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The effect of travel speed and speedhead design on yield and quality of wild rice harvested by airboat

O. W. ARCHIBOLD[1] and W. B. REED[2]

[1]Department of Crop Science and Plant Ecology, and [2]Department of Agricultural Engineering, University of Saskatchewan, Saskatoon, SK, S7N 0W0. Received 1 November 1988, accepted 27 November 1989.

Archibold, O. W. and Reed, W. B. 1990. **The effect of travel speed and speedhead design on yield and quality of wild rice harvested by airboat.** Can. Agric. Eng. **32**: 75–79. The effect of travel speed on the quality and quantity of wild rice harvested by airboat was investigated together with the efficiency of beater bars placed across the speedhead. Total grain yields increased by 57% as speed increased from 17 to 21.5 km/h in a good stand of rice. However, this was accompanied by a significant increase in empty hulls and smaller kernels. Travel speed could vary by as much as 48% depending on prevailing winds and the condition of the screen at the rear of the speedhead. An increase in total yields of grain and a reduction in the percentage of empty hulls was noted when beater bars were used, but the mean weight of kernels was reduced. The efficiency of the beater bars varied according to the number used and their inclination within the speedhead.

INTRODUCTION

Wild rice (*Zizania palustris* L.) is successfully grown in shallow lakes and rivers in many parts of northern Saskatchewan. Depending on weather conditions, ripening begins in early August and will continue for a period of 15-30 d. The kernels mature gradually, starting from the uppermost part of the panicle. About 3-6% of the potential yield matures each day, but the kernels shatter readily, hence, timely harvesting of the crop is required to prevent the grain from being lost. Maximum production can only be achieved if harvesting is repeated every 4-7 d. Typically, a stand of wild rice would be harvested at least four times during this period. Harvesting in Saskatchewan is carried out by airboats; their general design is discussed in an earlier paper (Archibold and Reed 1990).

The expansion of the wild rice industry in northern Saskatchewan has been strongly encouraged by the provincial government. Instructional workshops covering the construction, operation and maintenance of airboats have been run at various centers in the north, and financial assistance has enabled many growers to manufacture and purchase their own harvesters. There are currently about 200 airboats in use in Saskatchewan. However, no data are available concerning optimum operating procedures or the effect of design modifications on grain yield. Previous research in Saskatchewan (Kushwaha et al. 1984), in which a power reel was attached to an airboat, proved unsuccessful. In Minnesota a non-shattering variety of wild rice is grown in paddies and harvester research there is concerned with modifications to standard grain combines (Chinsuwan and Schertz. 1981; Boedicker et al. 1986; Schertz et al. 1987).

Airboat travel speed, which operators regulate by engine speed, is recognized as having the potential to affect both the quantity and quality of harvested grain because the kernels are dislodged by the impact of the panicles on the speedhead. Airboat speedheads are of simple design without moving parts. The function is to strike the wild rice plants with the rounded leading edge. This impact causes high acceleration of the stem. The mature rice kernels are dislodged from the panicle and then are free to fall into the shallow hopper-like bottom of the speedhead. High-speed photography has shown that the kernels have a forward velocity after they are loosened, but since the speedhead is also moving forward the falling kernels have a greater opportunity to be collected. Because of different growth rates of the main stems and secondary tillers, the height of the panicles in a stand of wild rice may range from a few centimetres to perhaps 1 m above the water surface. To improve impact between the speedhead and panicles, and to reduce possible plant damage, some operators have attached beater bars across the speedhead. These are commonly constructed from 12.5-mm copper pipe or 25-mm plastic pipe. However, the number of beater bars to use, their attitude to the speedhead, or even if they increase yields at all has not been previously studied.

This paper reports on various harvester trials which were conducted in 1987 to examine the effects of travel speed and speedhead design on harvest yields and the quality of wild rice grain recovered.

METHODS

Travel Speed Trials

The speed trials involved running an airboat through a measured section of wild rice at approximately 16.0 and 22.0 km/h and comparing total grain yield and grain quality. Two runs were completed at each speed. Because conventional boat speed monitoring devices get entangled in the straw, a Dickey-john radar unit (model DjSAM 100 speed area monitor) was used. This was mounted on the rear of the airboat. The equipment was accurate to within ± 1 km/h provided the radar signal was directed into the airboat's wake: smooth water did not reflect the signal. The radar unit was calibrated over a 500-m course following the manufacturer's instructions. The effect of wind on travel speed was measured using a fiberglass airboat equipped with a 3-m speedhead and a 503 Rotax engine. Measurement of travel speed was made while travelling directly into and with the wind while maintaining a constant engine speed of 5000 rpm. Because kernels, chaff and leaves get caught in the screen at the rear of the speedhead, the effect of drag was simulated by completely covering the screen with kraft paper and the trials repeated.

