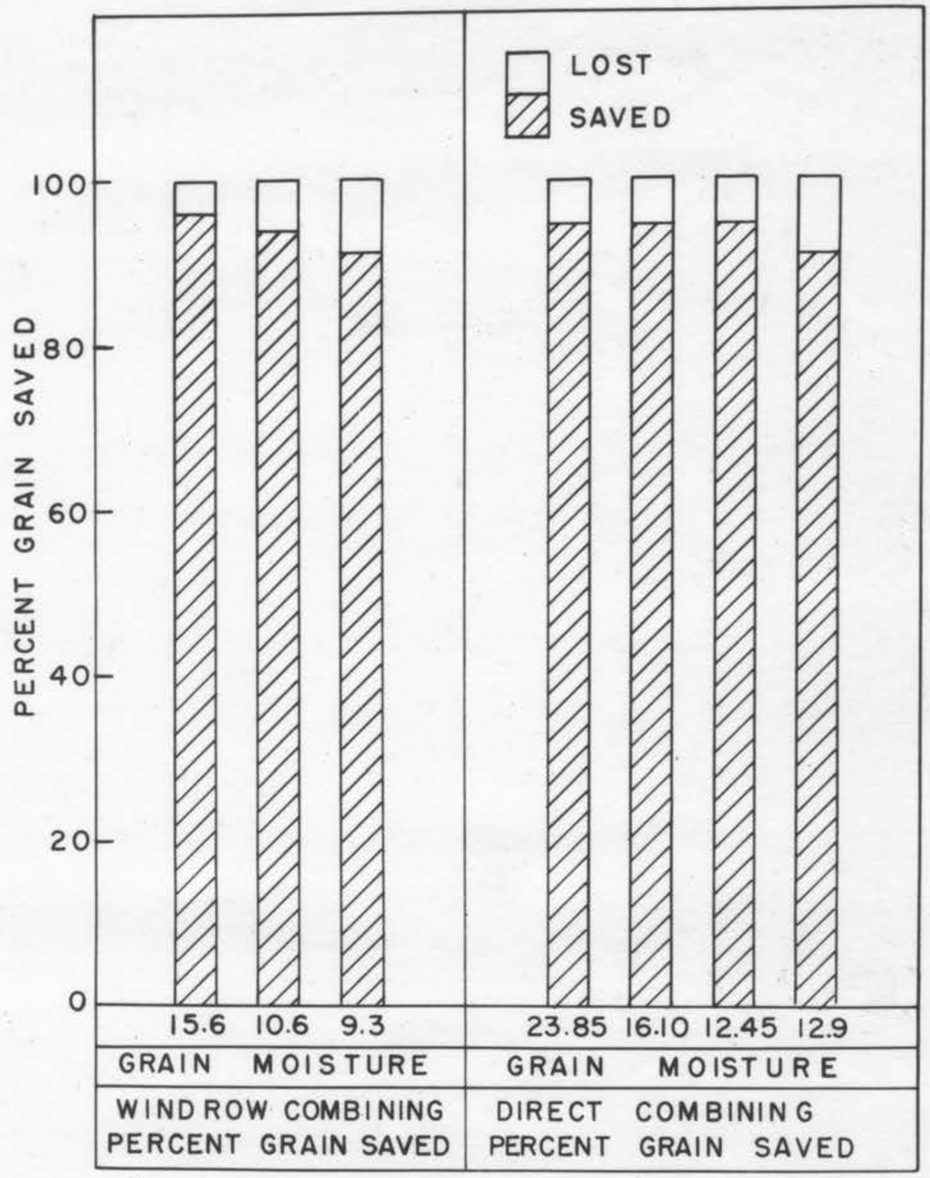

Fig. 13. Per Cent Grain Saved from the Windrow Combining and Direct Combining of Clinton Oats at Different Grain Moistures

Yield determinations were calculated for all plots in the case of direct combining on a 16.0 per cent moisture basis and in the case of windrow combining on a 15.6 per cent moisture basis.

Gross yield of grain per acre was compiled by addition of net yield and the total losses in both cases.

