Evaluation of Grain Losses as Affected by Combine Forward Speed

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Abstract: Header losses were evaluated at forward speeds 4.24, 2.95 and 2.04 km/h in combine A and 3.81, 2.73 and 1.9 km/h in combine B. Header grain losses initially decreased with an increasing forward speed from 2.04 km/h to 2.95 km/h but increased with an increase of the speed from 2.95 to 4.24 km/h in combine A. Header grain losses were also increased due to the increase of the speed from 2.73 to 3.81 km/h from combine B. Forward speed of 2.95 km/h in combine A and 2.73 km/h in combine B resulted in lower header losses of 38.7 and 45.8 kg/ha, respectively. The increasing forward speed of combine A from 2.01 to 4.24 km/h increased the effective field capacity from 0.245 to 0.38 ha/h. Similarly, in combine B forward speeds from 1.9 to 3.81 km/h increased effective field capacity from 0.175 to 0.197 ha/h. Increasing forward speed in combine A from 2.01 to 4.24 km/h decreased the field efficiency from 60.9% to 49.3%, whereas, increasing forward speed from 1.9 to 3.81 km/h decreased the field efficiency from 50.8% to 30.6% in combine B.

Keywords: Combine harvester, forward speed, field capacity, field efficiency, header loss

I. Introduction

Harvesting and threshing operations are known as crucial and influential processes on quantity, quality and production cost of paddy. Manual harvesting of paddy is such a troublesome, time consuming and costly operation that it needs about 100-150 man hour labour to harvest one hectare of paddy field (Nadeem, 1983).

Some paddy producing countries in Asia have seriously attempted to introduce compatible technologies for current circumstances and pass from this crisis (Bora and Hansen, 2007). Therefore, in order to overcome the labour shortage, majority of the farmers in the paddy growing areas have sought after combine harvesters to take over the task, which are playing a more important role in harvesting paddy and many types of harvesters are widely used in these days.

However, there are many factors that control the performance of combine harvesters, which can be divided into machine and plant factors. Machine variables include combine forward speed, peripheral speeds of combine devices, and feeding rate. During the past few years, farmers have drawn to purchase substantial number of combine harvesters and it is estimated they will consider utilizing more machinery due to increasing trend of wages for upcoming years. Therefore, it is required to conduct technical investigations on the viewpoint of grain losses and performance of the combine harvesters at local conditions.

The data presented by many other researchers indicated that forward speed plays an important role during the harvest process in determining the proportion of harvest losses as it has negative impact on the process of harvest because losses proportionate with the speed of the harvester due to its impact on the operating units and feeding rate (Al-Kazaz 1990; Al-Tahhan *et al*., 1990; Chen *et al*., 2012; Mohammed and Al-Kazaz 2000; Ramadan 2010; Randal and Mark, 2002). Therefore, this study aimed to evaluate grain losses from two widely used combines in terms of different forward speeds and to assess their field performances.

II. Materials and Methods

A. Study Area and Test Field

The 450 m x 20 m field was planted with BG 94-1, paddy variety in Batticaloa, Sri Lanka. The experiment was conducted with two different brands of combine harvesters of Japanese (A) and Chinese (B) origin. Both combines were crawler type with 2m cutting width. All the field trials were conducted according to RNAM test code (RNAM Test Codes, 1995). The reel angular velocity of 30 rpm was used in both types of combines. Each combine harvester was operated at 3 different levels of gear positions namely 1st gear (high), 2nd gear (low) and 2nd gear (high) at an engine speed of 3000 rpm which resulted in different forward speeds as sub plot factors. Combine forward speeds obtained at these gear positions in each combine harvester are given below (Table 1).

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TABLE. 1. OPERATIONAL FORWARD SPEED EMPLOYED AT HARVESTING

Brand of combine	Gear position	Forward speed (km/h)
A	1st high	4.24
	2nd low	2.95
	2nd high	2.04
B	1st high	3.81
	2nd low	2.73
	2nd high	1.9

B. Measurement of grain yield and pre-harvest losses

Grain yield was determined by throwing a quadrate made of stiff steel measuring 0.71m x 0.71m (0.5 m^2) area and the panicles enclosed in such area were harvested using a sickle. Pre-harvest losses were determined by placing the quadrate in five randomly selected places in each plot before the combine harvester entered the plots. Loose grains and panicles shattered on the ground were picked up from within the quadrate and weighed after drying.

C. Measurement of Header Losses

The combines were allowed to move forward for about 20 m (1m from the border of each experimental plot) 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 mentioned above was placed in front of the parked machine and the grains and panicles were manually picked up and weighed. The samples for header loss were collected in four replicates in each experimental plot.