Beater bar experiments

To evaluate the usefulness of beater bars two compartments were installed in a 3-m speedhead mounted on a 503 Rotax powered airboat. The test compartment was fitted with a frame to permit different beater bar settings to be used. The amount of grain

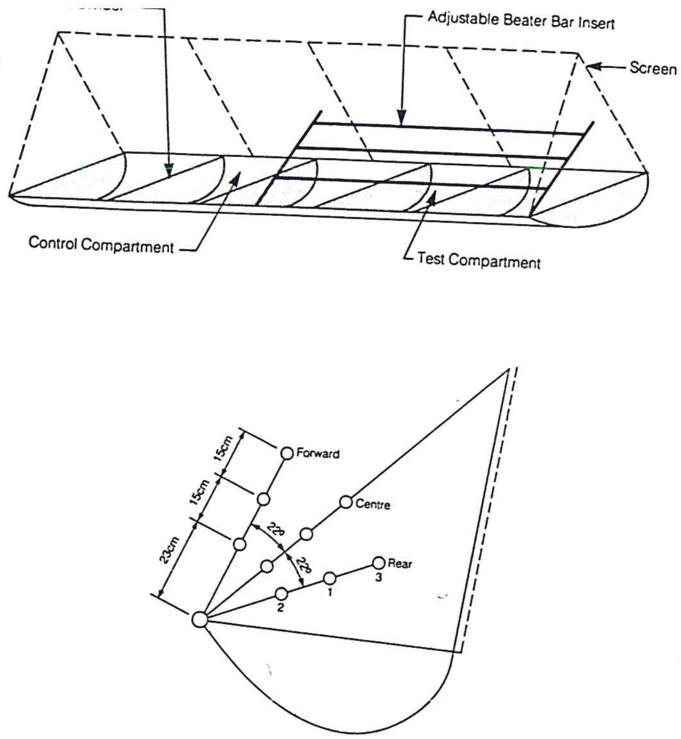

Figure 1. General speedhead design and setting of the beater bars used in the harvester efficiency trials. Each compartment was 60 cm in length.

harvested in the test compartment was compared directly to the control compartment; the results of each trial were recorded as the percentage difference between the two sides of the speedhead. This procedure obviates the need to adjust yields for varying conditions within the wild rice stand. Because of the limited area of the wild rice patch, it was decided to carry out two runs for each setting. If the results from these runs were not consistently higher or lower than the standard speedhead, or varied by more than 20%, then a third run was completed. The general design of the speedhead and the various beater bar settings used are shown in Fig. 1.

A modified speedhead design which incorporated the beating action of bars and improved airflow was used by some growers during the 1987 harvest. In this speedhead the lower end of the screen was brought forward 18 cm from the rear of the trough (Fig. 2). This not only provided a surface against which the panicles were threshed, but also provided a through draught which carried off some of the empty hulls, thereby producing a cleaner product. Without this rear opening, turbulent air movement carries grain to the outer ends of the speedhead effectively reducing its capacity. The only speedhead of this design that was available for evaluation was 6 m in length and fitted to a pontoon harvester.

Comparative data on total grain yield and grain quality were collected in each of the trials. Grain yield represented the amount of grain recovered from the speedheads during each run. Harvested grain quality was assessed in two ways. First the percentage of mature and immature kernels and the percentage of empty hulls was determined for a sample of 500 kernels. A mature kernel was defined as one which filled at least 75% the length of the hull: those at least 25% of the length of the hull were classed as immature kernels. Secondly, the weight of 250 air-dried kernels (still enclosed in their hulls, $<5\%$ moisture content) taken from each compartment was determined.

The condition of the crop at the time of harvest was based on stand density (calculated from 25, 0.5×0.5-m quadrats) and the maturity of 100 panicles. Three maturity categories were used. Ripe kernels could be readily shattered by lightly drawing the panicle through one's fingers, mature kernels had filled but would not shatter, and empty hulls were less than half filled.

