



COMBINE HARVESTER HEADER LOSSES AS AFFECTED BY REEL AND CUTTING INDICES

Almosawi, Abdulaziz, A.

Diwanya Technical Institute , Al-Furat Al- Awsat Technical University, Iraq

Email : azizalmosawi5@gmail.com

Abstract

A field study was conducted to test a self propelled reel feeding combine harvester while harvesting the local variety forat 39. The effect of three levels of reel index (1.21, 1.45 and 1.70) and three levels of cutting index (1.31, 1.55, 1.71) on combine header losses and some related parameters were investigated. The results demonstrated that the higher header advancement, the larger number of plants processed per radian and the lower contact index at the reel index 1.21 which was associated with the more amount of header losses. On the other hand, the lower header advancement, the lower number of plants processed and the greater contact index at the reel index 1.7 which coincided with the highest header losses. The reel index 1.45 produced significantly the least header losses. Regarding the effect of cutting index, it was significant only in the contact index and the header losses which behaved similar to reel index. However, both factors formed a quadratic relationship with the combine header losses. The levels 1.45 and 1.55 for the reel and cutting indices respectively can be considered as indicators of reducing combine header losses

Key words: Combine harvester, reel index, cutting index, header losses

Introduction

The rapid increase in population in Iraq accompanied with the increase in demand for food necessitates minimization of losses during rice harvesting. According to Almosawi (2007), the harvester header recorded the highest levels of loss caused by the harvester. Therefore, he stated that combine header loss ranging from 3.3% at low harvesting speed to 5.8 % at high harvesting speed. This range of losses out of the national production is a large figure that requires a deep consideration.

According to sail *et al.* (1992) shattering losses caused by combine harvester header are function of reel index and cutting index.

Researchers differ in their recommendations of reel index for the standing crops, some recommended an index range of 1.25 to 1.5 others recommended 1.1 to 3.4 for a 1.1 m diameter reel operating over range of ground speeds (Zelege *et al.*, 2014).

Zelege (2012) revealed that the reel has two kinds of movements, one is linear transition movement (V) which coincides with movement of the combine, the other is the rotary movement of the reel (U). When U is greater than V the trajectory of the reel motion called trachoid which require the origin of the coordinate is located at 0 and the x-axis in the direction of the motion and y-axis directed upward.

Bawatharani *et al.* (2013) conducted a field study to measure the header grain losses for two brands of combine harvester as influenced by three levels of reel

indices. The results showed that the relationship between header loss and reel index tend to produce a quadratic curve. However, the header loss was found to be the least at the vertex of the parabolic curve that is at index 1.7 for the observations.

Jalali and Raza (2014) reported that the combine ground speed, reel rotational speed and reel height were 2.1 km.hr⁻¹, 32 r.p.m and 87 cm respectively and he concluded that well setting of the three mentioned factors will minimize header losses.

The cutter bar is a key determinant of the combine field capacity and an important element in determining the amount of combine header losses. Therefore; it is so important to improve the crop cutting action in order to reduce header losses accordingly (Guarnieri *et al.*, 2007). The cutter bar cutting action take an interval of time much shorter than the entire cutter bar stroke. In addition to, the area between the guard fingers cannot be covered completely by the plants and cutting action would not take place until the plants reach a counter cutting support which forces the stems of the plants to slide and the force required to overcome the stems shear strength (Guarnieri *et al.*, 2007). All of these parameters have the stems to agitate during the cutting action and consequently some of rice kernels were fall around the header area. Sangwejit *et al.* (2010) drew a relationship between the cutter bar speed and the losses of chainat rice variety, the results indicated that as cutter bar speed increased the losses tended to increased and he attributed this results to the impact of cutter bar on rice stems. The objectives of this research were to determine

the effect of the reel and cutting indices and some related parameters on combine header losses.

Material and Methods

A self propelled, reel feeding, crawler wheel adapted system, spike tooth threshing unit combine harvester was tested in the field while harvesting the local rice variety forat 39. The combine was equipped with 4 m full feeding header. The experiment was conducted according to the randomized complete block design to evaluate the effect of reel and cutting indices and some related parameters on header losses. Three levels of reel indices 1.21, 1.45 and 1.70 and three levels of cutting indices 1.31, 1.55 and 1.72 were the experimental treatments. The reel index was assigned as the main plot where as the cutting index was assigned as the sub-plot. The functional specifications of the combine used and the relevant indices are exposed in table 1.

