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Operational Efficiency of Combine Harvesters on Different Field Size in the Selected Area of Bangladesh

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ABSTRACT

The length and width of the rice field play a crucial role in the performance of the combine harvester. Effect of field size (length of the field) on field performance of head feed (Kubota PRO588I-G and Yanmar AG600A) and whole feed (Yanmar YH700 and FM World WM 4LZ-4.0EA) combine harvesters were assessed in both irrigated dry season 2021-22 and non-irrigated wet season 2022 in two different regions of Bangladesh. Five levels of field length, i.e. ≤30m (L1), 30-40m (L2), 41-50m (L3), 51-60m (L4), and 61-70m (L5), were chosen to investigate forward speed, theoretical field capacity, effective field capacity, and field efficiency. The results revealed that all the performance parameters increased significantly with the increase of field length for all types of combine harvesters in both seasons. In the irrigated dry season, forward speed varied from 1.4 to 3.4 and 4.0 to 6.7 km/h of the head feed and whole feed combine harvester respectively with the field length L1 to L5, whereas significantly higher forward speed was observed for whole feed combine harvesters. On contrary, the field efficiency varied from 20 to 64 and 23 to 65% of the head feed and whole feed combine harvesters respectively with the field length L1 to L5. In the non-irrigated wet season, forward speed varied from 3.1 to 4.5 and 3.7 to 4.8 km/h of the head feed and whole feed combine harvesters respectively with the field length L1 to L5. Contrary, the field efficiency varied from 40 to 80 and 38 to 76% of the head feed and whole feed combine harvesters respectively with the field length L1 to L5. The field length for the studied combine harvester should not be less than 41-50 m to obtain more than 50% field efficiency of the machine in both the irrigated dry and non-irrigated wet season in Bangladesh.

Key words: Combine harvester, forward speed, actual field capacity, field efficiency, rice harvest

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INTRODUCTION

Bangladesh's rice sector has made significant progress in mechanization as a result of several governmental and non-governmental activities over the past few years, specially focused on paddy harvesting. The upshot was that Bangladesh's agricultural economy became one of South Asia's most mechanized (Islam and Shirazul, 2009 and Baudron *et al.,* 2015). Harvesting nourmally accounts for 24.9% of the total labor requirement for rice cultivation, which is more than other rice production activities. Total labour requirement of rice production in Bangladesh is about 149 man-hr/ha (Ali et al., 2019). In 2016, mechanized harvesting of paddy made up about 2% (MoA, 2016); today, it makes up 18% (Hossen, 2023). The Bangladesh government is implementing a project of Taka 30.2 billion entitle "Farm Mechanization through Integrated Management" to distribute 51,300 units of agro-machinery (combine harvester: 15,000 units) from 12 categories during 2020-2025 giving special importance on paddy harvesting and transplanting through the Department of Agricultural Extension (Financial Express, 2022). A total of 7,256 combine harvester already distributed to farmers under the above project (Bangladesh Post, 2023). Hence, combine harvesters are becoming more and more popular as an alternative to the traditional methods of harvesting and threshing of rice. Both head feed and whole feed combine harvesters are available in Bangladesh with different size and specifications. Medium to large type combine harvester, horse power rages 50-120, is importing under this project (Financial Express, 2022) while the average farm size in the country has decreased to less than 0.6 hectare, and 58 percent of people lack access to land (Financial Express, 2021). Normally large field are pre-requisite for efficient operation of the combine harvester. Other factors such as field size and shape, soil condition, crop condition, load bearing capacity of soil., etc. influence the field performance of the both head feed and whole feed combine harvester (Islam *et al.,*2020*)*. This study has been conducted to identify the effect of field size on the performance of the both head feed and whole feed combine harvesters available in Bangladesh that will help the policy maker to estimate the suitable rice area and number of combine harvester required for sustainable mechanization. In addition, it would help the users to operate the combine harvester in profitable way

MATERIALS AND METHODS

This study has been conducted at Sadar Upazila of Habiganj district (24.351263 N, 91.424143 E) and Raiganj upazial of Sirajganj districts (24.5295° N, 89.5452° E) of Bangladesh during the irrigated dry season (Boro season) of 2021-22 and non-irrigated wet season (Aman season) in 2022 (Fig. 1). Both the head feed and whole feed combine harvesters were studied. Kubota PRO588I-G (Head feed) and Yanmar YH700 (Whole feed), two popular models available in the study areas, were used in Boro season, 2021-22 while FM World WM 4LZ-4.0EA (Whole feed) and Yanmar AG600A (Head feed) model combine harvesters were used in Aman 2022 season.