D. Performance Evaluation

1) Effective Field Capacity (S)

Time consumed for real harvesting and that lost for unproductive activities were used to calculate the effective field capacity based on Equation 1. The unproductive time elements included the time lost for turning the machine, unloading the grain tank, rearranging the grain tank, removal of straw clogging and other idle times during harvesting.

$$S = \frac{A}{T_p + T_l} \quad \text{………………} (1)$$

where,

S – Effective field capacity (ha/h)

A – Area covered (ha)

T_p – Productive time (h)

T_l – Unproductive time (h)

2) Field efficiency (E_f)

It was calculated from the test data as the ratio of productive time to the total time using the following equation (Equation 2).

$$E_f = \frac{T_p}{T_p + T_l} \quad \text{…………………} (2)$$

III. Results and Discussion

A. Effect of Forward Speed on Header Losses

The header grain losses initially decreased with the increasing forward speed from 2.01 km/h to 2.95 km/h but increased with a further increase of the speed from 2.95 to 4.24 km/h from *combine A*. There was an increase in the total header grain losses due to

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the increase of the speed from 2.73 to 3.81 km/h from *combine B*. In this respect, header losses showed the highest rate of increase with increased forward speed in both types of combines (Figure 1).

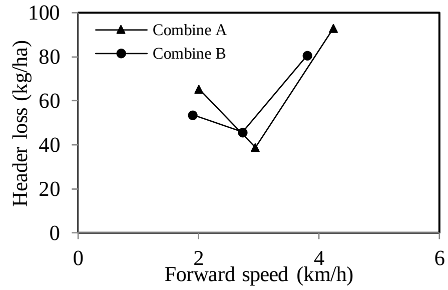

Figure 1. Relationship between forward speed and header losses

Minimum header losses of 38.7 and 45.8 kg/ha were noticed from *combine A* at the speed of 2.95 km/h and at 2.73 km/h from *combine B,* respectively. The forward speeds of 2.73 km/h in *combine B* and 2.95 km/h in *combine A* have offered a gentle handling of the panicles while cutting. It can be explained that *combine A* showed greater forward speed at each given gear positions than that of *combine B*, hence greater the header losses from *combine A*.

There was a trend of increase in header losses as the forward speed increased. Forward speed of 2.95 km/h in *combine A* and 2.73 km/h in *combine B* resulted in comparatively lower header losses of 38.7 and 45.8 kg/ha, respectively. When the speed increased to 4.24 km/h in combine A and 3.81 km/h in combine B the header losses were found to be increased by 140% and 76% from combine A and B respectively. This result could be attributed to the vibration and a large number of moving parts so that the reel constituted a large proportion of grain losses in the header unit.

B. Field Performance Evaluation

1) Effective Field Capacity

Field capacity and field efficiency varied from one combine to another due to the wide variation of power and speed of combine harvesters. The effect of machine forward speed on actual field capacity is shown in Figure 2. Even though the effective field capacity increased, the field efficiency decreased with the increase in speed for both types of combine harvesters due to the time losses at higher speeds (Table 2).

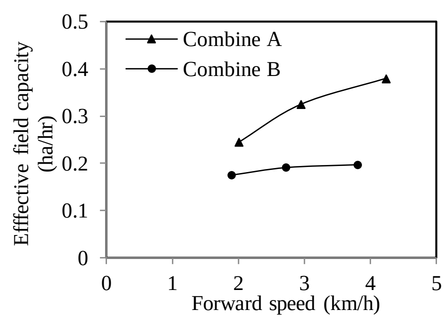

Figure 2. Effect of forward speed on effective field capacity in combine *A* and *B*

The increasing forward speed of *combine A* from 2.01 to 4.24 km/h increased the effective field capacity from 0.24 to 0.4 ha/h. Similarly, increasing the forward speed of *combine B* from 1.9 to 3.81 km/h increased effective field capacity from 0.17 to 0.19 ha/h. This finding is in accordance with Wahby (1976) who found that percentage of turning time to total operating time increased with an increase in speed and decrease in travel length. However, effective field capacity increased in general by an increase in operating speed.

