Operating Factors Affecting Harvesting Losses of Cleaning Unit of Rice Combine Harvesters

Somchai Chuan-Udom [1*]
Winit Chinsuwan [2]

Abstract

The objective of this study was to study operating factors affecting harvesting losses of cleaning unit of rice combine harvesters. Results of the study indicated that, for Khao Dok Mali 105 variety, harvesting losses were affected by cleaning air velocity, sieve inclination, and height of the barrier plate at 38.4%, 28.1%, and 15.8 %, respectively. On the other hand, for Chainat 1 variety, the air velocity, the height of the barrier plate, and the sieve inclination affected the losses at 46.2%, 33.5%, and 13.7 %, respectively. Effects of Grain moisture content, grain feed rate, sieve speed, and sieve length on the losses were insignificant for both varieties.

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อ ศึกษาปัจจัยการทำงานของชุดทำความสะอาดของเครื่องเกี่ยวนวดข้าวที่มีผลต่อความสูญเสียจากการเก็บเกี่ยว ผลการศึกษาพบว่า สำหรับข้าวพันธุ์ขาวดอกมะลิ 105 ความเร็วลมทำความสะอาด มุมเอียงของตะแกรง และความสูงแผ่นกั้นท้าย มีผลต่อความสูญเสียเท่ากับ 38.4 28.1 และ 15.8 เปอร์เซ็นต์ ตามลำดับ ส่วนข้าวพันธุ์ชัยนาท 1 ความเร็วลมทำความสะอาด ความสูงแผ่นกั้นท้าย และมุมเอียงของตะแกรง มีผลต่อความสูญเสียเท่ากับ 46.2 33.5 และ 13.7 เปอร์เซ็นต์ ตามลำดับ ส่วนปัจจัยด้านความชื้นของเมล็ด อัตราการป้อนเมล็ด ความเร็วรอบของตะแกรง และความยาวของตะแกรง มีผลค่อนข้างน้อยต่อความสูญเสียสำหรับข้าวทั้งสองพันธุ์

Keywords: Rice Combine Harvester, Cleaning Unit, Operating Factors

[1] *Lecturer, Department of Agricultural Engineering Khon Kaen University*
[2] *Assoc Prof, Department of Agricultural Engineering Khon Kaen University*
[*] *Corresponding author, e-mail: somchai.chuan@gmail.com*

Introduction

Rice harvesting is one of the most important processes influencing the quality and quantity in rice production. Considering a tremendous amount of rice production in Thailand, harvesting losses could cause severe damages to the country's economy in both quantity and amount. Currently, rice combine harvesters are becoming widely used, thus playing a vital role in Thailand's rice harvesting.

According to the Assessment of the Off-Season Rice Harvesting Losses in Rice Combine Harvesters by Chinsuwan et al. (2002), the results showed that up to 85% or 5.36% of the harvesting losses were mainly caused during the screening and cleaning process, whereas very small losses occurred during harvesting and threshing process. The losses results were different when using rice combine harvesters with Thai Hom Mali rice, which the harvesting losses were mainly caused during the harvesting process, at approximately 3.43%. The losses from screening and cleaning process ranked lower at 1.37% on average, followed by those from threshing process at 0.0062% (Chinsuwan et al., 1999). This is due to the fact that Thai Hom Mali rice variety is a local variety that has seeds which fall easily when ripe, thus the losses occur during harvesting more than during screening and cleaning. On the contrary, the off-season rice or rice sensitivity photoperiod variety have seeds which do not fall easily and are harder to thresh compared to the local varieties. Therefore, it can be assumed that the major losses in rice combine harvesters occur in the threshing unit during screening process and occur in the cleaning unit during cleaning process.

