วารสารวิจัย มข. 15 (6) : มิถุนายน 2553

Prediction Equations for Losses of Axial Flow Rice Combine Harvester when Harvesting Chainat 1 Rice Variety

Prapagon sangwijit[1*]
Winit Chinsuwan[2]

Abstract

The objective of this study was to predict the losses of combine harvester when harvesting Chainat 1 rice variety. The results of the study indicated that grain moisture content (MC), cutter bar speed (V), reel index (RI), stem length (H), product of MC and V (MC*V), product of V and RI (V*RI), V^2, RI^2, louver inclination (LI) and product of MC and LI (MC*LI) were the major parameters affecting the harvest losses. The prediction equations had R^2 of 0.93. The average losses given by the estimation equation was 0.57 % different from the measurement. The predicted losses errors were 8.47 % and 0.51 % for average percentage error and standard error respectively.

Keywords: Axial Flow Rice Combine Harvester, Loss, Prediction Equations

Introduction

Chainat 1 is a hybrid rice variety (Rice Department, 2010), commonly grown off- season. In 2006, it was estimated that Chainat 1 rice variety was grown in approximately 20 % of all the off-season rice area in Thailand (Land Development Department, 2006). Rice harvesting is one of the most critical processes affecting its quantity and quality. Especially during off-season, farmers need to harvest just in time before rainy season comes. Most of the rice combine harvesters used in Thailand are manufactured domestically and are called Axial Flow Rice Combine Harvester (Chinsuwan et al., 2003a). According to the research by Chinsuwan et al. (2001) which studied the harvesting losses in 49 rice combine harvesters during off season, the results showed an average of 6.25 % losses. The losses were caused by 2 main factors: rice conditions and operating conditions of rice combine harvesters. Rice conditions consisted of rice variety (Chinsuwan et al., 2001), grain moisture content (Chinsuwan et al., 1997), incline of the angle of the rice (Chinsuwan et al., 2004), grain to material other than grain ratio

[1]*Graduate Student, Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University*
[2]*Associate Professor, Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University*
**Corresponding author, e-mail: mesiyanee@yahoo.com*

(Andrews et al, 1993), and rice plant density (Yore et al., 2002). The factors affecting operating conditions of rice combine harvesters can also be divided into 2 categories: factors involving header unit and factors involving threshing unit. Cutter bar speed (Hummel and Nave, 1979), reel index (Chinsuwan et al., 2004), tine clearance over cutter bar (Quick, 1999), tine spacing (Mohammed and Abdoun, 1978), service life of cutter bar (Klenin et al., 1986), and stem length (Siebenmorgen et al., 1994) are factors influencing header unit's performances, whereas cylinder speed, feed rate (Chinsuwan et al., 2003a), clearance between concave rod (Chinsuwan et al., 2003b), concave clearance (Andrews et al., 1993), and louver inclination (Gummert et al. 1992).

Junsiri & Chinsuwan (2009) have studied the "Operating Parameters Affecting Header Losses of Combine Harvesters for Chainat 1 Rice Variety". The results showed that grain moisture content, reel index, cutter bar speed, service life of cutter bar, tine spacing, and stem length were factors influencing losses during harvesting.

Chuan-udom & Chinsuwan (2007) have studied the "Operating Parameters Affecting Threshing System Losses of an Axial Flow Rice Combine Harvester", and the results indicated that cylinder speed, louver inclination, grain moisture content, and feed rate were factors influencing losses during threshing process when harvesting Chainat 1 rice variety.

According the harvesting and losses issues of rice combine harvester as well as factors mentioned above, if an equation could provide accurate prediction of losses of rice combine harvester for Chainat 1 rice variety, it could be one of the solution in estimating possible losses in various operating conditions of rice combine harvesters. Moreover, it might be one of the considerations in modifying rice combine harvester's functions. Therefore, this study aims to create prediction equations for losses of axial flow rice combine harvester when harvesting Chainat 1 rice variety.

