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Optimization of Key Operating Parameters on Header Losses from Combine Harvesters in Sri Lankan Paddy Fields

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Abstract: This study was performed to determine the header losses at different operational conditions of combine harvesters using regression analysis. The regression equation showed the coefficient of determination of 67.9%. However, the reel index had a greater share in causing the header losses than the other contributory factors.

Keywords: combine harvester, reel index, header losses

I. Introduction

Combine harvesting is a successful answer to shortage of manual labour for harvesting paddy crop since fast and efficient method of paddy harvesting is the immediate need of farmers in Sri Lanka. There are many factors contributing to the performance of combine harvesters and they can be divided into machine and plant factors. Machine variables include combine forward speed, peripheral speeds of combine devices, and feeding rate. Moreover, the plant variables such as variety, moisture content and degree of maturity are considered as critical factors. The above mentioned factors affect directly on the grain losses, energy requirements, and efficiency, which in return, influence crop yield, and total operational cost. Therefore, care should be taken to operate the combines to minimize both losses because combine harvesters encounter problems with grain losses and frequent breakdowns.

Research studies showed that two main factors that cause header loss are crop conditions and machine regulation such as cutter bar speed, reel index etc. In general, header loss depends on reel rotational speed and ground speed and cutter bar speed. Reel rotational speed and ground speed are mostly efficacious and it can be shown that their losses are 0.5 to 2% of field yield (Mazaheri, 1997). Crops with low height couldn't be cut by a cutter and seeds drop when they contact with reel wheel. Behroozi-Lar (1995) showed that reel wheel should be placed in 15-25 cm above the cutter bar; also, cutting height should be lower than lowest size of crop; furthermore, the reel speed should be adjusted about 1.25- 1. 5 of ground speed. Junsiri and Chinsuwan (2009) showed that head grain loss increased with increase in reel rotational speed and reel height. Mansoori and Minaee (2003) studied the effect of forward speed on header loss and indicated that header loss intensified with increasing ground speed.

Determination of optimum operational parameter to harvest the paddy crop and the improvement of combine performance during harvesting are very important to minimize both grain losses and operating costs. Considering the importance of grain loss in the header unit of the combine, the combine operational factors for the header losses must be identified. Studying these factors, therefore, would provide useful guidelines in determining critical factors influencing header losses, and can be great foundations for further studies to be conducted on each factor.

Therefore this study aimed at investigating the effect of key machine operating parameters using *indica* type paddy variety in different fields and under different machine operational conditions. This would enable a prediction of the losses from the combine harvester and help farmers make appropriate decisions in their use.

II. Materials and Methodology

Independent field evaluation trials were carried out as per RNAM test code procedures for which a total of six brands of combine harvesters were tested in 10 different fields in Batticaloa and Ampara districts in the Eastern Province of SriLanka with different paddy varieties (Table 1).

Table1. Combine harvester type and crop specifications during the evaluation trials

Test site	Type of combine evaluated	Paddy variety harvested
1	*Danxia 2200*	LD 365
2	*John Deere (Standard TSC 513)*	BG 300
3	*John Deere(Standard TSC 513)*	BG 300
4	*Danxia 2200*	LD 365
5	*Agrotech (4 LL-200Z)*	BG 352
6	*Claas (Crop tiger 30)*	LD 365
7	*Kubota DC 68G*	BG 94-1
8	*Mubota*	AT 362

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9	*Kubota DC 68G g*	BG 360
10	*Danxia 2200*	BG 360

Measurement of Crop and Machine Operating Parameters

The key parameters for header losses in the operation of rice combine harvesters were analysed; namely, forward speed of the combine harvester, rotational speed of the reel, cutter bar speed and cutter bar height were measured during actual machine operations in each field.

Reel Index

Reel index of each combine harvester was determined using Equation 1 reported by Oduori *et al*., 2012.

$K=\frac{\omega R}{v}$…………. (1)

where,

K – Reel index (dimensionless)

ω – Angular velocity of reel (rad/s)

R – Radius of reel (m)

v – Header advance velocity (m/s)

Measurement of Header Losses

The combines were allowed to move forward for about 20 m (1m from the border of each experimental plot) to ensure the stable workload before data collection at 15m. After the combine attained a steady state speed under full load condition, it was suddenly stopped. The header unit was lifted up and the machine was moved back about 5m. A metal quadrate of 0.5 m^2 was placed in front of the parked machine and the grains were manually picked up. Grains were then manually threshed and the header losses were determined by weighing the collected loose grains and panicle-grains. The samples for header loss were collected in four replicates from each experimental field.

Data Analysis

A multiple regression analysis was conducted to establish the relationship between independent variables and a dependent variable based on the data obtained in this study. Header losses were designated as the dependent variables and the operating parameters of rice combine harvesters i.e. reel index (RI), cutter bar speed (V), cutter bar height (H) and grain moisture content (M.C) were used as independent variables.

