A REVIEW OF RESEARCH ON THE USE OF THE WINDROWER FOR HARVESTING CEREAL CROPS

by

M. E. Dodds
Member C.S.A.E.
Canada Department of Agriculture Research Station,
Swift Current, Saskatchewan

INTRODUCTION

The history of the development of the windrower and its introduction into the grain growing areas of the Great Plains of North America was coincidental with the advent of the combined harvester-thresher.

The early reports in reference to the combine (20), appearing about 1924, suggested that the advantages of this method of harvesting were:

- Decreased costs and labour
- Simplified harvest financing
- The return of straw to the field
- The disposal of the crop and the clearing of the land in one operation
- The handling of light crops at a minimum expense
- The grain grower became independent of outside help
- The handling of larger acreages.

The disadvantages were excessive waste, damp wheat, the spreading of weed seeds, and no straw for livestock. The final conclusion was that the combine would not come into general use in the immediate future, but that its acceptance would spread gradually. Research workers were reluctant to recommend the use of the combine (23) because they lacked knowledge as to how much grain would be lost from prolonged standing and exposure of crops. They realized too, that nonshattering, stiff-strawed varieties of wheat were necessary for straight combining to be a successful operation. Other reports (3) indicated that these machines had been used successfully in the Midwestern States to harvest small grains. The use of the combine did spread rapidly as indicated by later accounts (2, 4, 14, 16, 19, 24, 25, 27, 28).

The problems of green weeds, insects, rain, early frosts and uniformity of grain maturity plagued the users of the combine. Reports (1) about experimental windrows indicated that this implement and the pick-up attachment for combines were being considered seriously as supplementary harvesting equipment. It would appear from early observations (15, 17, 21, 22, 26) that the windrower was almost indispensable when harvesting a weedy field. It was suggested (18) that the windrower be used to reduce the green weed problem in spring wheat, and that early cut grain be picked up from the windrow while later maturing crops be straight-combined. This suggestion still has merit, but it is not generally followed. A tendency persisted, on the part of the farmer, to wait for uniformity of maturity before windrowing, and the advantages of the use of the windrower became less and less as the gap between this operation and straight combining became shorter. Windrowing, as a harvest procedure, was almost forgotten in the early 1930s.

Severe infestations of the wheat stem sawfly Trachelus tabidus Fab. posed a threat to straight combining. An unpublished report from an investigation at the Swift Current Research Station in 1943 revealed that the windrower could be used to avoid the damage caused by that insect. Wheat cut at a stage of maturity when the kernel moisture content was about 35 percent and allowed to mature in the windrow produced a threshed sample that graded and yielded very well. Early windrowing eliminated the loss caused by the sawfly by cutting the crop before the damage had occurred. The use of the windrower increased as a result of this report, and it has become an accepted harvesting practice in spite of the fact that sawfly-resistant varieties of spring wheat have been developed.

The present project on the use of the windrower for harvesting cereal crops was initiated in 1950 at Swift Current. It was designed to study the mechanical operation of this machine in regard to the effect of forward speed of travel, and cutter bar and canvas speed, on the formation of a windrow; to make observations on ground drive versus power take-off drive; and to note the way in which the windrow was recovered by the pick-up of the combine. These objectives resolved into the determination of the earliest stage of maturity at which wheat, barley, oats and fall rye could be windrowed without a loss of quality and quantity, grain losses in the field when harvesting wheat and barley, the effect of weather factors on kernel moisture of the standing crop, and observations of the operation of the self-propelled windrower in the formation of a windrow.

This paper summarizes the results of research on the use of the windrower for harvesting cereal crops to focus attention on correct field usage and on some design factors.

RESULTS OF RECENT RESEARCH

Stage of Maturity of Crops For Windrowing

Preliminary tests with wheat in 1952 substantiated the findings made in 1943 that this crop could be windrowed at an early stage of maturity without loss of yield or grade. A detailed study was initiated in 1953 to determine the effect of windrowing wheat, barley, oats and fall rye at different stages of maturity on the bushel weight and yield.