The harvesting losses during cleaning occur when there are paddy rice seeds screened out from the cleaning unit, which is meant to screen only dusts, leant rice, flower grass and straws. This is majorly because there is high variation in the machine's function, due to plant conditions, machine application and modification. The main components in the cleaning unit are the sieve and the fan. Chinsuwan et al. (2003a) have studied operating factors influencing the cleaning unit, at farmer level, tested on the Khao Dok Mali 105 rice at low moisture content of 12% wet basis. Double sieve were used in the experiment: the top sieve with circular holes of 10 millimeters in diameter and the bottom sieve with a size of 4 x 16 millimeters. The study indicated that the appropriate sieve inclination should be between 3 to 5 degree from horizontal, the sieve speed should range from 62 to 70 meter/minute, and the cleaning air velocity should be between 450 to 500 meter/ minute with the feed rate of 5 tons/hour/ 1 meter of sieve width. Moreover, the study of a cleaning unit in the rice combine harvesters, by Chinsuwan et al. (2003b), on Chainat 1 rice variety with moisture content of 27.72% wet basis, suggested that the appropriate sieve inclination should be in the range of 8 to 11 degree and the sieve speed should be between 0.50 to 0.66 meter/second.

Provided that the number of rice combine harvesters used is currently increasing, so is the amount of rice produced in Thailand, the reduction of harvesting losses in the cleaning unit would be a great benefit to the industry. Nevertheless, there are only a few studies focusing on the many factors influencing the operation of cleaning units of rice combine harvesters. Studying these factors, therefore, would provide useful guidelines in determining critical factors influencing harvesting losses, and can be great foundations for further studies to be conducted on each factors.

Equipments & Methodology

Since there are several factors influencing the operation of the cleaning unit, it would be rather costly to use typical experimental methods because an extremely large field would be required. Additionally, the preparation of samples must be done prior to the experimental date in order to maintain their original conditions, and rice combine harvesters used in Thailand also have cleaning units with various functional levels. With these limitations and the nature of machine usage, the experiment was set to be randomized, where rice combine harvesters were randomly tested for various influential factors. The total of 16 rice combine harvesters, in the Thung Kula Rong-Hai area, were tested with Khao Dok Mali 105 rice variety. And the total of 16 rice combine harvesters, in the Khon Kaen and Kalasin Provincial Irrigation area, were tested with Chainat 1 rice variety. Factors, including moisture content, feed rate, sieve speed, sieve length, sieve inclination, cleaning air velocity, and height of the barrier plate, were set and measured during the actual machine operation. The harvesting losses caused by the cleaning unit were used as an indicator, whereas the cleanliness percentage was not. This is because this study focused only on the factors influencing the operational function of the machine for further study usage. Therefore, rice conditions as well as types and quantity of weeds grown in the field might vary, affecting the cleanliness of the rice produced.

Under the actual machine operation, the harvesting losses in the cleaning unit were tested by using a net to catch the debris released from cleaning unit (Figure 1). Other materials were screened out, leaving only rice grains. This procedure was done in 3 replications; each replication required the rice combine harvester to run in the distance of at least 15 meters. To ensure steady operating condition, the data was collected after 10 meters.

Figure 1. Data Collection of Harvesting Losses of Cleaning Unit

The collected data was then used to create a regression equation, shown in Eq. 1, then each factor was analyzed in percentage. The analysis was done by determining the difference between R2 of regression equation containing all factors and regression equation containing focused factors. This method is known as the Best Subset Regression (Draper and Smith, 1998)

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots + B_nX_n \quad (1)$$

Where: Y = dependant variable

$X_1, X_2, \ldots, X_n$ = any independent variables

$B_0, B_1, \ldots, B_n$ = any constants

Results & Comments

The operating conditions, which influenced harvesting losses in the cleaning unit, of the 16 rice combine harvesters were tested with Khao Dok Mali 105 rice variety, and another 16 with Chainat 1 rice variety. The observed rice conditions were straw moisture, height of crop plant, height of stubble, rice density, and total productivity, as shown in Table 1 and Table 2, respectively.