Equipments & Methodology

The study was divided into 2 parts: the creation of predicting equation for losses of rice combine harvester and the evaluation of the equation. The details of each part are as follow:

1. Creating the Prediction Equation for Losses of Rice Combine Harvester

The prediction equations for losses in the operation of rice combine harvester for Chainat 1 rice variety was created during off-season in 2007, in Khon Kaen provincial district. The losses and their influential factors were randomly observed across 10 brands, for the total of 16 rice combine harvesters. The losses could be categorized into 2 groups: losses during header unit and losses during threshing unit. The measurements were done in 3 replications. Results were then averaged, provided that, for each replication, the rice combine harvesters were to run in the distance of at least 15 meters, to ensure the stable workload before data collection at 10 meters. The discharged materials were collected in a net bag, and straws were removed to obtain grain loss from the threshing unit. Grains dropped on the floor at the discharge point other than pre-harvesting dropped grains were also collected as the total loss from the header unit. The equations incorporated the two portions of losses comprising the total losses designated as the dependent variables.

The measured factors, involving operating performances of rice combine harvesters were used as independent variables in the equation from 2 studies: the study by Junsiri & Chinsuwan (2009)

"Operating Parameters Affecting Header Losses of Combine Harvesters for Chainat 1 Rice Variety", and the study by Chuan-udom & Chinsuwan (2007) "Operating Parameters Affecting Threshing System Losses of an Axial Flow Rice Combine Harvester". There were a total of 9 factors and 18 independent variables, i.e. grain moisture content (MC), service life of cutter bar (Y), reel index (RI), cutter bar speed (V), tine spacing (R), stem length (H), MC*Y, MC*V, Y*RI, Y*H, V*RI, V^2, RI^2, cylinder speed (CS), louver inclination (LI), feed rate (FR), MC*LI, and CS*FR.

Regression equations were created based on the collected data at 95% confidence. If the equation gave less than 95% confidence, then the new set of independent variables were chosen to create a new regression equation which eventually yielded more than 95% confidence (Chap, 2003). In the case that the chosen variable is a squared or a product of other variables, the first degree variable must be related to the remaining second-degree variables or a product of variables.

2. Evaluating the Prediction Equations

The equation assessment was done by randomly measuring losses on relating factors across 13 brands of rice combine harvesters, in the total of 18 machines. The data collection was during off-season in 2008, in the similar method to the equation creation process. Data collected were compared to the prediction from the equations. The difference from measurement is shown in Eq.1, while the average percentage error in Eq.2 and the standard error in Eq.3.

$$E = \left|TL_p - TL_f\right| \quad (1)$$

$$E_p = \frac{\left|TL_p - TL_f\right|}{TL_f} \times 100 \quad (2)$$

$$SEP = \sqrt{\frac{\sum (TL_f - TL_p)^2 \left\{ \frac{\left[\sum (TL_f - TL_p)\right]^2}{N} \right\}}{N-1}} \quad (3)$$

Where: E = Difference from Measurement (%)
E_p = Average Percentage Error (%)
SEP = Standard Error (%)
TL_p = Losses from Prediction (%)
TL_f = Losses from Measurement (%)
N = Number of calculated data

Results & Discussion

Creating Predicting Equations of Losses of Rice Combine Harvesters

Results from measuring losses of rice combine harvester for Chainat 1 rice variety in 10 brands across 16 rice combine harvesters. Table 1 indicated that, from the created equation, grain moisture content (MC) ranged from 17.75 - 31.75 %wb, service life of cutter bar (Y) ranged from 20 - 1,000 rai (6.25 rai = 1 ha), reel index (RI) ranged from 1.38 - 4.46, cutter bar speed (V) ranged from 0.61 - 0.91 m/s, tine spacing (R) ranged from 9 - 16 cm, stem length (H) ranged from 33.75 - 49.20 cm, louver inclination (LI) ranged from 61.88 - 72.35 degree, cylinder speed (CS) ranged from 15.22- 20.84 m/s, and feed rate ranged from 8.92 - 20.47 t/ h.