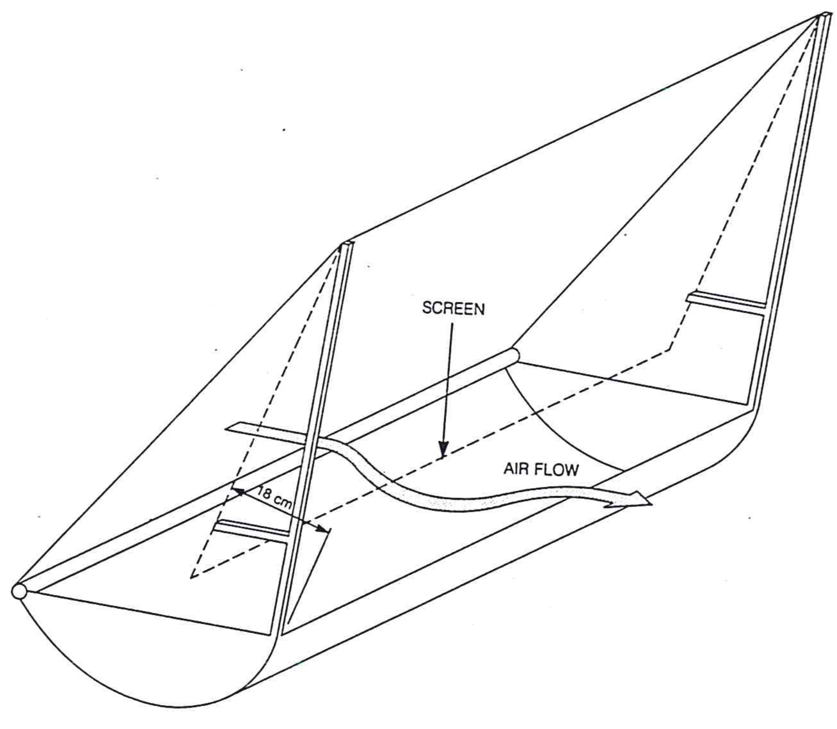

Figure 2. Modified speedhead design in which the rear screen is brought forward. In this position the screen functions as a beater bar and also permits airflow to the rear. This removes chaff and could reduce air drag.

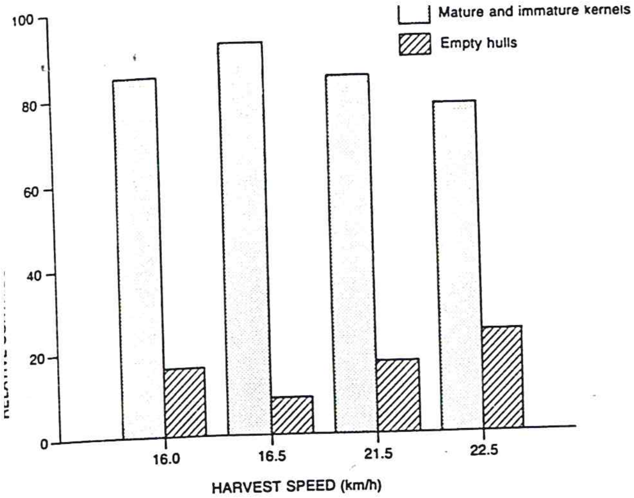

Figure 3. The effect of harvest speed on grain quality.

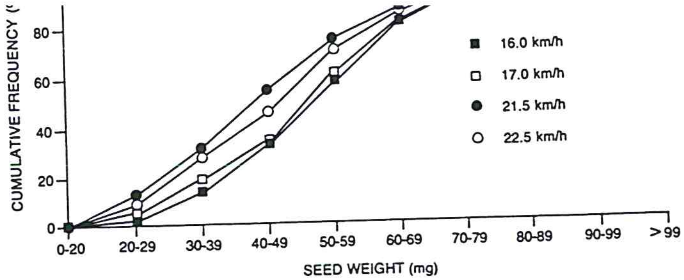

Figure 4. The effect of harvest speed on grain size.