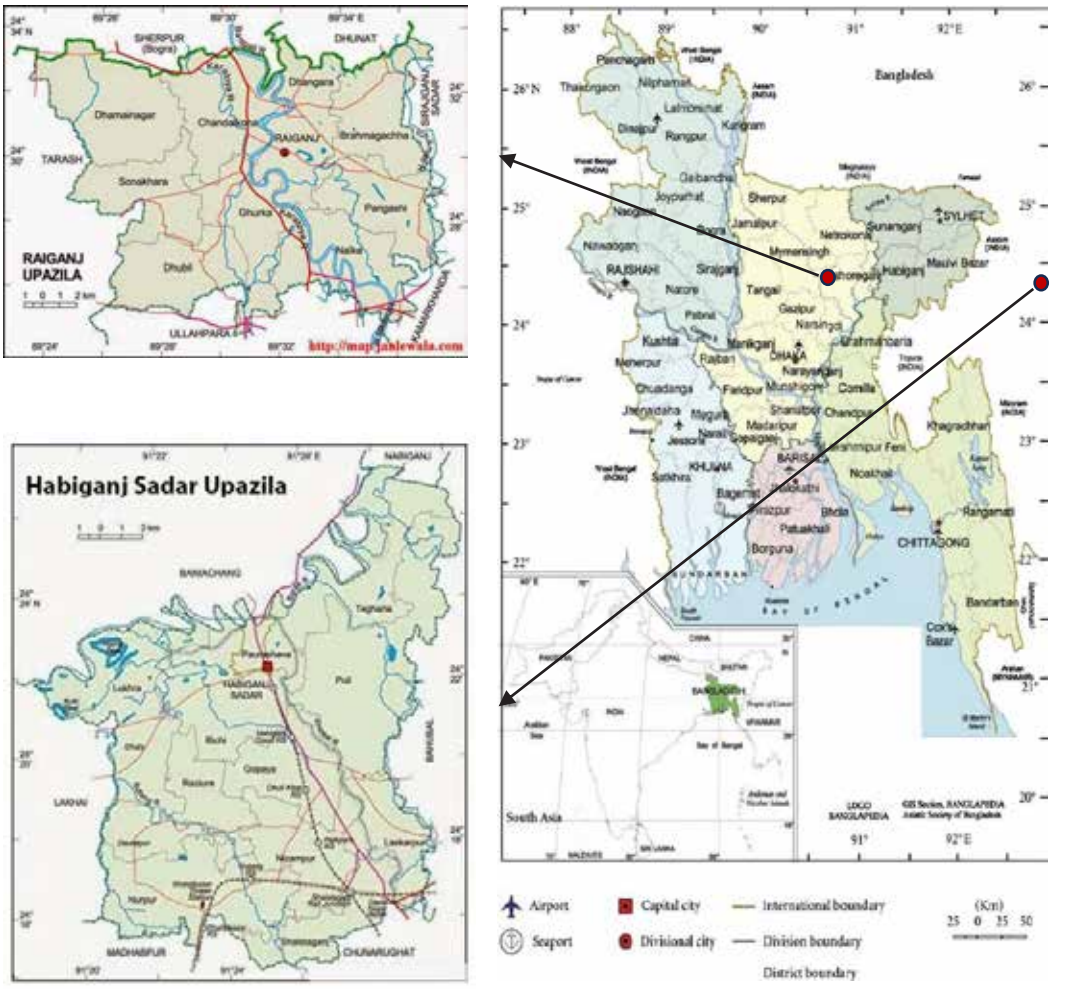


Fig. 1. Location of the study.

Experimental design

This study has been conducted in two different locations of the country and two different seasons (Table 1). Both the head feed and whole feed type combine harvesters used to determine the effect of field length on the performance of the machine. Hard soil layer of the field in the respective locations was almost same, which was measured manually during machine operation (Table 1). Soil type and field conditions during machine operations are presented in the Table 1.

Table 1. Experimental design and field conditions.

Season	Location	Model	Area (ha)	Length of the field (m)	Width of the field (m)	Depth of hard soil layer (mm)	Soil type	Field status during operation
Boro, 2021-22	Sirajganj	Kubota PRO588I-G	0.3515	62	57	2.5	Sandy	wet and 10.5 mm standing water
		Yanmar YH700	0.2015	63	32	2.7	Sandy	wet and 10.75 mm standing water
	Habiganj	Kubota PRO588I-G	0.224	65	34	38.1	Sandy loam	wet and 11.5 mm standing water
		Yanmar YH700	0.4905	75	65	38.5	Sandy loam	wet and 12.0 mm standing water
Aman, 2022	Sirajganj	Yanmar AG600A	0.456	70	65	17.1	Sandy	dry
		FM World Ruilong	0.452	71	64	18.5	Sandy	dry
	Habiganj	Yanmar AG600A	0.454	73	62	24.0	Sandy loam	dry
		FM World Ruilong	0.426	67	64	23.5	Sandy loam	dry

Note: Three trials were conducted in each site of the respective model of combine harvester.