Table 1. The result of random measurement of operation and loss from combine harvesters to build prediction equations for losses from harvesting Chainat 1 variety

Brand	No.	MC (%w.b.)	Y (rai)*	RI	V (m/s)	R (cm)	H (cm)	LI (degree)	CS (m/s)	FR (T/hr)	Loss (%)
A	1	22.55	1000	4.46	0.68	13	34.22	67.88	20.84	13.42	11.15
	2	22.77	1000	2.14	0.65	11	43.82	67.52	16.13	10.54	3.17
	3	25.29	400	1.38	0.69	16	36.75	65.95	17.40	18.12	5.97
B	1	29.61	100	3.17	0.67	11	46.23	70.31	16.05	9.44	3.71
	2	27.79	100	2.34	0.88	10	33.75	69.10	16.24	11.79	4.04
C	1	24.39	200	2.32	0.76	10	37.93	64.49	17.63	9.06	9.45
	2	25.79	500	2.64	0.88	11	47.80	72.35	18.52	18.85	2.73
D	1	23.24	100	1.90	0.7	13	43.20	68.51	16.76	17.62	7.65
	2	20.34	500	2.07	0.61	12	43.07	68.51	15.22	17.12	4.27
E	1	24.01	200	1.75	0.78	11	38.60	68.51	16.81	20.47	6.90
	2	17.75	400	1.72	0.74	12	42.81	61.88	17.69	18.25	2.16
F	1	31.75	20	2.83	0.91	11	49.20	68.84	19.40	14.84	9.48
G	1	26.23	550	1.88	0.84	11	36.22	64.89	19.19	8.92	12.96
H	1	30.61	400	2.97	0.65	11	43.51	68.20	17.05	17.03	6.99
I	1	22.24	100	2.05	0.75	10	44.22	62.65	16.63	14.95	8.69
J	1	23.15	200	2.03	0.9	9	34.67	66.70	15.91	17.28	7.29
Maximum		31.75	1000	4.46	0.91	16	49.20	72.35	20.84	20.47	12.96
Minimum		17.75	20	1.38	0.61	9	33.75	61.88	15.22	8.92	2.16
Average		24.84	360.63	2.35	0.76	11	41.00	67.27	17.34	14.86	6.66
Standard deviation		3.73	301.34	0.74	0.10	1.63	4.98	2.74	1.50	3.84	3.17

*6.25 rai = 1 ha

Measured data in the study could be used to create a regression equation to estimate the losses, as shown in Eq. 4. The R^2 from the equation was 0.93, while the omitted independent variables were service life of cutter bar (Y), tine spacing (R), MC*Y, Y*RI, Y*H, cylinder speed (CS), feed rate (FR), and CS*FR. The omitted variables yielded less than 95% confidence level and rarely affecting losses compared to those remained in the equation.

$$LOSS = -435.374+15.638MC+22.042RI+139.885V-0.357H+2.823(MC*V)-38.191(V*RI)+1.162RI^2-70.262V^2+5.377LI-0.258(MC*LI) \quad (4)$$

Relationships between factors and losses can be drawn from the regression equation by converting each factor. Factors which were not converted would be assumed as constants and equal to an average from the measurements: 24.84 %wb for grain moisture content; 0.76 m/s for cutter bar speed; 2.35 for reel index; 41.00 cm for stem length; and 67.27 degrees for louver inclination.

The converted result of grain moisture content showed that, as grain moisture content was increased during harvesting, the losses tended to linearly increased (Figure1.), which was in accordance with the study by Chuan-udom & Chinsuwan (2008).

The reason for the increased losses was supposedly due to the fact that high grain moisture content caused difficulties in the threshing and screening process in the threshing chamber.

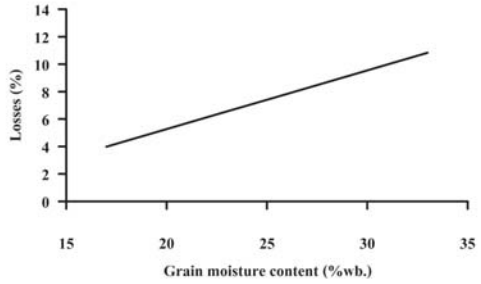

Figure 1. Relationship between grain moisture content and losses

The converted results of cutter bar speed indicated that, as the speed was increased, the losses tended to increase (Figure 2). This could be because the excessive cutter bar speed increased impact of cutter bar on rice stem, thus causing grains to fall easily around the headers area.