RESULTS

Travel speed trials

The wild rice stand used for the speed trials had been harvested about one week prior to this study. Two runs (16.0 and 21.5 km/h) were conducted in a stand of rice with an average density of 125 stems m^{-2}; in other runs (17.0 and 22.5 km/h) stand density averaged 76 stems m^{-2}. Unfortunately, the wild rice was of rather poor quality: an average of 13 kernels were produced by each panicle, but of these approximately 30% had shattered, 5% were mature, 25% were immature, and 40% were empty. Increasing speed from 16.0 to 21.5 km/h in the denser stand resulted in a 57% increase in grain. However, in the open stand a similar speed increase raised total yields by only 1.3%. The percentage of empty hulls ranged from 8.4% at 17 km/h to 32.4% at 22.5 km/h (Fig. 3). This decline in grain quality with speed was shown to be highly significant (chi-square analysis, $P \leq 0.01$). Similarly, the mass of an individual kernel declined significantly with speed, averaging 46.8 mg at the lower speeds and 41.4 mg at the higher speeds (analysis of variance, $P \leq 0.01$). Likewise a noticeable difference was noted in grain size distributions among runs (Fig. 4). Approximately 32% of the grain harvested at 16.0 and 17.0 km/h was lighter than 40 mg. This compares to 43% for the 22.5 km/h pass and 52% for the 21.5 km/h pass. Since smaller grain size invariably reflects less mature kernels, a slower harvest speed is likely to result in higher quality, large, ripe kernels.

The effect of wind on travel speed

Although ambient wind velocities during these trials was 13 km/h it greatly affected airboat travel speed (Table I). Speed reductions ranged from 25 to 32% when travelling into the wind at a constant engine speed, compared to travelling with the wind. Covering the speedhead screen further decreased speed when heading into the wind, but had little effect in a tailwind. The net result of covering the screen was to reduce travel speed by as much as 48% in a headwind, although this could be overcome by increasing engine speed. However, low-powered engines are less versatile and operators of Rotax 447 airboats have reported difficulty in maintaining sufficient headway to effectively harvest the grain even under ideal wind conditions. Such airboats may therefore be of limited value in commercial wild rice operations.

Table I. Effect of wind on airboat travel speed

Speed against wind (km/h)	Speed with wind (km/h)	Speed reduction (%)
	Screen uncovered	
17.9	24.0	25
18.6	27.2	32
18.9	26.7	29
	Screen covered	
13.6	25.6	47
14.1	26.9	48
15.2	24.0	37

Table II. Wind drag on a pontoon harvester fitted with a modified speedhead

Wind velocity (km/h)	Speed with wind (km/h)	Speed against wind (km/h)	Speed reduction (%)
	With speedhead		
7.4	23.5	20.8	11
10.9	25.6	21.4	16
	Speedhead removed		
13.6	25.6	19.2	25
15.8	25.8	21.3	17
17.4	26.4	21.9	17
18.1	25.8	20.0	22

The results of the wind drag trials using the modified speedhead and pontoon harvester are presented in Table II. Unfortunately, wind speeds steadily increased during the course of the trials; however, initial results suggest that this design of boat and speedhead affords less drag than conventional designs despite its larger size.

Beater bar experiments

The density of the stand used for these trials averaged 148 stems m^{-2} with each panicle averaging 54.2 kernels. Approximately 12% of these kernels were ripe, 16% mature, 64% immature and 8% empty. Comparative yield data for the various beater bar arrangements are presented in Fig. 5. The amount of grain collected in the control compartment in each split speedhead trial was used as the basis of comparison. Because of variability in the crop, yield in the control compartment has been standardized at 100% to determine the relative efficiency of the various beater bar settings. The use of beater bars, with one exception, increased yields compared to the control compartment. The most efficient arrangement was a single beater bar in the rear position; this increased yields on average by 22%.

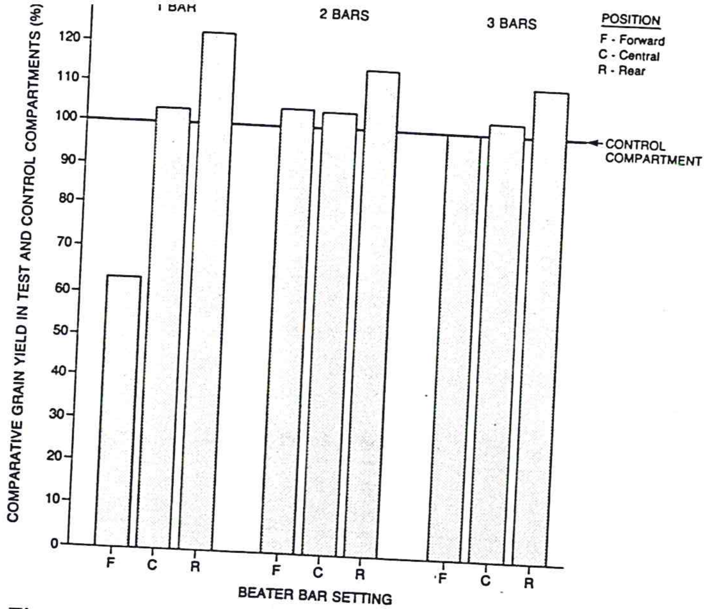

Figure 5. The effect of beater bars on the total amount of wild rice harvested compared to the standard (control) speedhead design.