Table 1 : Specifications of combine relevant to the reel and cutting indices

Specifications relevant to cutting index			
Cutter bar Index	Cutter bar speed m. sec ⁻¹	No. of stroke .sec ⁻¹	Stroke length (m)
1.31	1.245	15.57	0.08
1.55	1.472	18.4	0.08
1.72	1.637	20.4	0.08
Specification relevant to reel index			
K	λ	RRS rad. sec ⁻¹	Vm m . sec ⁻¹
1	1.21	1.15	0.95
1.26	1.45	1.38	
1.48	1.70	1.61	

Vm = combine velocity m. sec⁻¹

RRS = reel rotation rad. sec⁻¹

λ = reel index dimensionless

K = Number of strikes on rice panicles

Reel index

Reel index is defined as the peripheral reel speed relative to the ground speed (combine speed). Reel index was calculated using equation 1.as stated by Odouri *et al.* 2012

$$\lambda = \frac{\omega R}{V} \quad \dots(1)$$

where as:

λ = reel index (dimensionless)

ω = angular velocity of reel rad.sec⁻¹

V = header advancement velocity m.sec⁻¹

Cutting index :

Cutting index is defined as the speed of the reciprocating movement of cutter bar (speed of the cutter bar) in m.sec⁻¹ relative to the ground speed of the combine m.sec⁻¹. The reel index was calculated using equation 2 as reported by Sial, *et al.* (1992) to find the cutting index.

$$\text{Cutting index} = \frac{2Lsp}{v} \quad \dots(2)$$

where as:

Sp = speed of cutter bar drive pullym.sec⁻¹

L = cutter bar stroke m

V = velocity of the combine (Forward speed) m .sec⁻¹

To illustrate the nature of the combine header losses and the most effective factor on it , there are some indicators that must be taken into consideration these are:

1. Header advancement (Ro)

The header advances in meter (m) per radian of reel rotation. It was determined using equation 3. (Oduri *et al.*, 2012).

$$Ro = \frac{V}{\omega} \quad \dots(3)$$

where as :

Ro = header advance per radian of reel rotation (m)

V = header advance velocity m.sec⁻¹

ω = angular velocity of reel rad . sec⁻¹

2. Strikes on rice panicles per meter sweep of the combine (k)

The number of strikes (k) directed by the reel tine bars on the rice panicles per meter sweep of the combine was calculated by equation 4.

$$K = \frac{Z\lambda}{2\pi R} \quad \dots(4)$$

(Bawatharni *et al.*, 2013)

Where as:

K= number of strikes on rice panicles.

Z=number of reel tine bars

R= reel radius m.

3. Number of plants processed by header advancement per radian

$$N.P. = \frac{Vm \text{ m. sec}^{-1} . w.m. p.p. \text{ m}^{-2}}{\omega \text{ rad. sec}^{-1}} \quad \dots(5)$$

N.P. = number of plants processed per rad

Vm= combine velocity m. sec⁻¹

W= header width m

ω = angular velocity of reel rad. sec⁻¹

p.p. = rice plant population m⁻²

4. Reel contact index

Reel contact index is percent of stems that are fed to the cutter bar under the influence of the reel bars and can be calculated by the following equation used by Quik, 1972.

$$\eta = \frac{n}{2\pi} \left[\frac{\pi}{\theta - 2 + \sqrt{\lambda^2 - 1}} \right] \dots(6)$$

Where as

- = Contact Index
- n = Number of tine reels bars
- = Angle of point on any reel bars at instant of crop entry relative to horizontal datum through center of rotation of reel degrees.

Results and Discussion

Header advancement Ro

The analysis of variance indicated that the most significant effect on the combine header advancement in meter relative to the reel rotation in radian Ro was attributed to reel index factor. The value of Ro decreased as the reel index increased and the reason for this is the increase in the number of the reel rotation per minute relative to the distance travelled by the combine harvester per unit of time. These results correspond to what was found by Bawathurani *et al.* (2015). The results shown in table 2 indicate that the effect of the cutting index was not significant in the Ro parameter. This is considered realistic result because the lateral reciprocating motion of the cutting knife cannot add any momentum to the forward advancement of the combine header. The statistical analysis also indicated that the binary interaction between the study factors was not significant. This means that each factor has an independent effect on the Ro, such phenomena what gave the reel index importance in determining the header advancement in meter relative to the reel rotation in radian.

