GRAIN LOSSES IN THE FIELD WHEN WINDROWING AND COMBINING BARLEY

M.E. Dodds
Member CSAE
Research Station
Research Branch, Agriculture Canada
Swift Current, Saskatchewan

INTRODUCTION
The loss of grain in the field resulting from windrowing and combining operations has been the subject of much research since this harvesting system was introduced (4). Based on previously reported research methods (9), which were used later in combine performance studies (2, 8), preliminary field studies were conducted at Swift Current in 1948 and 1949 with the windrower and combine to develop a technique for determining and classifying harvesting losses. These were classified as natural and mechanical losses, the mechanical loss being further subdivided into windrowing, pickup, and combining losses (4). Pickup loss and combining loss have been renamed ‘gathering loss’ and ‘processing loss’ (1).

The purpose of this study was to determine the loss of grain in the field when harvesting barley by the windrower-combine method, and to observe the effects of windrowing at progressively later stages of crop maturity on the magnitude of four separate harvesting losses.

PROCEDURE
This study was made in 1966, 1967, 1969, and 1970 using barley (Hordeum vulgare L.) cultivar Vantage, as a test crop. This cultivar is a six-rowed, smooth-awned feed barley with good kernel retention in the head, and a mid-long, relatively strong straw. Maturity is midseason to late.

The statistical design for this test was a randomized block consisting of four replicates of each treatment. Treatments were dates of windrowing, and provision was made in the field layout for at least 20 such dates. The numbers of treatments varied from year to year depending on the rate at which the crop matured.

The cuts were made with a 12-ft (3.65-m) self-propelled windrower through the centre of a 30-ft (9.14-m) wide plot. The length of the plot varied with field location each year and ranged from 125 to 190 ft (38 to 58 m). The work was done by an experienced operator who attempted to maintain a constant forward speed of travel of 3 mph and a stubble height of 6 inches (15 cm).

Kernel moisture content, wet-weight basis, was used as a measure of grain maturity. It was suggested by previous research with barley (3, 5) that in tests of this kind, a practical range of kernel moisture to be observed was from approximately 50 to 14%. Windrowing then, was started when the grain was in the early dough stage of maturity, and continued until fully ripe. Plots were cut on consecutive days, when weather and field conditions permitted. A grab sample of the windrowed grain was gathered by hand from the length of the windrow immediately after cutting, threshed in a laboratory thresher and cleaned. Kernel moisture was determined by drying triplicate samples in a thermostatically controlled oven for 20 h at 98°C.

The windrowed grain was harvested with a self-propelled combine equipped with a draper pickup when the kernel moisture had decreased naturally to 14%.

Four types of losses were determined in this test. These were measured in grams per square foot (grams per 0.093 square meters) and converted to bushels per acre (kilograms per hectare) based on the bushel weight of the crop when harvested by the combine. The following field procedure was used:

(1) Natural loss: Eight samples within each replicate of kernels and heads of grain on the ground were taken at random through the plot prior to windrowing on each day of cutting. The samples were from an area one square foot (0.093 m²) in size, four being taken on each side of the area where the windrow would be placed.

(2) Windrowing loss: Similarly, after windrowing, eight samples of kernels and heads on the ground were taken at random within each replicate. Four samples were taken on each side of the windrow. This loss minus the natural loss is equal to the windrowing loss. It is realized that some further shattering may take place on the windrower canvasses and be conveyed and placed in the windrow or on the ground. Such a loss has not been measured separately in this test, but because it is not recoverable, has been considered to be part of the gathering loss.

(3) Gathering loss: Square-foot (0.093-m²) collections of kernels and heads of grain on the ground were taken in an area from which all threshable material had been removed by the combine (i.e., the 50-ft (15.24-m) length in which the processing loss was determined). Eight samples were taken in 1966 and 1967 and four samples were taken in 1969 and 1970. The windrow was 4 ft (1.22 m) wide in most cases. The square-foot (0.093-m²) samples, which included the natural and windrowing losses already on the ground, represented a concentration of kernels and heads from a swath 12 ft (3.65 m) wide. The gathering loss therefore, was the total square-foot (0.093-m²) collection minus the natural and windrowing losses, divided by three.