Crop condition and yield

In Boro 2021-22 season, BRRI dhan89 and BRRI dhan29 were harvested in the locations of Sirajgaj and Habiganj while BRRI dhan49 and BRRI dhan75 were harvested in Aman 2022 season (Table 2). Prior to operation, plant height, grain moisture content, grain yield, grain maturity during harvesting, and cutting height from the ground after harvesting of the crops were measured (Table 2).

Table 2. Crops attributes and yield of the experimental field.

Season	Location	Paddy variety	Plant height (mm)	Grain moisture content (%)	Grain maturity during harvesting (%)	Cutting height from the ground (mm)	Grain yield (t/ha) at 14% MC
Boro 2021-22	Sirajganj	BRRI dhan89	1163	24.61	85	196.2	7.15
		BRRI dhan89	1194	25.66	85	345	7.34
	Habiganj	BRRI dhan29	932	26.84	90	195.5	6.34
		BRRI dhan29	951	27.69	90	348	6.31
Aman, 2022	Sirajganj	BRRI dhan49	1146	23.06	90	75	5.47
		BRRI dhan49	1122	22.79	90	250	4.82
	Habiganj	BRRI dhan75	1032	22.13	85	75	6.14
		BRRI dhan75	1038	22.29	85	250	5.39

Physical parameters of the combine harvester

Prior to field study, dimensions, load bearing capacity, and cutting width were measured; nevertheless, general data of each model of the combine harvesters and engine were also recorded from the manufacturers' specification (Table 3).

Field performance test

Field performance of the studied combine harvesters was tested in two different locations during the Boro 2021-22 and Aman 2022 season. Field performance was determined using various field lengths ≤30m, 31-40m, 41-50m, 51-60m, and 61-70m. In each case, the main length of the field was divided into the appropriate length type for the investigation. The lengthwise time per pass, without accounting for turning or any other losses, was measured in order to determine the theoretical field capacity of the machine as well as its forward speed. Total operational time and total area were measured to calculate the effective field capacity for different field length. The machine's field efficiency in the specified type of field was calculated using both the actual and theoretical field capacity.

Forward speed was determined by dividing the distance by the time needed to run the machine over that distance. The forward speed of combine harvester is determined using the following equation (Hunt,1995).

$$S=\frac{D}{T}\times 3.6$$

Where,

S= Forward speed of the machine, km/hr

D= Distance covered by the combine harvester, m

T= Time required to cover that distance, sec

Table 3. Physical parameters of the studied combine harvesters

Item	Model			
	Kubota PRO588I-G	Yanmar YH700	Yanmar AG600A	WM 4LZ-4.0EA
1. General Information				
1.1: Brand	Kubota	YANMAR	YANMAR	FM WORLD
1.2: Country of Manufacturer	China	China	China	CHINA
1.3: Country of origin	Japan	Japan	Japan	CHINA
1.4: Types	Head Feed	Whole Feed	Head Feed	Whole Feed
2. Dimensions				
2.1: Overall length × width × height (mm)	4240×1900×2800	5070×2285×2820	2990×1940×2410	49600×2890×2700
3. Engine				
3.1: Overall weight (kg)	2705	3571	3117	3200
3,2: Displacement (CC)	2434	3318	3318	3300
3.3: Engine power (kW)	49.2	51.5	47.59	65.65
3.4: Fuel tank capacity (l)	50	115	67	150
3.5: Oil tank Capacity (L)	9.1	9.4	9.4	9.0
4. Machine and travelling				
4.1: Grain tank Capacity (kg)	600	1500	1000	1200
4.2: Steering	HST	HST	HST	HST
4.3: Gearshift	Manual (3 steps)	Manual (3 steps)	Manual (3 steps)	Manual (3 steps)
4.4: Forward speeds	0 to 2.05 max	0 to 3.00 max	0 to 1.65 max	0 to 2.56 max
4.5: Reverse speeds	0 to 2.05 max	0 to 3.00 max	0 to 1.65 max	0 to 2.56 max
4.6: Driving wheel/crawler	Crawler type	Crawler type	Crawler type	Crawler type
Track width (mm)	450	500	450	500
Traction area (mm^2)	675000	1750000	675000	2060000
Load per unit area (kg/mm^2) in unload condition	0.00200	0.00204	0.00241	0.00155
5. Reaping				
5.1: Reaping mechanism	Reciprocating blade type	Reciprocating	Reciprocating	Reciprocating
5.2: Cutter bar				
Effective width (m)	1.5	2.0	1.5	2.2

Note: All studied models are tank type.