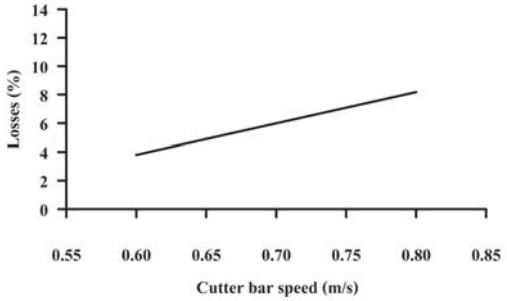

Figure 2. Relationship between cutter bar speed and losses

The converted results of reel index indicated that when the reel index was increased the losses tended to decrease initially. However, as the reel index more than tripled, the losses increased dramatically (Figure 3), which was in accordance with the study by Chinsuwan et al. (2004). Very low reel index created more losses because the fingers could not collect all the rice into the chamber. Similarly, very high reel index caused the fingers to hit rice too hard creating more losses as well.

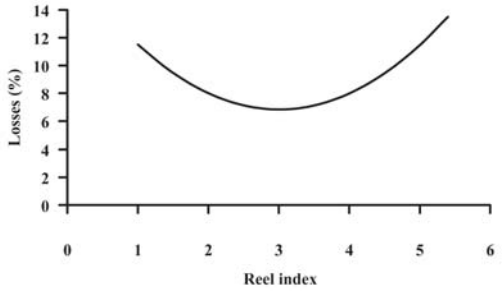

Figure 3. Relationship between reel index and losses

The converted results of stem length showed that the longer the stem, the higher the losses (Figure 4). The long stem was cut close to the base, thus the density was higher and more difficult to cut. This caused more grains to fall around the combine head area. Furthermore, more stem cut lowered the grain to material other than grain ratio, thus could partially cause more losses in the threshing process.

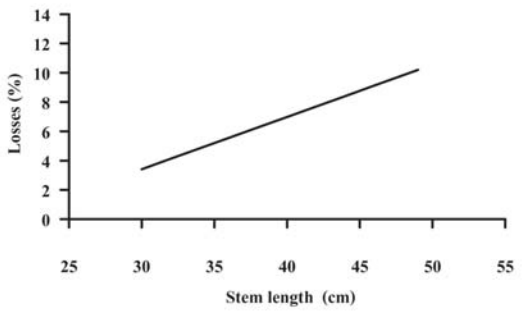

Figure 4. Relationship between stem length and losses

As the for the louver inclination, the converted results indicated that when the louver inclination was increased, the losses tended to decrease (Figure 5). This was because more louver inclination enabled grains and other materials to stay longer in

the threshing chamber. The suggested louver inclination for rice combine harvester is at least 68 degrees (Chuan-udom & Chinsuwan, 2009).

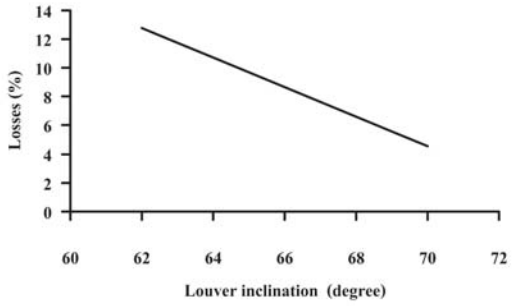

Figure 5. Relationship between louver inclination and losses

Evaluating the Prediction Equations

Table 2 shows the evaluation of the prediction equations. It was found that the prediction equation for losses of rice combine harvester for Chainat 1 rice variety gave between 0.00 - 1.89 % difference from measurement, with an average of 0.57 %. The average percentage error was 8.47 %, ranging between 0.00 - 23.95 %. Part of the reason some percentage errors were rather high was due to early harvesting which can be observed that color of the stem and leaves were still green. Farmers had to harvest early in order to be done before the rainy season comes. Additionally, some parts in some of the tested rice combine harvesters were modified or worn out. The last louver, in rice combine harvester No.2 by brand B, was shortened and adjusted for more inclination. In rice combine harvester No.2 by brand C, the belt in the threshing unit was slippery during the operation. Rice combine harvester No.1, from brand I, had less spike tooth space in the front compared to the back and the shaping of the threshing concave was also modified. Finally, the spike tooth around the feeder of rice combine harvester No.1 from brand L was worn out. Nevertheless, the standard error given by the prediction equation was only 0.51%, which was relatively low. Therefore, it can be assumed that the prediction equation from the study, Eq.4, can be used to predict or estimate losses of rice combine harvester manufactured in Thailand, for harvesting Chainat 1 rice variety.