Table 1. Conditions of Rice Combine Harvesters for Harvesting Khao Dok Mali 105 Rice Variety

No.	Straw MC (% wb)	Height of crop plant (cm)	Height of stubble (cm)	Rice density (no./rai)	Total yield (kg/rai)
1	61.59	88.5	35.5	477,600	251
2	64.08	79.6	34.6	343,200	166
3	66.23	101.7	35.0	511,200	535
4	65.73	105.7	45.5	402,933	212
5	63.74	96.7	40.1	431,200	367
6	64.93	111.5	46.8	329,600	294
7	59.93	86.5	27.1	426,133	359
8	61.74	90.1	40.0	322,933	371
9	66.66	91.8	37.5	370,667	254
10	63.53	83.9	24.1	656,267	499
11	63.14	91.9	36.3	291,733	280
12	63.83	83.9	33.9	578,400	375
13	60.51	86.8	34.1	165,867	200
14	64.48	81.6	32.0	171,467	314
15	58.50	88.6	34.3	489,867	466

Table 2. Conditions of Rice Combine Harvesters for Harvesting Khao Chainat 1 Rice Variety

No.	Straw MC (% wb)	Height of crop plant (cm)	Height of stubble (cm)	Rice density (no./rai)	Total yield (kg/rai)
1	64.39	73.2	39.8	620,000	847
2	63.74	70.4	26.8	972,267	832
3	61.32	65.9	24.7	869,333	893
4	61.35	66.5	30.0	1,099,467	906
5	69.85	73.2	25.6	705,067	754
6	63.66	70.7	25.3	833,333	692
7	65.52	69.9	32.2	808,533	874
8	65.75	64.6	23.3	627,200	820
9	65.54	66.1	31.7	821,867	980
10	66.62	71.2	38.8	645,333	951
11	64.44	71.0	33.1	762,667	1,048
12	61.09	77.3	34.5	1,099,200	884
13	61.98	75.0	25.4	873,067	772
14	58.13	78.5	38.3	689,333	719
15	63.08	65.0	20.8	388,800	517
16	61.12	79.0	35.6	708,267	842

The experimental results measuring key operating factors affecting harvesting losses of cleaning unit, i.e. grain moisture, feed rate, sieve speed, sieve length, sieve inclination, cleaning air velocity, height of the barrier plate, and harvesting losses of cleaning unit for Khao Dok Mali 105 rice variety and Chainat 1 rice variety, are shown in Table 3 and Table 4, respectively.

Table 3. Key Operating Factors and Cleanliness of Cleaning Unit from Harvesting Khao Dok Mali 105 Rice Variety

No.	Grain MC (% wb)	Grain feed rate (T/hr)	cleaning sieve			cleaning air velosity (m/s)	Height of the barrier plate (mm)	cleaning loss (%)
			Speed (rpm)	Length (mm)	Angle (Degree)*			
1	25.91	1.86	369	737	10	5.60	230	0.69
2	24.94	1.44	364	711	7	3.48	250	0.28
3	23.18	2.92	334	686	6	4.23	370	0.08
4	23.45	1.82	326	762	7	3.98	250	0.09
5	22.96	4.38	432	762	10	4.60	350	0.27
6	22.20	3.44	399	635	5	4.60	250	0.29
7	18.21	3.49	354	838	10	6.63	320	0.72
8	23.45	3.67	311	762	5	4.23	340	0.06
9	24.61	2.54	445	762	8	5.60	180	0.12
10	25.82	4.26	371	711	10	4.57	241	0.38
11	24.86	2.09	435	762	5	6.27	260	0.62
12	22.84	3.06	338	711	10	4.03	240	0.47
13	21.00	2.58	382	711	10	6.27	241	0.26
14	25.62	2.42	306	762	10	6.43	340	0.34
15	21.47	4.60	381	762	10	5.03	240	0.49
16	22.49	5.19	407	762	10	6.48	340	0.24

** degree from horizontal*

Table 4. Key Operating Factors and Cleanliness of Cleaning Unit from Harvesting Chainat 1 Rice Variety