The results of three years of tests with wheat Triticum aestivum L., var. Chinook showed that this grain could be windrowed as soon as the kernel moisture had decreased to 35 percent. This represents a total gain of three to five days in harvest time over the stage of maturity at which
wheat may be straight-combined (6). Later work (13) indicated that the protein content of spring wheat did not increase significantly after the kernel-moisture content had decreased to 35 percent.

Similar studies with barley were made at two locations. Hordeum vulgare L., var. Vantage was grown at Swift Current, and H. vulgare L., var. Olli was grown at Lacombe, Alberta. These tests showed that barley could be windrowed at 40 percent moisture without loss of bushel weight or yield (10). This offered a five- to seven-day advantage over straight combining. Further research at Lacombe (5) indicated that it would be advisable to wait until the kernel moisture of malt barley was 30- to 35-percent range before windrowing, in order to maximize certain malt qualities.

Fall rye (Secale cereale L., var. Antelope may be windrowed at 45 percent kernel moisture (7). This crop requires a longer time in the windrow to mature than other grains. The gain in time over straight combining was only one to two days but a large saving in shattering loss was realized. Also, the loss of bushel weight was avoided when late summer rains promoted stubbling and the production of lightweight immature kernels.

An advance of three to five days over straight combining was realized by windrowing oats at 35 percent kernel moisture (8); the test crop was Avena sativa L., var. Garry.

In all instances the crops matured uniformly in the windrows, remained well supported on the stubble, and losses from natural causes were reduced.

Grain Losses in the Field

A technique for determining and classifying the losses of grain in the field at harvest time was developed in 1948 and 1949. The natural loss which occurred prior to and continued through the harvest operations, was caused by wind, rain, insects, animals and birds. The mechanical losses were caused by the reel and cutter bar of both the windrower and combine, by the pick-up, and by the threshing and separating mechanisms of the combine. Later research (9) reported on these individual losses when harvesting wheat.

The natural loss of grain in the field increased rapidly as the standing grain matured, from 0.25 bushels per acre at the windrowing stage of maturity to 0.75 bushels per acre when the crop was ready for straight combining. This loss could approach 100 percent of the potential yield if the crop was damaged by wind or hail.

The reel and cutter bar loss also increased as the standing grain matured and, when added to the natural loss, the result totaled from 0.60 to 1.20 bushels per acre at the two harvest stages, respectively. The advantage of early windrowing in order to minimize these losses is apparent.

The loss caused by the action of the pick-up remained fairly constant at 0.35 bushels per acre. The total loss for the windrower-combine method of harvesting ranged from 1.0 to 1.6 bushels per acre depending on the stage of maturity at which the crop was cut.

The loss in the threshing and separating mechanisms of the combine was determined for four harvest seasons and was found to be less than 0.1 bushel per acre. The importance of machine adjustment and operation was confirmed by these findings. It was realized, however, that this could be a serious loss under certain conditions and could only be minimized if the combine operator exercised extreme caution during the threshing operation.

Weather And Harvesting Procedures

It was observed from data on kernel moisture content of wheat, collected over the period 1953 to 1965, inclusive, that the annual variations in the date harvesting commenced were as high as 27 days for windrowing and 36 days for straight combining. The interval between windrowing and straight combining varied from five to 19 days. The difference in the occurrence of these two stages of maturity prompted an examination of the climatic conditions that caused them, because their event can affect the selection of harvest equipment if grain losses caused by greenweeds, rain, early frosts and insects are to be minimized (12).

Climatic data obtained from local records included temperature, relative humidity, rainfall, hours of sunshine, wind velocity and evaporation. The vapor pressure deficit, over which the air was calculated from the hourly temperature and humidity data. The available soil moisture at the time of seeding, and periodically during the growing season was also recorded.

Several meteorological variables affected the rate of change of kernel-moisture content during that period of plant development between the windrowing and straight combining stages of maturity. Rain was a major contributor to an increase in kernel moisture prior to and immediately following the windrowing stage of maturity. Kernel-moisture gain at later stages of plant development was caused by condensation during periods of high relative humidity and low temperature. Hours of sunshine, representing the amount of sky cover, influenced the rate and amount of drying of both standing and windrowed grain, particularly following rains. Wind, in combination with high temperature and high evaporation, contributed to kernel-moisture reduction. Vapor pressure deficit appeared to be an excellent measure to use to describe the causes of kernel-moisture fluctuations.

