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Field Performance of a Conventional Combine Harvester in Harvesting Bg-300 Paddy Variety in Batticaloa, Srilanka

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Abstract: This study was performed to determine the performance of a conventional combine harvester in two fields cultivated with BG-300 rice variety in SriLanka. The performance of the combine was affected by the operational condition as wells as the crop conditions in both fields.
Keywords: combine harvester, reel index, header losses

I. Introduction

Combine harvesting is the successful answer to harvest rice crop since fast and efficient method of rice harvesting is the immediate need of farmers in Batticaloa due to shortage of manual labour. However, care should be taken to operate the combines to minimize both losses and cost because combine harvesters encounter problems with grain losses and frequent breakdowns. Further, the performance of combines are mainly controlled by machine and the plant factors, of which the machine variables include combine forward speed, peripheral speeds of combine devices, and feed rate. Moreover, the plant variables are considered critical factors which include variety, moisture content and degree of maturity. The above mentioned factors affect directly on the crop losses and efficiency, which in return, influence crop yield, and the total operational cost. Therefore this study aimed at investigating the performance of a conventional combine using BG-300 paddy variety in two fields and under different machine operational conditions.

II. Materials and Methodology

A self-propelled, full feeding, tyre type combine harvester was studied in both of the fields while harvesting BG-300 paddy variety. The combine had a 3.95m of cutting width fitted with 48.9 hp diesel engine. The overall dimension of the combine was 7590x4343x3454 mm with the grain tank capacity of 1050 kg. The performance of the combine was evaluated in both fields in consideration of its field capacity, field efficiency and header losses of grains. Effective field capacity and field efficiency of the tested combines were obtained from the formulae reported by Hunt, 1995.

$$S = \frac{A}{T_p+T_l}$$

$$E_f = \frac{T_p}{T_p+T_l}$$

where,
S – Effective field capacity (ha/h)
A – Area covered (ha)
T_p – Productive time (h)
T_l – Unproductive time (h)
E_f – field efficiency

Measurement of Crop and Machine Operating Parameters

Selected crop and machine parameters were determined using the methods given in Table 2 to understand the machine operating conditions.

Table 2.Methods Employed in the Analysis of Crop and Machine Parameters

Parameters	Method of analysis
Grain moisture content	'Satake' grain moisture meter
Reel rotational velocity	Stop watch and counter
Reel radius	Measuring tape (steel)
Cutter bar pulley speed	Tachometer (HIOKI 3404, Japan)
Speed of combine harvester	Stop watch and measuring tape
Height of cutter bar	Measuring tape (steel)
Height of the reel axis above the ground	Measuring tape (steel)

Reel Index

Reel index was determined using the following equation as reported by Oduori *et al*., 2012.

$$K = \frac{\omega R}{v}$$

where,
K – Reel index (dimensionless)
ω – Angular velocity of reel (rad/s)
R – Radius of reel (m)
v – Header advance velocity (m/s)

Header Advance (R_0)

The header advance per radian of reel rotation was determined using the following equation (Oduori *et al*., 2012).

$$R_0 = V / \omega$$

where,

V – Header advance velocity (m/s)

ω – Angular velocity of reel (rad/s)

R_0 – Header advance per radian of reel rotation (m)

Tine bar velocity at impact with the panicle

The tine bar velocity when it impacts with the panicle is given as reported by Oduori *et al*., 2008.

$$U_i = V\sqrt{1 + 2\left(\frac{Y_i - Y_r}{R_0}\right) + \left(\frac{R}{R_0}\right)^2}$$

where,

$$Y_i = Y_r + R\cos\omega t_i$$

U_i – Velocity of tine bar at impact with the panicle (m/s)

Y_r – Height of the reel axis above the ground (m)

Y_i – Height of the point of impact between tine bar and the panicle (m)

t_i – Time at the moment of impact (s)

Number of Impacts between Tine bars and the Panicles

For a unit distance of a metre of reel advance, the number of crop-tine bar impacts is given by the following equation as reported by Oduori *et al*., 2008:

$$n_i = \frac{1}{\alpha R_0}$$

where,

n_i – Number of tine bars - panicle impacts per metre of header advance (m^{-1})

t- An arbitrary time interval (s)

α – Angle between successive tine bars (rad)

Measurement of Header Losses

The combine was allowed to move forward for about 20 m to attain a steady state speed and it was suddenly stopped. The header unit was lifted up and the machine was moved back for about 5m. The quadrate with an area of $0.5m^2$ was placed in front of the parked machine and the grains and panicles were manually picked up. The panicles were then manually threshed and the header losses were determined by weighing the fallen grains and panicle-grains collected.