No.	Grain MC (% wb)	Grain feed rate (T/hr)	cleaning sieve			cleaning air velosity (m/s)	Height of the barrier plate (mm)	cleaning loss (%)
			Speed (rpm)	Length (mm)	Angle (Degree)*			
1	24.37	8.3	394	813	10	5.64	270	0.51
2	22.58	5.8	393	686	10	4.45	340	0.41
3	29.36	5.9	386	813	10	5.32	240	0.58
4	25.65	9.1	403	737	7	4.88	230	0.28
5	29.72	4.0	298	864	5	4.92	340	0.04
6	25.19	4.9	353	711	10	4.88	260	0.09
7	26.14	8.7	432	737	10	4.43	210	0.13
8	24.25	5.5	450	787	8.5	5.14	250	0.40
9	23.63	8.9	373	737	7	4.78	220	0.25
10	26.96	9.9	404	610	10	4.82	279	0.27
11	21.91	11.1	406	737	10	5.92	241	0.26
12	22.90	4.8	460	660	12	5.26	340	0.12
13	21.31	6.3	393	737	10	4.32	340	0.08
14	23.75	6.6	440	787	11	4.46	360	0.04
15	22.23	3.6	523	686	6	4.82	370	0.19
16	22.03	7.9	330	737	12	4.96	260	0.45

** degree from horizontal*

From Table 3, a correlation regression equation for Khao Dok Mali 105 rice variety can be derived as shown in Eq. 2.

$$CL = -0.0186 - 0.0103MC - 0.0271FR + 4.371\times10^{-5}SS + 4.648\times10^{-4}SL + 0.0255SI + 0.6245AV - 7.67\times10^{-4}HF \quad (2)$$

$R^2 = 0.329$

Eq. 3 represents a correlation regression equation for Chainat 1 rice variety.

$$CL = -0.275 - 1.16\times10^{-3}MC - 8.92\times10^{-3}FR + 7.997\times10^{-5}SS + 1.916\times10^{-4}SL + 0.01541SI + 0.13AV - 1.19\times10^{-3}HF \quad (3)$$

$R^2 = 0.321$

Where: CL = Losses from cleaning process (%)

MC = Moisture Content (% Wet Basis)

FR = Feed Rate (ton/hour)

SS = Sieve Speed (revolution/minute)

SL = Sieve Length (millimeter)

SI = Sieve Inclination (degree)

AV = Cleaning Air Velocity (meter/second)
HF = Height of the Barrier Plate (millimeter)

From the correlation equations of both Khao Dok Mali 105 and Chainat 1 rice variety, it can be observed that as moisture content increased, the harvesting losses tended to decrease. Since the increase in moisture content caused more grain density, or, in other words, causing the grains to be heavier and do not flow with the cleaning air, unlike grains with low moisture content. As for the feed rate, higher feed rate tended to decrease harvesting losses. This could be because higher feed rate could make the sieve overload, causing grains to expand the mesh size which consequently allowed less amount of cleaning air and less harvesting losses. On the contrary, higher sieve speed tended to increase harvesting losses because high sieve speed allowed less grain through the mesh and caused grains to float. The higher the speed, the more the grains float. In addition to high sieve speed, the cleaning air also helped grains to float along with other debris. When the sieve length increased harvesting losses of cleaning unit increased as well, since the screening mainly occurred at the beginning of the sieve and decreased along its length. It is easier for a small amount of grains to flow with the cleaning air. In the meantime, large amount of grains cause the sieve to be overload and excessive grains would fall into auger to be threshed again, which does not count as losses. The increased sieve inclination resulted in harvesting losses increase. This is because of the sieve moved in a shaking motion causing the grains to flow over the sieve with higher degree of inclination. Naturally, with cleaning air blowing, more grains flying over the sieve means more harvesting losses. As for the cleaning air velocity, an increase in the cleaning air velocity tended to increase the harvesting losses of cleaning unit, because the blowing air consequently carried more grains with the debris (Streicher et al., 1986). On the other hand, the higher the barrier plate, the lower the harvesting losses of cleaning unit. This is due to the fact that high barrier plate could better block grains to flow over, thus they instead fall into the auger to be re-threshed. Although the auger might have to work harder, the harvesting losses decreased. According to the analysis of operating factors affecting harvesting losses of cleaning unit for both Khao Dok Mali 105 and Chainat 1 rice variety, the factors can be divided into 2 groups: the high influence group and the low influence groups. The factor with highest influence for Khao Dok Mali 105 rice variety was cleaning air velocity, 38.4%, followed by sieve inclination and height of the barrier plate, 28.1% and 15.8%, respectively. The low influence factors were feed rate, moisture content, sieve length, and sieve speed, with harvesting losses of 6.8%, 5.5%, 4.8%, and 0.7%, respectively, as shown in Table 5.