Equipment Used for Harvesting

As there is an increased demand for labor-saving machinery for economical production due to high wages and labor shortage, a J. I. Case picker-sheller was selected for this investigation. Moreover, the picker-sheller also fits in with the use of driers, which are now gaining acceptance in this part of the country. After making a number of preliminary tests it was found that a John Deere Model A tractor was most suitable and was used for the experimental work. All necessary adjustments were made according to the operator's manual for maximum efficiency.

Experimental lay-out

Three test plots each 1/100 of an acre were marked as shown in Fig.14 and stakes were placed at both ends of each plot. The distance between each plot was enough to insure that the picker-sheller was working at normal load while the net yield sample was being taken.

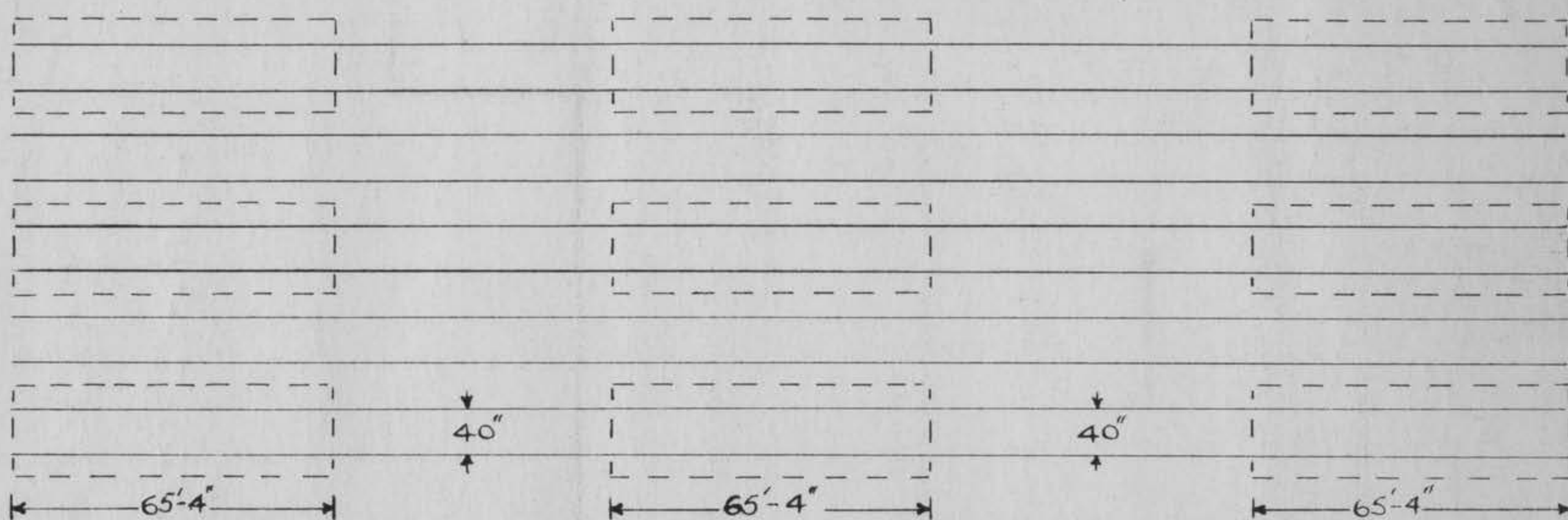

Fig. 14. Plot Lay-out for Corn

Samples taken

Condition of crop. Before picking, the condition of the crop was noted. For one hundred stalks in the area of the test plot a count was made for the following conditions:

1. Standing stalks
2. Bent and leaning stalks
3. Down stalks, ears touching the ground

From the three counts made, an average was taken for the condition of the crop.

Loose ear loss. This loss which is due to wind and other forces was picked from each plot, before the test, and put in separate paper sacks. The plot number and the date was noted on each sack.

Net yield. Net yield samples were collected from an area .01 acre. All the grain coming out of the spout between the stakes was collected in a jute sack. A slip indicating the number of plot and date was placed in each sack for identification.

Picker ear loss. The ears knocked down by the picker constitute this loss. These ears were picked from each plot and put in separate paper sacks.

Picker shelled corn loss. As the ears are removed from the stalks by the snapping assembly some corn is shelled and is lost as it falls on the ground. This loss was picked from an area .001 of an acre in every plot.