Table 2 : header advance per radian of reel rotation (m)

Cutting index CI				Reel index RI
Mean	1.72	1.55	1.31	
0.4540	0.4493	0.4523	0.4603	1.21
0.3767	0.3807	0.3767	0.3727	1.45
0.3288	0.3283	0.3307	0.3273	1.70
	0.3861	0.3866	0.3868	Mean
L . S . D RI = 0.01148 , CI = 0.01148 , RIXCI = 0.01989				

Number of plants processed by the combine header per radian

According to the circumstances in which the research was carried out and the speed of the harvester was stabilized at 0.95 m.sec⁻¹ as well as to what was

found in the previous parameter, the distance advanced by the combine header per radian decreased as the reel index increased. On this basis the number of plants per radian treated by the whole width of the combine header decreased with increased of reel index factor. The analysis of variance and the test of means L.S.D. at 0.05 level as shown in table 3 further illustrates that the reel index had a very significant effect on the number of plants per radian treated by whole width of the combine header. The number of plants per radian treated decreased by 20% and 32% relative to the grand means for the 1.45 and 1.7 reel index respectively.

The statistical analysis of variance showed no significant effect of the cutting index on the number of plants per radian treated by combine header. This indicates that the main factor in determining the number of plants per radian is the reel index with the effect of its components the speed of the reel and the speed of the harvester.

The least significant difference L.S.D indicates that the interaction between the research factors had a significant effect on the number of plants treated by combine header per radian at probability of 0.05. The highest number of plants treated by the combine header was 623 recorded by the interaction between the reel and cutting indices at levels of 1.21 and 1.31 respectively, while the least number of plants was 444 recorded by reel and cutting indices at levels of 1.7 and 1.72 respectively.

Table 3 : Number of plants per radian treated by the whole width of the combine header

Mean	Cutting index CI			Reel index RI
	1.72	1.55	1.31	
613.9	607.3	611.7	622.7	1.21
509.2	524.7	509.3	503.7	1.45
444.7	444.0	447.0	443.0	1.70
	523.1	522.7	523.1	Mean
L.S.D RI = 15.64, CI = 15.64, RIXCI = 27.09				

Contact Index

Before addressing the result of this parameter, it is necessary to develop some assumptions, first placing the reel axis vertically above the cutter bar, second the reel bar pushes the rice stalks over a distance equal to ΔX. This distance was calculated by Almosawi 2007 using the relationship stated in Fig. 1.

The analysis of variance indicated that both research factors (reel index, cutting index) had a significant effect on the contact index at 0.01 probability. It was found in table 4 that the plant contact index had increased steadily with the increase in the reel index factor, despite the decrease in the number of plants per radian fed by the combine reel towards the

cutter bar, which was proved in the previous parameter Table 2. The lowest contact index was 0.1432 which was scored with the lowest reel index 1.21, this mean that the number of reel cycles per minutes dose not correspond to the speed of the combine.

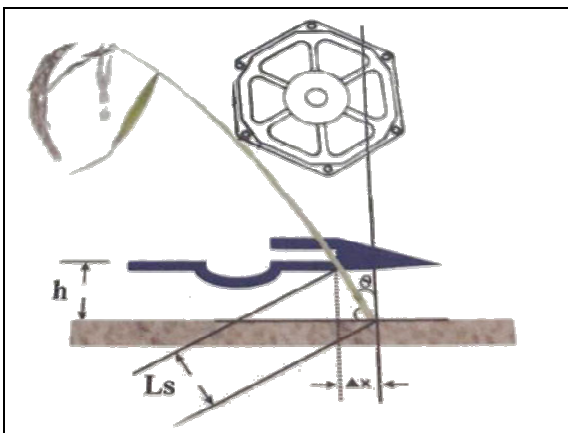


Fig. 1 : Δx and reel position relative to combine header cutter bar. (Almosawi 2007)

This low contact index causes cutting of some plants stems before they gets the impact of reel bars which likely allow some of these plants to fall down under the combine platform. On the other hand , the highest contact index was 0.453 found at the highest reel index this refer to an increase in the number of reel cycles per minutes in relation to the combine speed which in turn resulted in an excessive beating on the rice panicales. In the same way as in the reel index the contact index increased as the cutting index increased, however, the increase was almost constant and steady when reviewing the levels of this parameter from the smallest level to the highest. Although the analysis of variance indicated that the interaction between the factors of the study was significant at probability of 0.05, but the focus on the results shows that both factors acted independently in determining the contact index.

Table 4 : The contact index.