Table 5. The Percentage Analysis of Factors Affecting Harvesting Losses of Cleaning Unit for Khao Dok Mali 105 Rice Variety

Analyzed Factors	R^2 of Equation with Analyzed Factors	Differences of R^2 between Eq.2 & Equation with Analyzed Factors	Affects of Factors on Harvesting Losses of Cleaning Unit (%)
Grain Moisture Content	0.321	0.008	5.5
Feed Rate	0.319	0.01	6.8
Sieve Speed	0.328	0.001	0.7
Sieve Length	0.322	0.007	4.8
Sieve Inclination	0.288	0.041	28.1
Cleaning Air Velocity	0.273	0.056	38.4
Height of the Barrier Plate	0.306	0.023	15.8
TOTAL		0.146	100.00

The factor with highest influence on harvesting losses for Chainat 1 rice variety was cleaning air velocity, 46.2%, while the second highest influence was from the height of the barrier plate and sieve inclination at 33.5% and 13.7%, respectively. Feed rate, sieve length, sieve speed, and moisture content were low influence factors, with 3.6%, 1.5%, 1.0%, and 0.5% influence, respectively, as shown in Table 6.

Table 6. The Percentage Analysis of Factors Affecting Harvesting Losses of Cleaning Unit for Chainat 1 Rice Variety

Analyzed Factors	R^2 of Equation with Analyzed Factors	Differences of R^2 between Eq.2 & Equation with Analyzed Factors	Affects of Factors on Harvesting Losses of Cleaning Unit (%)
Grain Moisture Content	0.32	0.001	0.5
Feed Rate	0.314	0.007	3.6
Sieve Speed	0.319	0.002	1.0
Sieve Length	0.318	0.003	1.5
Sieve Inclination	0.294	0.027	13.7
Cleaning Air Velocity	0.23	0.091	46.2
Height of the Barrier Plate	0.255	0.066	33.5
TOTAL		0.197	100.00

For both Khao Dok Mali 105 and Chainat 1 rice variety, factors including cleaning air velocity, height of the barrier plate, and sieve inclination were highly affecting harvesting losses. On the contrary, factors such as feed rate, sieve length, sieve speed, and moisture content had little influences on harvesting losses. As a result, it is highly recommended that there be study on cleaning air velocity, height of the barrier plate, and sieve inclination in further details.

The analysis indicated that cleaning air velocity, height of the barrier plate, and sieve inclination were factors affecting harvesting losses for both rice varieties. Therefore, this study suggested that the cleaning air velocity not exceed 5 meter/second and the height of the barrier plate not lower than 300 millimeters, while the sieve inclination not exceed 5 degree. The rest of the factors, including moisture content, feed rate, sieve speed and length, insignificantly influenced harvesting losses of cleaning unit. Therefore, these factors can be set at ordinary levels depending on typical operating conditions of rice combine harvesters in Thailand.

Conclusions

The factors affecting harvesting losses of the cleaning unit can be divided into 2 groups: the high influence group and the low influence groups. The factors with high influences are cleaning air velocity, height of the barrier plate, and sieve inclination. The grain moisture, feed rate, sieve speed, and sieve length are factors with little influences on harvesting losses.

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