Fig. 15. J. I. Case Picker-Sheller Used for Harvesting

Shelling and separating loss. After the ears passed through the sheller some grains were either left on the cobs or were passed out with the cobs as a separating loss. This loss was collected on a canvas 6.53 feet long and was for .001 of an acre. The canvas was spread in the plot so that all the cobs and the unseparated grain coming out of the separator fell on it.

Grain and cob moisture. For this,three samples of five ears each were taken before the test, from the same row but from outside of the marked plots. The ears were shelled by hand and the grain and cobs were used for moisture determination.

The moisture percentage was determined by weighing the shelled corn and the cobs on a Toledo grain balance before and after drying in an electric oven at 100° C. It was noticed that it usually took about three days for the cobs to dry to a constant weight.

Damaged grain. By t aking samples from the net yield samples already collected, and separating the damaged grain from the whole grain, the percentage of such damaged grain was determined.

Yield determinations were calculated for all plots on an 18.0 per cent moisture basis. Gross yield of grain per acre was compiled by addition of net yield, loose ear loss, picker ear loss, picker shelled corn loss, and sheller corn loss.

Table 8. Harvesting Losses - J. I. Case Picker-Sheller

November 2, 1951

Condition of crop: Standing stalks 58%
Bent and leaving stalks 7%
Down stalks 35%

Grain damaged: (i) 5.26% (ii) 5.88% (iii) 7.01% Average 6.05%

Test no.	Moisture per cent		Gross yield lbs/ acre	Net yield lbs/ acre	Loose ear loss		Picker ear loss		Picker shelled corn loss		Sheller corn loss		Total loss		Grain saved per cent
	Grain	Cobs			lbs/ acre	per cent	lbs/ acre	per cent	lbs/ acre	per cent	lbs/ acre	per cent	lbs/ acre	per cent	
I	24.16	30.4	6179	5290	52	0.84	443	7.16	172	2.78	232	3.75	889	14.55	85.5
II	23.3	31.15	5859	4930	45	0.767	554	9.44	230	3.92	100	1.71	929	15.83	84.17
III	22.0	31.25	6174	5475	68	1.102	310	5.02	205	3.32	116	1.88	699	11.32	88.68
Avg.	23.15	30.93	6070.6	5231.6	55	0.903	432.3	7.20	202.3	3.34	149.3	2.45	839	13.9	86.11

Table 9. Harvesting Losses - J. I. Case Picker-Sheller

November 9, 1951

Condition of crop: Standing stalks 50.00%
Bent and leaning stalks 8.33%
Down stalks 41.66%

Grain damaged: (i) 3.82% (ii) 3.54% (iii) 3.61% Average 3.65%

Test no.	Moisture per cent Grain	Moisture per cent Cobs	Gross yield lbs/ acre	Net yield lbs/ acre	Loose ear loss lbs/ acre	Loose ear loss per cent	Picker ear loss lbs/ acre	Picker ear loss per cent	Picker shelled corn loss lbs/ acre	Picker shelled corn loss per cent	Sheller corn loss lbs/ acre	Sheller corn loss per cent	Total loss lbs/ acre	Total loss per cent	Grain saved per cent
I	20.0	24.2	6280	5476	98	1.56	587	9.35	81	1.29	40	0.64	806	12.87	87.13
II	21.3	25.78	6796	5851	112	1.648	578	8.5	177	2.6	78	1.15	945	13.90	86.10
III	20.55	24.7	6137	5295	56	0.913	533	8.68	164	2.67	89	1.45	842	13.72	86.28
Avg.	20.61	24.89	6404.3	5540	88.66	1.37	566	8.84	140.66	2.18	69	1.08	864	13.49	86.50

Table 10. Harvesting Losses - J. I. Case Picker-Sheller

November 16, 1951

Condition of crop: Standing stalks 48.66%
Bent and leaning stalks 7.0%
Down stalks 44.33%