Soil moisture at the time of seeding, and the timeliness of subsequent rainfall can affect the date at which a standing crop reached the windrowing stage of maturity. A crop which developed under a stress from a lack of moisture matured early. Adequate soil moisture, sustained by rain, contributed to favourable growing conditions which caused crops to mature at a later date with an extended harvest season.

Windrower Operation

It was necessary for the purpose of this study to specify a good type of windrow so that this description could be used as a standard for comparison with the windrows made during the tests. A satisfactory windrow should be well formed and remain supported on top of the stubble; it should not be too firm thus allowing for the circulation of air to facilitate curing and drying following rains; and, it must be easily recovered by the pick-up of the combine.
Preliminary studies with pull-type windrowers showed that there was a relationship between forward speed of travel and the speed of the table canvas on the formation of a windrow. The most satisfactory windrows were made when the ratio of forward speed to canvas speed was 0.7:1. Later work with self-propelled windrowers revealed that the angle of the table affected the shape of the windrow and the way it was supported on the stubble. Windrowers with a horizontal table made a compact windrow whereas those with inclined tables made a wide windrow with the heads crossed in the center and the straw angled.

These observations prompted a study on a windrower on which the canvas speed, table and forward speed of travel could be varied. It was concluded from a series of tests that these three variables were inter-related, and that the formation of a well made windrow was dependent on combinations of forward speed, canvas speed and table angle. Furthermore, this relationship was different for different types of grain, and was also dependent on the stand and density of the crop. The degree of criss-crossing of the straw increased as the table angle increased. When windrows were placed on the stubble at extreme angles to the direction of travel they settled in the center, the butts became elevated and wind damage resulted. It was concluded that the angle of the table should not exceed 30 degrees to the horizontal (11).

**SUMMARY**

Wheat and oats may be windrowed at a stage of maturity when the kernel-moisture content had decreased to 35 percent, resulting in a gain of three to five days over straight combining. Barley may be cut when the kernel-moisture reached 40 percent, a gain of five to seven days, and fall rye at 45 percent kernel-moisture, a gain of one to two days.

Losses of grain from natural and mechanical causes increased rapidly as a crop of wheat matured, but windrowing when the kernel-moisture content decreased to 35 percent minimized these losses.

The date at which harvesting operations may be started was affected by the available soil moisture at seeding time and by later climatic conditions. Weather factors also influenced the length of the harvest season, and may have an effect on the selection of harvesting equipment.

The three factors that affected the formation of a windrow that was supported satisfactorily by the stubble were the variety of cereal, the stage of maturity at which it was cut and the operation of the windrower. A different combination of forward and canvas speeds and table angles was required for different crops. Grain cut at an early stage of maturity was formed into a better windrow than when cut when the grain was ripe. The forward speed of travel of the machine can be controlled by the operator, but it would be desirable if the speed of the table canvases could be varied to suit crop conditions. It was suggested that the angle of the table of a general purpose windrower should not exceed 30 degrees to the horizontal.

**REFERENCES**


**CONTINUED ON PAGE 108**
The sensitivity of the slip indicator, depending on the setting of $R_1$, however, is the least sensitive case, a slip change of 0.5 percent could be detected. Since the drive-wheel slip varied due to changes in soil conditions during a test, the operator must mentally “integrate” the reading to get an average value for the test run. The slip may vary by 5 to 10% in a typical test run. The error involved in making this decision was, no doubt, of more significance than any other error.

Extension of the Simple Slip Indicator

The drive wheel slip could be recorded by making a simple addition to the circuit if field recording equipment was available. The control knob which adjusts $R_2$ could serve as a potentiometer. This potentiometer would operate with a constant auxiliary voltage supply to act as a position transducer. The position of its wiper would coincide with the wiper of $R_1$ and the output voltage would be recorded as percent slip.

The slip indicator could also be adapted to operate as a position-control servo system. A dc servo motor could be used to drive potentiometer $R_2$, to continually maintain the galvanometer at the null point. This system would of course relieve the operator of the necessity of turning the indicator dial. No doubt, if a servo system were employed, one would also record the slip simultaneously with the implement draft on a two-channel recorder.

REFERENCES