(4) Processing loss: This loss was obtained by gleaning the loose grain, broken kernels, and un-
It was possible, in the report on grain losses when harvesting wheat (4), to pool the data for the 5 yr of that study for a single analysis to exhibit the trends of the four separate losses. The combination of data over the 4 yr of this study with barley was not possible because of the extreme variation of the data from year to year. Several factors that apparently caused this variation will be discussed later.

The losses have been expressed in bushels per acre. This decision was made because the ratios of the material other than grain-to-grain were not determined, nor were the combine runs timed. It was therefore not possible to calculate the machine losses as a percentage of the grain feed rate, as has recently been proposed (1). Some consideration was given to expressing losses as a percentage of the potential yield, but this method was abandoned when the resulting regression lines did not exhibit any appreciable difference in form to those derived when bushels per acre were used. The regression used were of the logarithmic form \( y = m \log x + b \); where \( y \) was loss in bushels per acre and \( x \) was the kernel moisture content in percent at the time the crop was windrowed.

RESULTS AND DISCUSSION

It was considered that the variation in the losses from year to year may have been caused partially by the weather conditions under which the crop was grown, and partially by the inherent characteristics of the crop itself. It was therefore decided that the losses for each year would be discussed separately and the causes for the variation described or suggested.

Rainfall during the growing season (May, June, and July) for 1966 was 6.39 inches (16.23 cm), slightly below the long-term average for this region of the Prairies. May was cool and cloudy with 0.77 inches (1.96 cm) of rain. June was marked by short warm periods between showers of rain which totalled 4.38 inches (11.12 cm). The month of July was warm, and the 1.24 inches (3.15 cm) of rain was sufficient to bring the crop through to a fairly heavy growth. The first few days in August were clear and hot, but a series of rain showers occurred between 3 and 7 August. The result of these weather conditions was an extended windrowing period starting on 1 August when the kernel moisture content was 55%. A rainfall of 1.09 inches (2.77 cm) on 19 and 20 August increased the kernel moisture of the standing grain, and further extended the harvest season. A clear, warm period followed that permitted the completion of the test on 26 August.

The natural loss that occurred during this 26-day period increased as the maturity of the crop advanced (Figure 1). The kernel moisture decreased slowly because of weather conditions. The loss ranged from 0.1 bu/acre (5.39 kg/ha) at 55% moisture on 1 August, to 2.8 bu/acre (150.6 kg/ha) on 26 August at 14% kernel moisture. The periods of high humidity and resulting low vapour pressure deficit contributed to a wetting of the standing crop (6, 7), and the following drying periods increased the natural shattering. The windrowing loss also increased as the crop was cut at successively later stages of maturity. When added to the natural loss, the combination ranged from 0.3 to 3.2 bu/acre (16.1 to 172.1 kg/ha). The gathering loss was larger in plots that were windrowed at the earliest stage than in plots windrowed when the crop was mature, and ranged from 1.4 to 0.1 bu/acre (75.3 to 5.38 kg/ha). This larger initial loss may reflect the length of time the crop weathered in a windrow. The small, immature kernels of grain windrowed at this early stage of maturity also shattered readily. The processing loss decreased slightly from 1.6 bu/acre (86.1 kg/ha) as the crop, windrowed at successively later stages of maturity, was combined. The general trend for both the gathering and processing losses to decrease was common to the results of all years, and warrants special consideration later in this discussion. The total loss increased from 3.3 to 4.5 bu/acre (177.5 to 242.2 kg/ha).