Grain damaged: (i) 2.39% (ii) 2.85% (iii) 1.95% Average 2.40%

Test no.	Moisture per cent Grain	Moisture per cent Cobs	Gross yield lbs/ acre	Net yield lbs/ acre	Loose ear loss lbs/ acre	Loose ear loss per cent	Picker ear loss lbs/ acre	Picker ear loss per cent	Picker shelled corn loss lbs/ acre	Picker shelled corn loss per cent	Sheller corn loss lbs/ acre	Sheller corn loss per cent	Total loss lbs/ acre	Total loss per cent	Grain saved per cent
I	17.88	17.3	5459	4698	105	1.92	525	9.61	128	2.34	3	0.055	761	13.93	86.07
II	18.4	18.08	5304	4523	89	1.68	615	11.62	72	1.36	5	0.094	781	14.75	85.25
III	17.7	18.35	5265	4217	125	2.375	755	14.36	165	3.135	3	0.057	1048	19.90	80.10
Avg.	18.0	17.91	5342.6	4479	106.3	1.99	631.6	11.86	121.6	2.28	3.66	0.068	863.3	16.19	83.80

Table 11. Losses Expressed as Percentage of Total Loss

Test no.	Average moisture per cent		Total loss	Average loose ear loss		Average picker ear loss		Average picker shelled corn loss		Average sheller corn loss	
	Grain	Cob	lbs/ acre	lbs/ acre	Per cent of total loss	lbs/ acre	Per cent of total loss	lbs/ acre	Per cent of total loss	lbs/ acre	Per cent of total loss
I	23.15	30.93	839	55	6.56	432.3	51.5	202.3	24.1	149.3	17.8
II	20.61	24.89	831	88.66	10.67	566	68.2	140.66	16.9	69	8.31
III	18.00	17.91	863.3	106.3	12.32	631.6	73.1	121.6	14.1	3.66	0.424
Avg.			844.43	83.22	9.85	543.3	64.26	154.85	17.36	73.98	8.84

