RELATIONSHIP OF THE HEIGHT RICE IS CUT TO HARVESTING TEST PARAMETERS

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ABSTRACT. Data were collected from four long-grain rice varieties to develop a relationship between the height at which rice is when combined and the amount of material other than grain (MOG) above the cut. A quadratic equation described the relationship between the MOG ratio (MOG above the cut divided by the total MOG) and the height ratio (height of cut divided by the plant height) with an R² value of 99.6% and a mean square error of 0.0004.

Using this equation, a procedure is described to estimate the feedrate through a combine for given header widths, combine ground speeds, and crop conditions. The crop conditions that must be input are the grain yield, which can be estimated prior to harvest, and the harvest index, which is a physiological parameter that relates grain yield to biological yield and which has been reported for many rice varieties. Keywords. Rice, Harvesting parameters, Biological yield.

Initial stages of an expert system to advise producers on when to harvest rice have been developed at the University of Arkansas. Data for the expert system were collected from a study (Andrews et al., 1993) to determine the effects of combine operating parameters on harvest loss and quality of the combine. Results of the study showed that two variables: (1) material feedrate through the combine and (2) material other than grain to grain ratio (MOG/G) were the most significant factors affecting loss rates.

The height at which the rice crop is cut plays a major role in determining feedrate and MOG/G. Feedrate is also determined by the forward speed of the combine, the header width, and the density of the crop. Combine test results are typically reported as a function of feedrate (ASAE, 1993a), which accounts for all of these variables, yet the expert system should be able to indicate to the operator the desired forward speed of the combine for optimum performance in terms of minimizing loss and maximizing grain quality. A general relationship between forward speed and feedrate is not available for rice, a crop in which plant height varies significantly with variety and management practices. If a relationship between the height of cut and the amount of MOG above the cut could be found for given crop densities, it would be possible to relate forward speed of the combine to feedrate. In order for the expert system to utilize combine test results, which are based on feedrate, and be able to make recommendations regarding the desired forward speed of the combine, the relationship between height of cut and feedrate must be determined.

OBJECTIVE

The objective of this study was to determine the relationship between the height at which rice is harvested (height of cut) and the MOG above the cut over a range of long-grain rice varieties. From this relationship, harvesting performance variables including MOG/G and total material feedrate through the combine can be estimated.

PROCEDURE

Four varieties of long-grain rice, ‘Lemont’, ‘Millie’, ‘Newbonnet’, ‘Tebonnet’, were chosen for the study. Reported plant heights for the four varieties are 88, 104, 109, 127 cm, respectively (Moldenhauer et al., 1990). All four varieties were grown using standard commercial practices at Keiser, Arkansas, in 1992. Rice at three grain moisture content (MC) levels was tested in ‘Millie’, two in ‘Newbonnet’ and ‘Tebonnet’, and one in ‘Lemont’. Each test consisted of collecting five randomly selected samples from a variety at a given MC level. A sample was collected by placing a 929-cm² (1-ft²) square metal frame over the rice canopy and cutting all stalks within the framed area at ground level. The stalks were then placed into a container so that no material would be lost during transportation to the laboratory.

The total weight of each sample was obtained, after which the kernels were stripped from the panicles with a Seedburo sample thresh. The grain and MOG were then weighed separately. The grain from each sample was placed in ziplock, plastic storage bags and stored at approximately 1° C for later MC determinations. The remaining MOG (stems and leaves) was cut in 5-cm increments from the bottom to the top of the stalk, and the MOG weighed for each increment. All MOG that had been cut into 5-cm lengths was then mixed and a random sample was obtained, placed in a ziplock, plastic storage bag, and stored at approximately 1° C for later MC determinations.

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The MC of the grain samples was determined using a Shizuoka Siek model CTR 800A individual kernel moisture meter. The MC of the MOG samples was determined by oven drying 25-g samples at 103° C for 24 h (ASAE, 1993b).