The seasonal rainfall in 1967 totalled 2.24 inches (5.69 cm). These drought conditions were accompanied by warm-to-hot temperatures in June and July, when less than half of the total rainfall occurred. The resulting crop was about 15 inches (38 cm) in height, and the stand was thin. The yield was low and of light bushelweight. August weather was warm-to-hot and the rainfall of 0.49 (1.24 cm) and 0.23 inches (0.58 cm) on 14 and 17 August did not affect the kernel moisture or interfere with the windrowing operation. The windrowing operation began on 9 August at a kernel moisture content of 52% and continued uninterrupted for 17 days.

The natural loss was small in this light, short crop, which did not shatter (Figure 2). There was only a slight increase in this loss, from the initial 0.2 bu/acre (10.8 kg/ha) to 0.4 bu/acre (21.5 kg/ha) as maturity advanced. The windrowing loss was fairly constant at about 0.5 bu/acre (26.9 kg/ha), and when added to the natural loss, the total ranged from 0.7 to 1.0 bu/acre (37.7 to 53.8 kg/ha). The gathering loss was very large because the light windrow settled to the ground in a sparse stubble. It was 3.3 bu/acre (177.5 kg/ha) in plots windrowed on 9 August, but decreased to 2.8 bu/acre (142.2

Figure 1. Grain loss when windrowing and combining barley, 1966.

Figure 2. Grain loss when windrowing and combining barley, 1967.
Most of the loss consisted of short-strawed heads that could not be recovered by the pickup of the combine. The processing loss was understandably small in this light crop because of the lack of straw that would create a load on the straw walkers and sieves. The total loss decreased slightly from the initial 4.2 bu/acre (220.6 kg/ha) to 4.0 bu/acre (216.8 kg/ha). These results suggest that this crop should have been straight-combined in order to eliminate costly gathering loss.

The month of May in 1969 was cool and cloudy with only 0.92 inches (2.44 cm) of rainfall. The weather remained cool in June. The temperature at grass level on 12 and 13 June was recorded at -9°C, which caused severe damage to the growing crop. Cool, damp weather continued with most of the 1.15 inches (2.92 cm) of rain falling between the 24th and 30th of the month. July too, was cool during the first 2 wk when rainfall totalled 3.15 inches (8.0 cm). The last half of this month was warm. These conditions encouraged a remarkable recovery and heavy tillering of the crop. The resulting crop was dense, with about 28 inches (71 cm) of straw length. Windrowing was started on 14 August at a kernel moisture content of 48%. The crop matured quickly and the windrowing period lasted only 11 consecutive days.

The small natural loss, which increased only slightly and averaged 0.2 bu/acre (10.8 kg/ha), may be accounted for by very light winds prior to and during the windrowing period (Figure 3). Windrowing loss remained constant at 0.3 bu/acre (16.1 kg/ha) as the crop was cut at successively later stages of maturity. The total of the natural and the windrowing losses was about 0.5 bu/acre (26.9 kg/ha). The gathering loss was small because the firm windrow was well supported on the dense stubble. The processing loss decreased from 1.1 to 0.75 bu/acre (59.2 to 40.3 kg/ha) over the 11 tests. This small variation might be attributed to the uniformity of the crop and the windrow. The total loss was small compared to other years because all the losses were small and ranged from 2.5 to 1.5 bu/acre (134.5 to 90.7 kg/ha).

May 1970 was a cool month and rainfall amounted to 0.89 inches (2.26 cm). The first half and the last few days of June were hot, but 7.32 inches (18.59 cm) of rain fell during the month. July was warm with no wind, and rainfall totalled 1.07 inches (2.72 cm). This more than average seasonal rainfall produced a tall, dense crop that was late in maturing. Windrowing was started on 17 August at 48% kernel moisture. The remainder of the month was very hot and dry, and windrowing continued daily until 28 August.