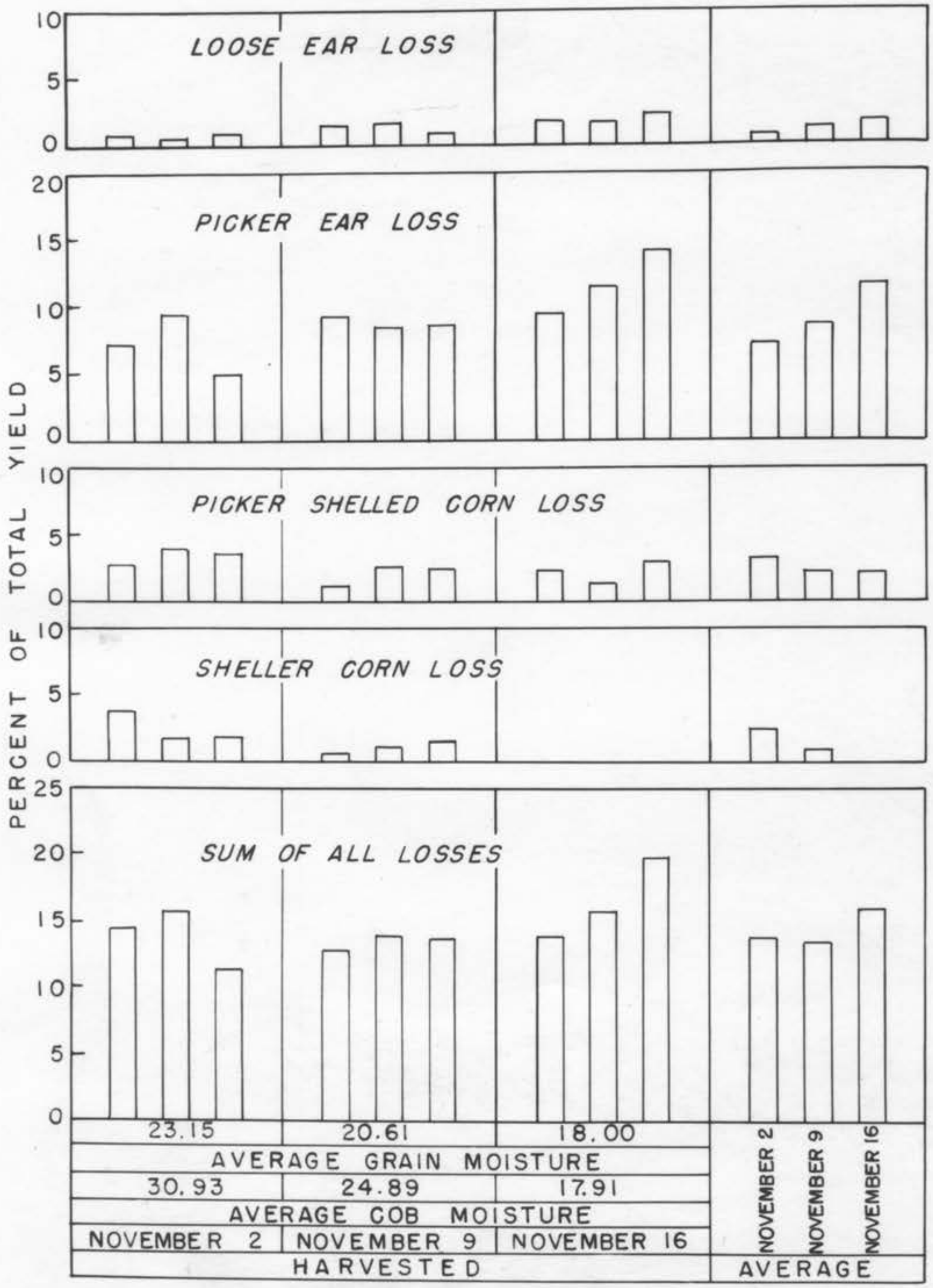

Fig. 16. Various Grain Losses Resulting from the Picker Sheller Harvest of Hybrid Corn Black's B-24 at Three Different Dates