III. Results and Tables

Influence of forward speed on field capacity and field efficiency of John Deere combine

Forward speed is probably the most important factor in optimizing the performance of a combine harvester (Hunt, 1983). Field capacity and field efficiency significantly varies from field 1 to field 2 due to the variation of combine speed and field conditions. Both field capacity and field efficiency under the field conditions are given in Table 1.

Table 1. Field Performance of the conventional combine harvester at field 1 and 2 in harvesting BG-300 paddy variety

Evaluation parameters	Field 1	Field 2
Area of plot harvested (ha)	0.137	0.145
Total harvested time (min)	9.83	18.76
Actual harvested time (min)	5.8	11.76
Forward speed (m/s)	1.1	0.58
Grain moisture content (%)	27.0	20.3
Average field capacity (ha/h)	0.83	0.46
Field Efficiency (%)	58.9	62.8

Forward speeds of 1.1 m/s at field 1 and 0.58 m/s at field 2 with variable grain moisture content of 27.0 % to 20.3% decreased field capacity from 0.83 to 0.46 ha/h. However, it is obvious that the lower combine forward speed of 0.58 m/s at field 2 resulted in the field efficiency to 62.8% but at the same time decreased the field capacity to 0.46 ha/h and the vice versa was noticed with the increased forward speed of 1.1m/s at field 1. The low field capacity of the combine at field 2 is attributed to the larger values of operational time that required for the harvesting operation. The major reason for the reduction in field efficiency at higher forward speed is due to the less time consumed for actual harvesting in comparison with the other time losses. Thus, the turning time to total operating time increase by an increase in speed and decrease in travel length. However, field capacity increases in general by an increase in operating speed (Wahby, 1976).

Influence of Reel Index on Header losses

Results obtained show that the header grain losses from the combine were remarkably higher with the reel index of 2.52 at a grain moisture content of 20.3% at field 2. The increase in header grain losses at higher reel index is attributed to the high impact of the reel on the plants. Higher header losses of 33.97 kg/ha was obtained at field 2 with a reel index of 2.52 and a lower loss of 30.74 kg/ha was observed at field 1 with a reel index of 1.65. It has been found out that the conventional combine with a reel index of 2.52 at field 2 had a header advancement of 0.20 m per radian of reel rotation at the forward speed of 0.58 m/s, whereas it had a header advancement of 0.26 m per radian of reel rotation with a reel index of 1.65 and at the forward speed of 1.1m/s at field 1 (Table 2).

Table 2. Reel advancement per radian of reel rotation and the number of impacts

Location	Reel Index	Reel advance (m)	No. of impacts	Header losses (kg/ha)
Field 1	1.65	0.26	3	30.74
Field 2	2.52	0.20	4	33.97

At reel index value of 2.52, the reel rotated with less advancement (0.20 m) into the crop and increased the amount of panicles gathered by the reel in a single cycle of its rotation which in turn resulted in higher header losses of 33.97 kg/ha at field 2. Added to that, the reel-crop impact was different at each reel index because the number of impacts per unit distance of reel advance is inversely proportional to the header advance per radian of reel rotation (Oduori *et al*., 2008). Hence, the number of impacts caused to the panicles at the reel index of 2.52 was higher than that at the reel index of 1.65 so that the tines hit the panicles harshly, thereby creating more header losses at field 2 than field 1. These observations were consistent with the results obtained by Chinsuwan *et al*., (1997), who reported that when the reel index was low, the tine failed to sweep all the rice towards the header. On the other hand, when the reel index was high, the tine would beat the panicles violently resulting in greater loss.

Influence of grain moisture content on header grain losses

Results show that percentage of grain losses varied inversely with grain moisture content. The lower percentage of grain losses of 30.74 kg/ha was observed when the grain moisture content was 27.0% at field 1. Low moisture content of 20.3% at field 2 caused higher header losses of 33.97 kg/ha. The decrease in grain losses by increasing grain moisture content is due to the elastic conditions of high moisture content materials. Therefore, the grain losses increased with a decrease in grain moisture content (Bukhari *et al.*, 1991).

IV. Conclusion

The highest field capacity of 0.83 ha/h, while the lowest field efficiency of 58.9% were observed at a constant forward speed about 1.1 m/s and grain moisture content about 27.0% at field 1. On the other hand, the lowest field capacity was 0.46 ha/h, while the highest field efficiency was 62.8% at a constant forward speed about 0.58 m/s and grain moisture content about 20.3% at field 2. The conventional combine with a reel index of 1.65 at field 1 caused lesser number of impacts on the panicles whereas it was higher at the reel index of 2.52 at field 2. Consequently, higher header loss of 33.97 kg/ha was found at the reel index of 2.52 at field 2. Further the percentage of grain losses varied inversely with grain moisture content at both sites.

As the performance of the combine varied with respect to the field and the machine operational conditions, several investigations with different types of paddy varieties and at various field conditions are needed to predict the performance of the combine and to optimize the operational factors.

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