Due to higher unproductive (idle) time, *combine B* showed a relatively lower field capacity than *combine A*, which is in conformity with the finding that increasing the clogging time tend to decrease the actual field capacity and efficiency (Helmy *et al.*, 1995). The effective field capacity of *combine A* was comparatively found to be greater, due to less time taken to harvest the plots which was related to its stepless movement of the HST (Hydro - Static Transmission) system with higher forward speeds. Various problems were observed while harvesting with *combine B*, *i.e.*, blocking of the header unit and threshing cylinder with the panicles and difficulties in movement etc. In general, the performance of the *combine A* was found to be satisfactory. The crawler travel unit and

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light body weight of *combine A* exerted only a relatively less ground contact pressure (37.03 kg/m^2) so that the chances for sinkage (bogging down) were not to be found, whereas *combine B* experienced little difficulties in the movement due to higher ground contact pressure (48.4 kg/m^2) which consumed additional idle time to complete the harvesting process. Further, a relatively high minimum ground clearance designed to *combine A* to travel smoothly than required lower time which resulted in comparatively greater field capacities in *combine A* (Table 2).

TABLE 2. FIELD PERFORMANCE OF COMBINES

Parameters	Combine A			Combine B		
Average speed (km/h)	4.2	2.95	2.01	3.81	2.73	1.9
Width of cutter bar (m)	2.0	2.0	2.0	2.0	2.0	2.0
Area of plot harvested (ha)	0.04	0.04	0.04	0.04	0.04	0.04
Total harvested time (min)	7.1	8.3	11.0	13.7	14.1	16.7
Actual harvested time (min)	3.5	4.9	6.7	4.2	6.0	8.5
Effective field capacity (ha/h)	0.4	0.3	0.24	0.19	0.19	0.17
Theoretical field capacity (ha/h)	0.8	0.6	0.40	0.71	0.50	0.33
Field efficiency (%)	49.3	59.0	60.9	30.6	42.5	50.8

2) Field Efficiency

Increasing the forward speed for *combine A* from 2.01 to 4.24 km/h decreased the field efficiency from 60.9% to 49.3%, whereas, increasing forward speed of *combine B* from 1.9 to 3.81 km/h decreased the field efficiency from 50.8% to 30.6% (Table 2). The major reason for the reduction in field efficiency by increasing forward speed is due to the less theoretical time consumed in comparison with the other items of time losses in both combines.

Field efficiency was mainly affected by the time losses in turning, grain emptying and removal of straw clogging. *Combine A* had comparatively higher field efficiency than *combine B* because switching the direction of movement between forward and reverse was easily accomplished in *combine A* without the use of a clutch so that operations continued smoothly without interruption. Moreover, clogging was found to be nil in *combine A* as it required only the simple operation of the reverse processing mechanism lever, which enabled easy and efficient reverse movements of the reel in the cutting and conveying stages so that unclogging took place with utmost ease with less time requirement.

But, this reverse mechanism in reel rotation is absent in *combine B*, so that every time the clogged panicles were removed manually after stopping the machine, which increased the idle time further, thereby resulting in poor field efficiencies. Therefore, it is clear that decrease in both field capacity and field efficiency for *combine A* is attributed to the larger values of operational time required for the harvesting operation as well as for minor field maintenance.

However, the effective field capacity and the field efficiency recorded for both types of combines were not reasonable, since many research reports indicate that the effective field capacity varied from 1.06 to 2.11 ha/h and the field efficiency varied from 58.7% to 80.7% using time studies (ASAE, 1977; Fouad *et al.*, 1990; Hasson and Larson, 1978; Smith and Wilkes, 1976). This was because the rate of work of a combine depends on the size, rate of travel, pattern of field operation, moisture and crop conditions and, yield of grain. i.e., field efficiency is not a constant for a particular machine but varies with the size and shape of the field. Small-sized plots (45 x 10 m^2) used in this study also contribute to the lower field efficiencies due to increased time losses. It is obvious that lower forward speed tends to increase field efficiency, but at the same time, significantly decreased the field capacity and vice versa was noticed with the highest forward speed.

IV. Conclusion

The ideal forward speed for minimum header grain losses is 2.95 and 2.73 km/h for combine A and B respectively under the experimental conditions. When the forward speed increased beyond these limits there were more header losses from both combines as there were more vibration occurred. This result could be attributed to the large number of moving parts in the header unit such as the reel which constitutes a large proportion of the losses in the header.

The effective field capacity of *combine A* was comparatively found to be greater than B, due to less time taken to harvest the plots which was related to its stepless movement of the HST (Hydro - Static Transmission) system with higher forward speeds. Due to higher unproductive (idle) time, *combine B* showed a relatively lower field capacity than *combine A*.

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Combine A had comparatively higher field efficiency than *combine B* because switching the direction of movement between forward and reverse was easily accomplished in *combine A* without the use of a clutch so that operations continued smoothly without interruption.

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