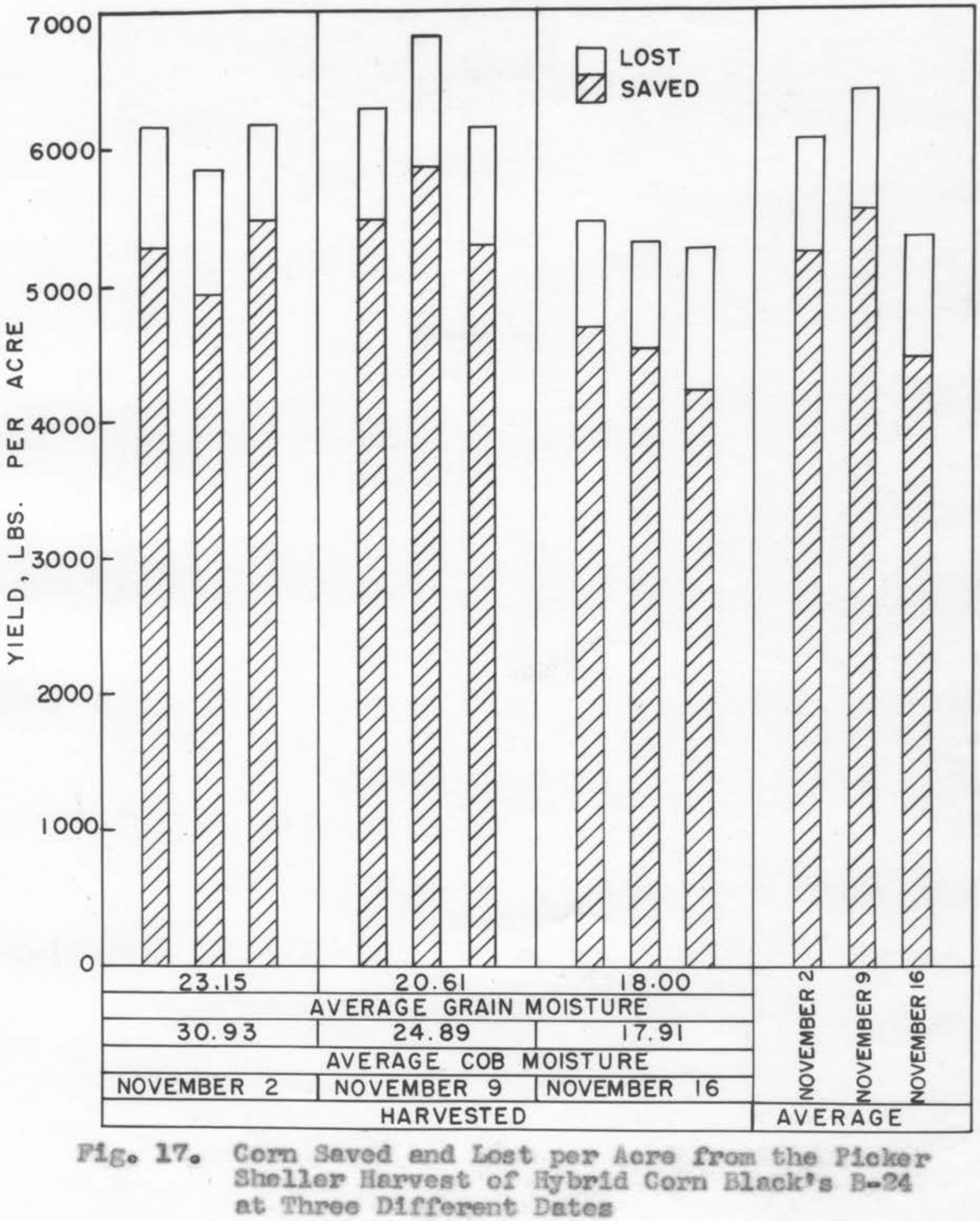

Fig. 17. Corn Saved and Lost per Acre from the Picker Sheller Harvest of Hybrid Corn Black's B-24 at Three Different Dates