Table 2. The result of random measurement of operation and loss from combine harvesters to assess the prediction equations for losses from harvesting Chainat 1 variety

Brand	No.	MC (%w.b.)	V (m/s)	RI	H (cm)	LI (degree)	Loss (%)		E (%)	Ep (%)
							TLf	TLp		
A	1	24.37	0.81	2.20	34.85	68.82	4.34	4.50	0.16	3.69
	2	22.58	0.86	2.82	44.80	69.45	4.72	4.50	0.22	4.66
	3	29.36	0.74	2.65	42.58	68.82	6.08	5.75	0.33	5.43
B	1	25.65	0.89	2.10	37.84	67.30	9.07	9.07	0.00	0.00
	2	21.96	0.89	2.38	35.40	64.71	5.36	4.16	1.20	22.39
	3	23.63	0.82	2.33	36.10	65.78	6.47	6.57	0.10	1.55
C	1	21.91	0.77	2.46	39.28	67.30	5.94	5.31	0.63	10.61
	2	24.25	0.86	3.29	42.83	63.80	8.57	7.27	1.30	15.17
D	1	32.77	0.77	2.84	37.10	67.86	6.65	7.22	0.57	8.57
E	1	28.21	0.66	1.78	42.61	66.70	6.22	6.51	0.29	4.66
F	1	23.75	0.66	1.53	49.56	67.22	6.98	7.12	0.14	2.01
G	1	29.72	0.92	3.57	50.61	68.25	5.93	5.59	0.34	5.73
H	1	25.19	0.81	2.37	46.60	67.13	9.43	10.12	0.69	7.32
I	1	26.96	0.93	1.93	34.10	70.03	5.29	6.27	0.98	18.53
J	1	27.92	0.70	1.44	42.03	68.18	6.58	6.04	0.54	8.21
K	1	22.90	0.63	3.53	44.28	69.09	9.32	10.17	0.85	9.12
L	1	22.23	0.85	2.88	45.64	66.03	7.89	6.00	1.89	23.95
M	1	27.34	0.78	2.62	48.74	67.86	10.12	10.03	0.09	0.89
Maximum		32.77	0.93	3.57	50.61	70.03	10.12	10.17	1.89	23.95
Minimum		21.91	0.63	1.44	34.10	63.80	4.34	4.16	0.00	0.00
Average		25.59	0.80	2.48	41.94	67.46	6.94	6.79	0.57	8.47
Standard deviation		3.12	0.09	0.62	5.24	1.63	1.73	1.92	0.51	7.17

SEP = 0.51 %

Conclusions

Factors, in the prediction equation, influencing the harvesting losses of rice combine harvesters in Thailand for harvesting Chainat 1 rice variety, are grain moisture content (MC), cutter bar speed (V), reel index (RI), stem length (H), MC*V, V*RI, V^2, RI^2, louver inclination (LI), and MC*LI. The prediction equations had R^2 of 0.93. The average losses given by the equation was 0.57 % different from the measurement. The predicted losses errors were 8.47 % and 0.51 % for average percentage error and standard error respectively.

Acknowledgement

The authors wish to thank the Postharvest Technology Innovation Center, and the Agricultural Machinery and Postharvest Technology Research Center, Khon Kaen University for providing financial support for this research.

References

Andrews, S.B., Siebenmorgen, T.J., Vories, E.D., Loewer, D.H. and Mauromoustakos, A. 1993. Effects of Combine Operating Parameters on Harvest Loss and Quality in Rice. **Transactions of the ASAE**. 36(6):1599-1607.