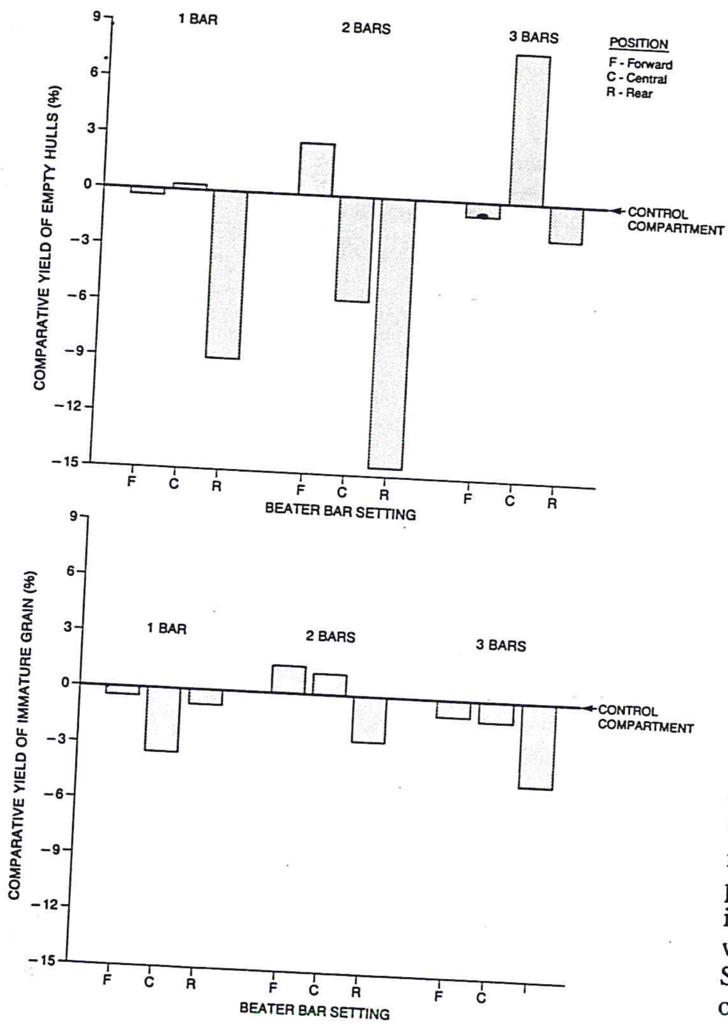

Figure 6. The effect of beater bar position on the relative percentage of empty hulls harvested (upper) and on the relative percentage of immature grain harvested (lower) compared to the standard (control) speedhead design.

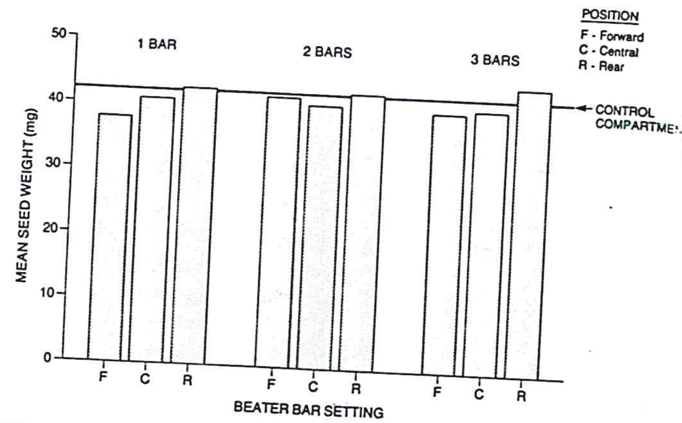

Figure 7. The effect of beater bar position on the mean seed weight of grain harvested compared to the standard (control) speedhead design.