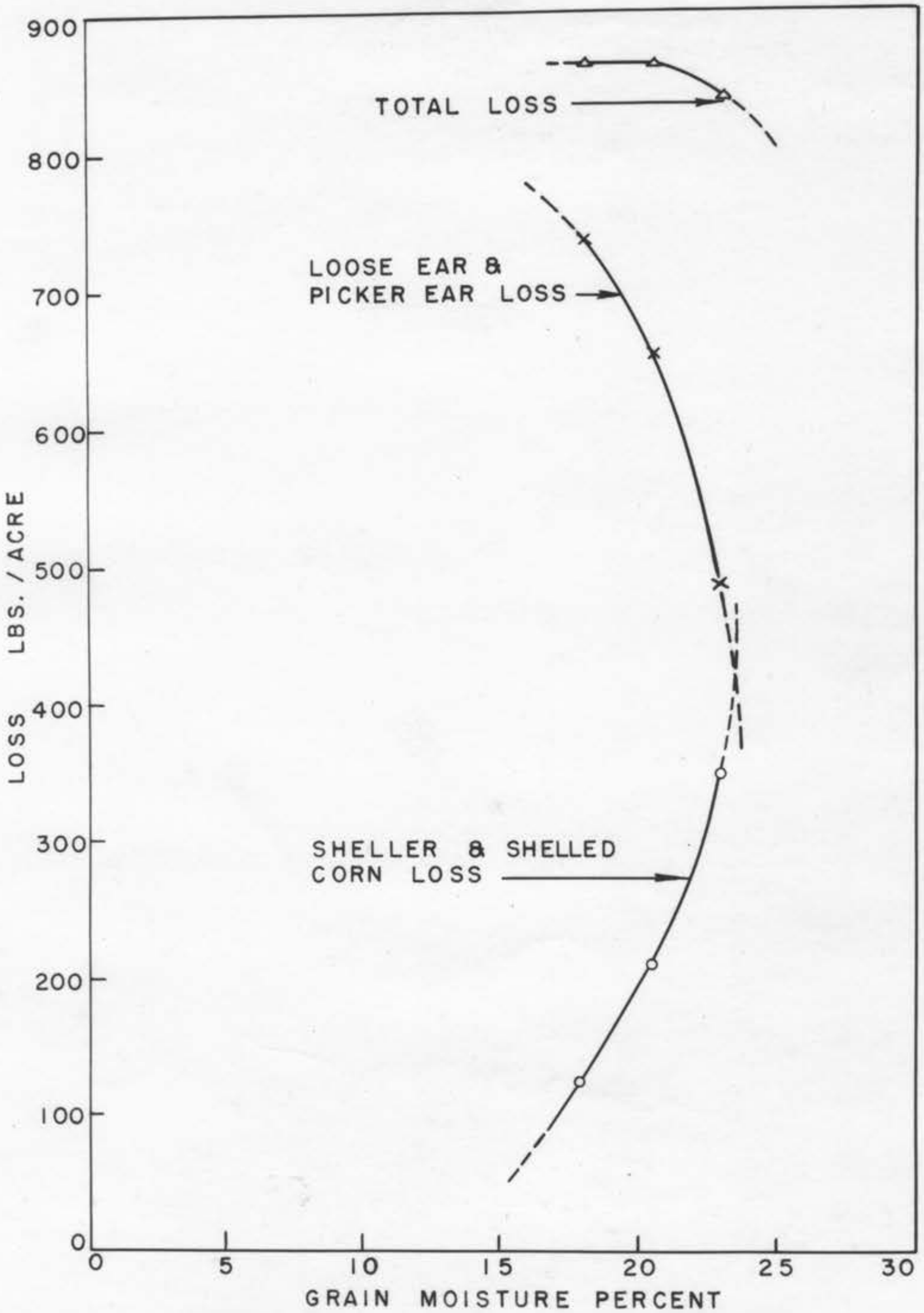

Fig. 18. Curves Showing Picker Sheller Losses at Different Grain Moistures

RESULTS

The data collected for studying the effect of grain moisture on efficiency of harvesting machinery for oats and corn is presented as follows:

Oats

Direct combining

The results of direct combining on four different dates are shown in Tables 1, 2, 3 and 4. A comparison of the various loss is shown in Fig. 8. The grain saved and lost is shown in Fig. 9.

Windrow combining

The results of windrow combining on three different eates are shown in Tables 5, 6 and 7. Various losses resulting from windrow combining are shown in Fig. 11. The grain saved and lost is shown in Fig. 12. A comparison of the grain lost and saved by the two harvesting practices is shown in Fig. 13.

Corn

Picker-shelling

The results of picker-shelling on November 2, 9 and 16 are shown in Tables 8, 9 and 10. In Table 11 the losses are expressed as percentage of total loss. A comparison of the various grain losses is shown in Fig. 16 and the corn saved and lost per acre is shown in Fig. 17. The sheller and shelled corn loss curve and the loose ear and picker ear loss curves at different grain moistures are shown in Fig. 18.

DISCUSSION

Interpretation of Results

Oats

A final analysis of the first part of this study shows that in the case of direct combining the total losses do not change appreciably with changes in grain moisture, the total losses being 5.40, 5.38 and 5.13 per cent of the total yield when the grain moisture was 23.85, 16.10 and 12.45 per cent, respectively. After 0.76 inch of rain on August 2 (23) the total losses increased to 9.20 per cent, the grain moisture being 12.9 per cent.

The cutter-bar losses increased with decrease in grain moisture and were 0.80, 1.10 and 1.36 per cent of gross yield while the grain moisture was 23.85, 16.10 and 12.45 per cent, respectively. Hurst and Humphries (7) in their studies in Illinois and Indiana in 1935 reported a cutter-bar loss of 1.38 per cent of the total yield, the average grain moisture being 9.6 per cent.

The separating loss which was 4.56 per cent of total yield at 23.85 per cent grain moisture decreased to 3.81 and 3.17 per cent at 16.10 and 12.45 per cent moisture. The separating loss reported by Hurst and Humphries (7) is 4.22 per cent of total yield.

The shatter loss, which was zero at 23.85 per cent moisture, increased to 0.48 and 0.60 per cent at 16.10 and 12.45 per cent moisture, respectively. After 0.76 inch of rain on August 2 this loss increased to 4.33 per cent.

In the case of windrow combining the total losses were 4.03 and 5.94 per cent of total yield at 15.6 and 10.6 per cent grain moisture. After 0.76 inch of rain on August 2 the total losses increased to 8.64 per cent.

The pickup losses increased from 0.83 per cent to 1.45 per cent as the grain moisture decreased from 15.6 to 10.6 per cent. After the rain on August 2 the pickup losses increased to 1.90 per cent.