The natural loss in 1970 increased from 0.7 to 2.6 bu/acre (37.7 to 140 kg/ha) as the crop matured (Figure 4). It is considered that the rapid ripening had the effect of increasing the shattering loss. For this same reason, a more severe shattering than usual occurred in the long-strawed, dense crop when the crop was windrowed. The loss increased slightly, and averaged about 1.8 bu/acre (96.8 kg/ha) in the kernel-moisture range of 48% to 18%. The natural and windrowing loss, when added, ranged from 2.5 bu/acre (134.5 kg/ha) to 4.4 bu/acre (236.7 kg/ha). Again in this year the gathering loss was small because the rank growth provided a good stubble to support a well-bound windrow that did not settle to the ground. This loss decreased, but averaged about 0.4 bu/acre (21.5 kg/ha) throughout the test. The processing loss decreased from 0.8 to 0.3 bu/acre (43.0 to 16.1 kg/ha) with later windrowing. Total loss ranged from 3.7 bu/acre (199.0 kg/ha) to 5.1 bu/acre (274.4 kg/ha).

The natural loss in all years except 1969 was highly significantly correlated with kernel moisture content at the time the crop was windrowed. This exception may have been caused by the unusual weather conditions that occurred during the growing season. The windrowing loss in all years except 1970 was considered to be exceptionally small, and did not increase very much as the crop matured. The loss was not correlated with kernel moisture at the time of windrowing. This could be attributed to the cultivar of barley grown for these tests, and does not suggest that it would be true for cultivars that shatter more readily under natural conditions or when handled mechanically.

The gathering loss exhibited a decreasing trend as windrows cut at successively later stages of maturity were picked up and threshed by the combine. Except for 1966 and 1967, this loss was not correlated with the kernel moisture content at the time the crop was windrowed. It was postulated that the decrease in this loss was related more to the length of time the crop remained in the windrow and was subject to the natural elements than to kernel moisture. It may also reflect how well the windrow remained supported on the stubble. The general trend for a decrease in gathering loss suggests that barley should not remain in the windrow for an extended period of time, but should be picked up and threshed as soon as the kernel moisture content has decreased to 14.8% and safe storage is assured.

Processing losses during the 4 yr decreased as barley windrowed at successively later stages of maturity was harvested with the combine. This may reflect the condition of the straw at the time of threshing. Being less weathered and brittle from a shorter time exposure, its breakup by the combine cylinder was thus minimized. There was no correlation between processing loss and kernel moisture content at the time of windrowing, except for the results of 1970. The dense growth and long straw from the crop that year may have contributed to this relationship. The postulate that barley should not remain in the windrow any longer than necessary is further substantiated by these results.
SUMMARY AND CONCLUSIONS

The natural loss in a crop of barley increased as the grain matured. The windrowing loss also increased as the crop was cut at successively later stages of maturity. Both these losses can constitute a major loss at harvest time. Previous research (3, 5) has shown that barley may be windrowed at a stage of maturity defined by a kernel moisture content of 35 to 40 percent. The natural and windrowing losses may be minimized by cutting the crop at this maturity stage. The gathering loss decreased as barley was picked up and threshed from windrows cut at successively later stages of maturity. This loss can be large, and reflects the length of time the crop remained in the windrow rather than the stage of maturity at which it was cut. These results suggest that barley should be picked up and threshed as soon as the kernel moisture content has decreased to a level that will assure safe storage. The processing loss was larger when harvesting the crops windrowed at an early stage of maturity than when harvesting the more mature crop. This decrease may be attributed to the condition of the straw, which had weathered from longer exposure in the windrow and was broken up by the combine cylinder, causing a loading of the separating components of the machine.

The weather conditions that prevailed during the growing season and the harvesting season exerted an influence on the losses measured in this test. These conditions are not controllable but should be observed as the crop develops, because the harvesting system may have to be adjusted to meet each situation.

The inherent characteristics of different cultivars of barley will affect harvesting losses. These include shattering, lodging, and height of growth. Weather conditions can also exert an influence on these factors. This would suggest that additional research on the harvesting properties of different cultivars of barley would be of value to the equipment designer, scientist, and farm operator.

REFERENCES