RESULTS AND DISCUSSION

The average crop conditions are summarized in Table 1. The table shows that plant height varied greatly among varieties, but for the tests within each variety the height was not significantly different. The total mass and grain mass per unit area, as well as the grain MC, varied within the varieties. However, the MOG mass was not significantly different among or within the varieties, which was due in large part to the high variability of the data. The MOG MC varied as much within varieties (4 percentage points in ‘Millie’) and 4.7 percentage points in ‘Newbonnet’) as among varieties. The variation present could have been a result of nonuniform fertilizer application, inconsistent rice stand densities, or variation in soil conditions.

In order to account for differences in crop densities, a normalizing procedure was used to relate the MOG above a cut to the total plant MOG. The MOG ratio (MOG_R) was determined by dividing MOG above the cut by the total MOG of the sample and ranged from one at the bottom of the stalk to zero at the top. Since rice varieties also differ in plant height, an analogous procedure was used for relating the height of cut to the initial plant height. The height ratio (H_R) was determined by dividing the height of cut (measured from ground level) by the plant height. This ratio ranged from zero at the bottom of the stalk to one at the top.

The data points in figure 1 represent the two ratios plotted against each other for samples from all variety and MC test combinations. As is evident from figure 1, there was not a clear distinction in the relationship of MOG_R to H_R between the four varieties.

The following equation was determined using multiple regression analysis (SAS, 1987) to describe the data from all variety/harvest MC combinations:

\[
\text{MOG}_R = 0.99 - 1.94 (H_R) + 0.95 (H_R)^2
\]  

(1)

As indicated in figure 1, the equation described the data well with an R² value of 99.6% and a mean square error of 0.0004. Figure 1 shows that as the height ratio increased, the MOG ratio decreased quadratically. Increases in the height ratio from 0 to 0.5 decreased the MOG ratio from 1 to 0.26, which indicates that changing the height of cut below a height ratio of 0.5 had a greater effect on the amount of MOG above the cut than changes in the height of cut above the height ratio of 0.5.

APPLICATION

Estimating feedrate requires quantifying both the grain and MOG above a cut. The grain mass per unit area can be readily estimated from historical field yield records and/or current projections. The procedure for determining the MOG above a cut is detailed as follows:

Step 1 (H_R). The average plant height for most popular rice varieties is reported in sources such as Moldenhauer et al., 1990. The height ratio can be calculated by dividing the height of cut by the plant height.

Step 2 (MOG_R). From equation 1 or figure 1, the MOG ratio can be found for the H_R value from Step 1.

Step 3 (Total Plant MOG). In order to calculate the MOG above a cut using the MOG_R value of Step 2, the

<table>
<thead>
<tr>
<th>Variety</th>
<th>Harvest Date</th>
<th>Plant Height (cm)</th>
<th>Total Mass (kg/ha)</th>
<th>Grain Mass (kg/ha)</th>
<th>Grain MC (% w.b.)</th>
<th>MOG_R Mass (kg/ha)</th>
<th>MOG MC (% w.b.)</th>
<th>Harvest Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Millie’</td>
<td>9-08-92</td>
<td>83.0cll</td>
<td>41,140c</td>
<td>11,280b</td>
<td>18.7d</td>
<td>62,700a</td>
<td>59.0b</td>
<td>0.488</td>
</tr>
<tr>
<td>‘Millie’</td>
<td>9-10-92</td>
<td>79.8c</td>
<td>52,370b</td>
<td>14,080a</td>
<td>19.2c</td>
<td>33,090a</td>
<td>61.7b</td>
<td>0.505</td>
</tr>
<tr>
<td>‘Millie’</td>
<td>9-12-92</td>
<td>91.4c</td>
<td>43,060b</td>
<td>11,100b</td>
<td>19.5c</td>
<td>26,670a</td>
<td>63.0ab</td>
<td>0.377</td>
</tr>
<tr>
<td>‘Newbonnet’</td>
<td>9-13-92</td>
<td>94.6b</td>
<td>54,190b</td>
<td>15,520a</td>
<td>22.9a</td>
<td>31,820a</td>
<td>61.5b</td>
<td>0.526</td>
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<tr>
<td>‘Newbonnet’</td>
<td>9-28-92</td>
<td>98.2b</td>
<td>56,210a</td>
<td>10,980b</td>
<td>21.3b</td>
<td>33,650a</td>
<td>66.2a</td>
<td>0.463</td>
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<td>‘Lemont’</td>
<td>9-24-92</td>
<td>69.2d</td>
<td>43,120b</td>
<td>7,620c</td>
<td>19.8c</td>
<td>29,540a</td>
<td>66.1a</td>
<td>0.410</td>
</tr>
<tr>
<td>‘Tebonnet’</td>
<td>9-24-92</td>
<td>116.0a</td>
<td>44,410b</td>
<td>10,400b</td>
<td>20.1bc</td>
<td>29,060a</td>
<td>67.1a</td>
<td>0.498</td>
</tr>
<tr>
<td>‘Tebonnet’</td>
<td>9-29-92</td>
<td>123.6a</td>
<td>44,890b</td>
<td>7,340c</td>
<td>17.0e</td>
<td>28,870a</td>
<td>66.7a</td>
<td>0.419</td>
</tr>
</tbody>
</table>