III. Results and Tables

Effect of reel index, cutter bar speed, cutter bar height and grain moisture content on header losses

The multiple regression analysis describes the effect of the four independent variables acting jointly on the header losses. The correlation coefficient between the variables such as the reel index, cutter bar speed and the height of the cutter bar from the ground and the header losses reveal that a strong correlation between the header losses and reel index, along with a weak correlation between variables such as cutter bar speed, cutter bar height and grain moisture content. Further, the reel index had a greater share in causing header losses rather than the other factors as indicated by its higher R^2 value of 64.6% (Table 2).

Table 2. Correlation between the independent variables and the header loss (dependent variable)

Independent variable	Correlation (r)	Coefficient of determination (R^2%)	Type of relationship
Reel index	0.793	64.6	Quadratic
Cutter bar speed	0.275	7.5	Linear
Height of cutter bar	-0.32	10.2	Linear
Grain moisture content	-0.128	1.6	Linear

It was also observed that the header losses were lower at reel indices between 1.19 and 1.65, and increases thereafter (Figure 1). This is in conformity with the results obtained by Bawatharani *et al*. (2013), who reported that the header losses from the combines were found to decline from reel indices 1.2 to 1.7, but there was a tendency for the header losses to be higher when the reel index was less than 1.2 or greater than 2.5. However, other researchers such as Oduori *et al*. (2012) recommended reel index values lower than 1.5 and Junsiri and Chinsuwan (2009) suggested reel index to be between 1.5 and 3.0.

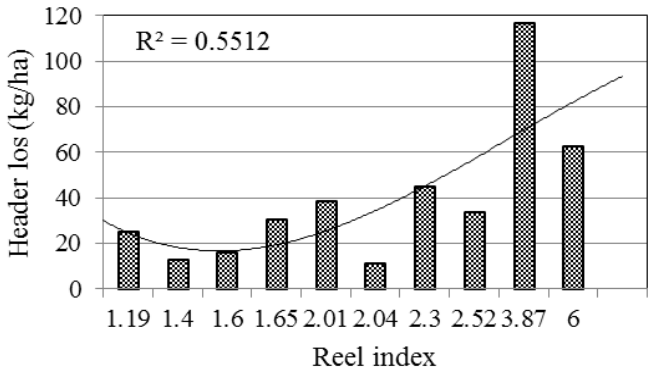

Figure 1. Variation of header losses with respect to reel index of the tested combines

Therefore, the regression equation (sample size n = 9) can be written as

Header loss = 24.0 + 9.76 Reel index + 22.3 Cutter bar speed – 0.13 Cutter bar height – 1.26 Grain moisture content.

$R^2 = 67.9$ %

The coefficient of determination (R^2) in above equation expresses that 67.9% of the variation on header loss can be accounted for by the reel index, cutter bar speed, cutter bar height and grain moisture content. The intercept (constant) corresponds to situations where the combine harvester would not be in operation, leading to a loss of 24 kg/ha, which could be accounted for the pre-harvest losses due to factors other than mechanical. High shattering ability of *indica* type paddy varieties that was considered in this study might have caused comparatively a higher value (24 kg/ha) as the intercept.

Analysis of variance indicates that the effect of reel index is significant at the 5% level, but the reel height and the moisture content are not significantly different. But, the effect of any given independent variable in the regression equation depends on which other variables have been included in the regression model. It cannot be determined by simply looking at the respective values of the β coefficients, because the value of the β coefficient depends on the unit of the independent variable. In this study, the reel index has no unit, the cutter bar speed was measured in m/s, the cutter bar height was measured in *cm* and the grain moisture content as *%*. Hence, there can be no comparison between such disparate quantities. Therefore, the t-ratios of the three variables for reel index is 3.96 which is higher than 1.91, -0.29, and – 1.11 for cutter bar speed, cutter bar height and grain moisture content, respectively (Table 3). So the effect of reel index is greater than the other three independent variables on the header losses.

Table 3. Coefficients of the regression equation

Predictor	Coefficient (β)	Std. Error	t	P
Constant	23.98	30.88	0.78	0.48
Reel index	9.76	2.46	3.96	0.01*
Cutter bar speed	22.34	11.7	1.91	0.12
Height of cutter bar	-0.13	0.44	-0.29	0.78
Grain moisture content	-1.25	1.13	-1.11	0.33

* - significant at 5% probability level

IV. Conclusion

The mechanical and crop parameters such as reel index, cutter bar speed, cutter bar height and the grain moisture content contributed to 67.9 % of the variation for the header losses. However, the reel index has a greater share in causing the header losses among the other contributory factors.

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