Mean	Cutting index CI			Reel index RI
	1.72	1.55	1.31	
0.1432	0.1680	0.1450	0.1167	1.21
0.2799	0.2997	0.2800	0.2600	1.45
0.4630	0.4810	0.4630	0.4450	1.70
	0.3162	0.1960	0.2739	Mean
L.S.D RI = 0.0066, CI = 0.0066, RIXCI = 0.011				

Combine Header Losses

The analysis of variance indicated that the effect of reel index in rice losses caused by combine header is significant Table 4 shows that the lowest level of the

reel index factor caused a loss of 19.82 $\text{g}\cdot\text{m}^{-2}$ that is equivalent to 198.2 $\text{kg}\cdot\text{ha}^{-1}$. This quantity means that a loss of a large percentage of national rice production when taking into consideration the vast areas that is used to grow rice all over the country .The reasons for this high amount of loss at such low level of reel index are the increase in the length of the advanced distance that harvester header progresses in relation to reel rotation per radian which is already shown in table 2, also the increase in the number of plants that must be positively thrust into the cutting zone per radian, as well as a lack of contact index between the plants and the reel bars. It should be noted that the points mentioned above will lead to fall of some of the treated plants under the combine header before being forced by the reel to fall in the platform. As well as sliding of some stalks for along distance on the cutting blades, which leads to stalks vibration and disintegrate of their ears. Table 4 also indicates that the amount of loss has decreased at the level of 1.45 reel index. The reason for this is the reduction of distance that the header progresses in relation to rotation of the reel and decrease the number of plants that must be forced by the harvester reel towards the header cutter bar.

Table 5 : Effect of reel and cutting indices on combine header losses $\text{g}\cdot\text{m}^{-2}$

Mean	Cutting index CI			Reel index RI
	1.72	1.55	1.31	
19.82	22.33	16.16	20.97	1.21
16.37	17.33	13.97	18.97	1.45
22.45	25.95	17.81	22.45	1.70
	21.87	16.35	20.41	Mean
L.S.D RI = 3.223, CI = 3.223, RIXCI = 5.582				

Another reason is the increase in the contact index between the plants and the reel bars. All of these effect led to a quadratic relation between rice losses and reel index. This quadratic relationship indicates that the least values of loss achieved at 1.45 reel index level and was the lowest at the curve vertex Fig 2. As for the highest level of reel index 1.7, its effect was characterized by an increase in the header loss. The loss at this level index was 22.45 $\text{g}\cdot\text{m}^{-2}$ that is 224.5 $\text{kg}\cdot\text{ha}^{-1}$, an increase of 13% as compared with the minimum reel index level 1.21.

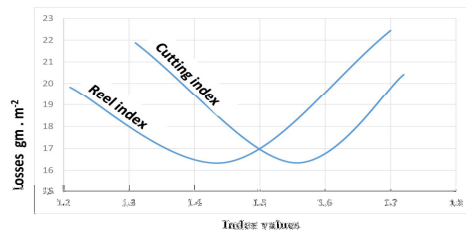


Fig. 2. Shows the relation between header losses and reel & cutting indices

This excessive loss of yield per hectare at this level of reel index has been due to the decrease in the distance that the harvester has advanced for each radian of the reel cycles, the decrease in the number of plants that have been forced by the reel to fall in the platform and increase the contact index to the extent that plants was over beaten table 6. Concerning the cutting index it showed the same behaviour as the reel index in term of the effect on the amount of losses. The loss was high at the lowest level of cutting index 1.31 and then decreased at the level of 1.55 and returned to score a high amount of loss at the cutting index 1.72. This phenomena shows an interesting quadratic relationship between the loss and the levels of the cutting index which require more consideration and more research work. The analysis of variance does not indicate the existence of a significant of the binary interaction between the reel index and the cutting index. This finding means that each factor behaves individually, which gives the reel index advantage in determining the minimum and the maximum losses values. Any way these results are in line with the circumstances of this study and its factor levels.

Table 6 : Combine header losses g.m^{-2} and related parameters values.

Combine header losses g.m^{-2}	Contact index	No. plants per radian	Header advancement Ro m	Reel index
19.82	0.143	613	0.454	1.21
16.37	0.28	509	0.377	1.45
22.45	0.46	444	0.33	1.7

Conclusion

- The results of this study showed a quadratic relation between the reel index and combine header losses. The levels of reel index 1.21 and 1.7 formed the ends of the parabolic curve and produced a high level of header losses, while the level 1.45 being at the vertex of the curve with low level of losses. This phenomenon is explained by the results that describe the relevant parameters such as the header advancement, number of plants processed per radian and reel contact index.

- Even though the cutter bar index behaved similar to reel index in term of the header losses, the study indicated superiority to the reel index in determining the header losses values.

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