* Averages are based on five samples from each day of testing.
† Material other than grain.
‡ Samples were collected from an area of 929 cm² (1 ft²). Some MOG may have been lost during threshing and thus, total mass is greater than the sum of grain mass and MOG mass.
§ Harvest index is defined in equation 2.
‖ Values with a column followed by the same letter are not significantly different (P = 0.05) using Duncan’s Multiple Range Test.
The total plant MOG must first be estimated. The total plant MOG for a given variety can be estimated using a harvest index (Tesar, 1984). The harvest index relates the amount of grain (corrected to 12% MC, w.b.) to the "total dry matter" of the plant and is defined as:

\[ HI = \frac{G_{12}}{G_{12} + \text{MOG}_0} \]  

(2)

HI = harvest index  
\( G_{12} \) = mass of grain at 12% MC (w.b.)  
\( \text{MOG}_0 \) = mass of MOG dry matter (0% MC)

Published reports of harvest index for rice range from 0.39 to 0.59 with most values being between 0.42 and 0.55 for direct-seeded rice grown with normal management practices (Dingkuhn et al., 1991). With good management practices, 'Lemont' and 'Newbonnet' had mean harvest indices of 0.53 and 0.47, respectively, over a three-year study. The study is described by Counce (1992), but the harvest index data were not included in the report. The harvest indices from the rice crops used in this study fell within the expected range (table 1).

For a typical harvest index associated with a variety and an assumed grain yield per unit area corrected to 12% MC, the total plant MOG dry matter can be determined using equation 2. This MOG dry matter value can then be adjusted to a desired MC, representative of the MOG being processed by a combine, to yield the total plant MOG. Table 2 lists total plant MOG values, adjusted for convenience to 60% MC, w.b., that were calculated for representative harvest indices and grain yields in rice.

**Step 4 (MOG Above a Cut).** Using the MOG ratio from Step 2 and the total plant MOG from Step 3, the MOG above an associated height of cut can be calculated from the definition of the MOG ratio.

Knowing the density of the harvested crop per unit area (sum of the MOG above the cut and the grain yield at the desired harvest MC), the forward speed of the combine, and the header width, the feedrate through the combine can be calculated.

**SUMMARY**

An equation was developed from experimental data to relate height of cut to the MOG above the cut in long-grain rice varieties. The equation described the data with an R² value of 99.6% and was independent of variety. This relationship, in conjunction with the use of a parameter termed the harvest index, enables the amount of MOG above the header height to be calculated for any given height of cut. In turn, adding the MOG above the header height to the grain yield allows the material feedrate through a combine to be related to the combine forward speed.

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**REFERENCES**