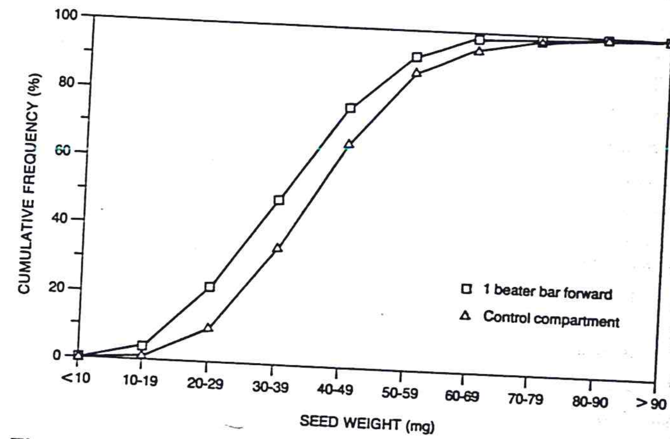

Figure 8. Comparative grain size distributions for speedheads fitted with one beater bar in the forward position and those of standard design.

The least efficient was a single bar mounted in the forward position, which resulted in an average reduction of 37%. Harvesting efficiency generally increased as the bars were inclined further to the rear of the speedhead. This was most apparent when a single beater bar was used. With the exception of the single front mounted arrangement, the number of beater bars used did not greatly affect harvester efficiency.

The use of beater bars improved grain quality by 2.5% (averaged over all trials) with only two of the trials showing significant increases in empty hulls over the standard speedhead arrangement (Fig. 6). The amount of empty hulls decreased by 14.2% relative to the control compartment when two beater bars were positioned in the rear and increased by 8.7% when three beater bars were used in the centre position. Placing the bars in the rear position significantly decreased the percentage of empty hulls harvested (analysis of variance, $P \leq 0.01$). Likewise, the relative percentage of immature grain was slightly reduced (1.3% overall): This improvement was most pronounced with three bars in the rear position. With two bars in the forward and center positions an increase in immature grain was noted. However, in no case were the results significant. Similarly, although general reduction in mean kernel mass occurred when beater bars were used in all but the rear positions (Fig. 7), only in the case of one bar in the forward position did the result differ significantly from the control arrangement ($P \leq 0.05$). In this trial the mean kernel mass was 37.5 mg compared to 42.4 mg for the control. A cumulative distribution plot for this sample is presented in Fig. 8. Despite fewer empty hulls and slightly less immature grain, there is a noticeably higher proportion of smaller kernels than in the corresponding control compartment.

Efficiency trials for the pontoon harvester fitted with the modified speedhead were conducted in an open stand of wild rice with a mean density of 103 stems m^{-2}. Each stem averaged 2.9 ripe kernels, 5.4 full kernels and 5.7 empty hulls. Comparative data following one pass by the harvester were 0.3 ripe kernels, 3.4 full kernels and 5.9 empty hulls. The retention of most of the non-ripe kernels suggests that the modified speedhead design could be less aggressive on the crop, thereby allowing the kernels to ripen more fully between successive harvests.

CONCLUSIONS

Because of the ripening characteristics of the plant, each stand is harvested several times during the fall.

The amount of wild rice harvested by airboat is greatly affected by the condition of the crop, but airboat travel speed is also an important factor. Increasing speed from approximately 16.5 to 22.0 km/h resulted in higher yields during the trial harvest. But the higher speed reduced grain quality by removing the immature, lighter kernels and a higher percentage of chaff. Such aggressive harvesting may reduce total harvest yields if too many kernels are removed before they are fully developed. Constant travel speed is difficult to maintain. Relative wind direction and strength can reduce travel speed up to 32% in the most commonly used 503 Rotax powered harvesters: further reductions are to be expected as the screen becomes clogged.

The use of beater bars may increase the amount of grain harvested, but a slight reduction in kernel size is to be expected. However, size, spacing and attitude of the beater bars can all affect yield. Based on the results of these trials, the number of beater bars used was less important than their inclination within the speedhead. Bars inclined at an angle of 44° to the rear of the speedhead were most efficient: a single beater bar approximately vertical with the leading edge of the speedhead was least efficient.

The continual ripening of the easily shattered kernels introduces an element of chance to the harvest process. If the crop is harvested too early and too aggressively, then total yields from the stands will be low and the finished product will be of poorer quality. If one delays harvesting the ripe kernels will fall into the water and be lost. The stands also exhibit great variation in density and height of stems. In dense stands boat speeds may be less than optimum for shattering the kernels. If stem heights are variable, the taller ones may be snapped and the lower ones passed over by the speedhead. Despite these inherent difficulties the design and operation of airboats can significantly affect the quantity and quality of wild rice harvested.

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