Department of Land Development, Ministry of Agriculture and Cooperatives. 2006. **Report on Survey and Projection of 2006 Off-Season Paddy Productivity Based on Remote Surveying Technology and Geological Information System**. Ministry of Agriculture and Cooperatives.

Chap, T.LE. 2003. **Introductory Biostatistics**. USA: Wiley Interscience.

Chinsuwan, W., Chuan-udom, S. and Payom, W. 2001. Rice Harvest Losses Assessment. **KKU Research Journal**. 6(2): 59-67.

Chinsuwan, W., Mongpraneet, S. and Panya, N. 1997. Optimum Harvest Period for Hommali Rice Using Combine Harvester. **KKU Research Journal**. 2(1): 54-63.

Chinsuwan, W., Pongjan, N. Chuan-udom, S. and Payom, W. 2003a. Effects of Feed Rate and Threshing Speed on Performance of Axial Flow Thresher. **TSAE Journal**. 10(1): 9-14.

Chinsuwan, W., Pongjan, N., Chuan-udom, S. and Payom, W. 2003b. Effects of Threshing Bar Inclination and Clearance between Concave on Performance of Axial Flow Thresher. **TSAE Journal**. 10(1): 15-20.

Chinsuwan, W., Pongjan, N., Chuan-udom, S. and Payom, W. 2004. Effects of Reel Index on Gathering Loss of Rice Combine Harvester. **TSAE Journal**. 11(1): 7-9.

Chuan-udom, S. and Chinsuwan, W. 2007. Operating Parameters Affecting Threshing System Losses of an Axial Flow Rice Combine Harvester. **KKU Research Journal**. 12(4): 442-450.

Chuan-udom, S. and Chinsuwan, W. 2008. Development and Validation of Estimation Equation for Threshing System Losses in Axial Flow Rice Combine Harvesters for Chainat 1 Rice Variety. **KKU Research Journal**. 13(2): 251-260.

Chuan-udom, S. and Chinsuwan, W. 2009. Effects of Louver Inclination on Threshing Unit Losses of an Axial Flow Rice Combine Harester. **KKU Research Journal**. 14(3): 322-330.

Gummert, M., Kutzbach, H.D., Muhlbauer, W., Wacker, P. and Quick, G.R. 1992. Performance Evaluation of An IRRI Axial-flow Paddy Thresher. **AMA**. 23(3): 47-58.

Hummel, J.W. and Nave, W.R.1979. Impact Cutting of Soybean Plants. **Transactions of the ASAE**. 22(1):35-39.

Junsiri, C. and Chinsuwan, W. 2009. Operating Parameters Affecting Header Losses of Combine Harvesters for Chainat 1 Rice Variety. **KKU Research Journal**. 14(3): 314-321.

Klenin, N.I., Popov, I.F. and Sakun, V.A. 1986. **Agricultural Machines: Theory of Operation, Computation of Controlling of Operation**. Russian translations series 31. New Delhi (India): Gidson Printing Works.

Mohammed, I.A. and Abdoun, A.H. 1978. Testing MF-400 Combine Harvest under Condition of the Sudan. **Agricultural Mechanization in Asia, Africa and Latin America**. 9(2): 39-42.

Quick, G. 1999. **The Rice Harvester Reference**. RIRDC Rice Research and Development Program. RIRDC Publication No. 99/38.

Rice Department, Ministry of Agriculture and Cooperatives. **Rice Knowledge Bank** [Online] 2010 [Cite 29 January 2010]. Available from: http://www.brrd.in.th/rkb/data_002/a2/rice_xx2-03_ricebreed_Chai_Nat_1.html

Siebenmorgen, T.J., Andrews, S.B. and Counce, P.A. 1994. Relationship of the Height Rice is Cut to Harvesting Test Parameters. **Transactions of the ASAE**. 37(1): 67-69.

Yore, M.W., Jenkins, B.M. and Summers, M.D. 2002. Cutting Properties of Rice Straw. **Presented at the 2002 ASAE** Annual International Meeting, Paper number 026154. ASAE, Chicago, lllinois, USA July 28-July 31.