The separating losses showed a slight increase from 2.25 per cent to 2.65 per cent of total yield, the grain moisture being 15.6 and 10.6 per cent, respectively.

The shatter losses increased from 0.326 per cent to 0.85 per cent as the moisture in the grain decreased from 15.6 per cent to 10.6 per cent. After the rainfall on August 2 the shatter loss increased to 1.53 per cent.

Corn

An analysis of the second part of this study shows that while harvesting with a picker-sheller the total losses increased from 13.9 per cent of total yield on November 2 to 16.19 per cent on November 16, as the grain and cob moisture decreased from 23.15 per cent and 30.93 per cent to 18.0 per cent and 17.91 per cent, respectively.

Figure 8 shows that as the moisture in the cobs and grain decreased the loose ear losses and the picker ear losses increased while the picker shelled corn losses and the sheller corn losses decreased. This is also evident from Table 11, where the loose ear losses increased from 6.56 per cent to 12.32 per cent of total losses and the picker ear losses increased from 51.5 per cent to 73.1 per cent of total losses. These high and increasing losses can be explained by the condition of the crop, of which 42 to 52 per cent of the stalks were down and leaning.

The total average sheller corn loss is 8.84 per cent of the total loss (Table 11) and the remaining losses are 91.16 per cent. The average sheller corn loss reported by Skelton and Bateman (18) in 1942 was 13 per cent of the total loss and the remaining losses 87 per cent.

CONCLUSIONS

Oats

Direct combining

1. In case of direct combining it appears the total losses do not change appreciably with decrease in grain moisture.

2. The cutter-bar and shatter loss increases and the separating loss decreases as the grain moisture decreases.

3. The shatter loss increases considerably after rain.

Windrow combining

1. In case of windrow combining the total losses seem to increase with decrease in grain moisture.

2. The pickup loss increases with decrease in grain moisture.

3. The separating loss does not change appreciably with decrease in grain moisture.

4. There is a slight increase in the shatter loss as the grain moisture decreases.

5. After rain there is little increase in the shatter and pickup loss and considerable increase in the case of

separating loss.

6. On the whole, more grain was saved by windrow combining than by direct combining. In case of windrow combining grain drying was not necessary for safe storage.

Corn

1. The increasing loose ear and picker ear losses and the decreasing sheller and shelled corn losses when added are compensating, with the result that the total losses vary only slightly throughout the season.

2. As the moisture in the grain and cobs decreases the loose ear loss and the picker ear loss increase, whereas the picker shelled corn loss and the sheller corn loss decrease. The increase in ear losses was due to the deteriorating condition of the crop and attendant decrease in stalk moisture.

3. Sheller damage to the grain decreases with decrease in grain moisture.

4. The optimum grain moisture for picker shelling from this study appears to be 23.5 per cent.

SUMMARY

Corn and oats, which are the first and second largest grain crops in terms of volume in the United States, are of great importance to a number of industries.

Since the introduction of harvesting machinery, improvements have been made gradually in the equipment and better varieties of oats and corn have been developed, but up until now the efficiency of the harvesting operation has been dependent on the weather conditions, condition of the crop, grain moisture, etc. In order to make the harvesting operation more efficient, considerable work is being done in the way of drying agricultural products and improving harvesting equipment for handling grain with high moisture content.

This study was made to investigate the effect of grain moisture on efficiency of harvesting machinery for oats and corn.

From the analysis of this study it appears that in case of direct combining of oats the total losses do not change appreciably with decrease in grain moisture. The cutter-bar and shatter losses increase whereas the separating loss decreases as the grain moisture decreases. After rain the shatter loss increases considerably.

In case of windrow combining of oats the total losses

increase with decrease in grain moisture. The pickup and shatter losses increase whereas the separating loss does not change much with decrease in grain moisture. After rain there is considerable increase in the case of separating loss and slight increase in shatter and pickup losses. On the whole, more grain was saved by windrow combining than by direct combining.

In the case of picker shelling of corn it appears that the total losses increase slightly with decrease in grain moisture. The loose ear loss and the picker ear loss increase, whereas the picker shelled corn loss and the sheller corn loss decrease. The optimum grain moisture for picker shelling seems to be 23.5 per cent.

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