The actual average rate of harvester coverage, depending on the total time of operation, is known as the actual field capacity. The actual field capacity was calculated by dividing the area covered by the entire time according to the (Hunt,1995):

$$AFC = \frac{A}{T}$$

Where,

AFC= Actual field capacity, ha/h

A= Total covered area, ha

T= Total time of operation, h

Theoretical field capacity is the rate of field coverage of an implement that would be obtained if the machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its width. It is also determined according to the (Hunt,1995):

$$TFC = \frac{W \times S}{C}$$

Where,

TFC= Theoretical field capacity, ha/hr

W= Cutting width of machine, m

S= Forward speed, km/h

C= Constant (Its value is 10)

Field efficiency is the ratio of effective field capacity and theoretical field capacity, expressed in percentages (Hunt,1995):

$$Ef = \frac{AFC}{TFC} \times 100\%$$

Where,

Ef= Field efficiency, %

AFC= Actual field capacity

TFC= Theoretical field capacity

Analysis

Data were analyzed as a single way factorial design (field length) according to Gomez and Gomez (Gomez and Gomez *et al.,*1984) using Statistix 10 programme (Statistix 10 software, 2013). Means were compared with the least significant difference (LSD) at which level of significant percentage test using Statistix 10 programme (Statistix 10 software, 2013).

RESULTS AND DISCUSSIONS

Field performance of the combine harvesters in Boro 2021-22 season

*Head feed combine harvester (*Kubota PRO588I-G*)*

The longer the field, the higher the forward speed, theoretical field capacity, practical field capacity, and field efficiency of the head feed combine harvester. Field efficiency for the head feed combine harvester was found to be 67.1 and 60.90% under the field length 61-70m in Sirajganj and Habiganj respectively, whereas field length ≤30m had the lowest field efficiency. Depending on the various field's length, forward speed and the effective field capacity in Sirajganj and Habiganj, which were varied significantly, ranged from 1.54 to 3.25 km/h and 1.3 to 3.56 km/h and 0.04 to 0.33 ha/h and 0.04 to 0.34 ha/h, respectively. Field efficiency did not vary significantly between the field lengths 51-60 and 61-70m in both the locations (Table 4). Traditional and medium-sized combine harvesters should operate at a forward speed between 3 and 6.5 km/h to work well when using a self-propelled combine (ASAE, 2009).

Table. 4. Field performance of the head feed combine (Kubota PRO588I-G**) harvester in the Boro, 2021-22 season.**

Field length type	Length, (m)	Total area (ha)	Forward speed, S (km/h)	Total operating time (h)	Effective field capacity (ha/h)	Theoretical field capacity (ha/h)	Field Efficiency (%)
Sirajganj							
L1	26	0.04	1.54	0.98	0.04	0.23	17.7
L2	39	0.10	1.82	0.98	0.10	0.27	37.4
L3	45	0.06	2.64	0.28	0.21	0.40	54.1
L4	52	0.09	2.93	0.33	0.27	0.44	62.1
L5	62	0.17	3.25	0.52	0.33	0.49	67.1
$LSD_{0.05}$	-	-	0.118	-	0.013	0.032	5.93
CV%	-	-	3.35	-	3.57	4.59	6.72
Habiganj							
L1	22	0.04	1.30	0.90	0.04	0.20	22.8
L2	32	0.07	1.61	0.85	0.08	0.24	34.1
L3	48	0.07	2.28	0.30	0.23	0.34	52.2
L4	56	0.07	2.98	0.35	0.20	0.45	58.5
L5	63	0.13	3.56	0.40	0.34	0.53	60.9
$LSD_{0.05}$	-	-	0.042	-	0.028	0.011	8.29
CV%	-	-	2.95	-	8.43	3.56	9.67

*Whole feed combine harvester (*Yanmar YH700*)*

The forward speed, theoretical field capacity, effective field capacity, and field efficiency of the whole feed combine harvester also increased significantly with the increase of the field length. In Sirajganj and Habiganj, field length 61-70m <30m determined to have the significantly higher field efficiency 62.6 and 68.1% for the whole feed combine harvester, whereas field length <30m had significantly lower field efficiency. The effective field capacity in Sirajganj and Habiganj varied significantly depending on the length of the different fields and was 0.25 to 0.87 ha/h and 0.13 to 0.87 ha/h, respectively (Table 5). Average harvesting speed and actual field capacity of the whole feed combine harvester (Zoomlion: 4LZT-4.0ZD) during Boro season in Haor region of Bangladesh were found 1.23 - 3.20 km/h and 0.15 ha/h (Islam, 2020). He also suggested to avoid the field sizes less than 800 m^2 for the Zoomlion combine harvester.

Table. 5. Field performance of the whole feed combine (Yanmar YH700**) harvester in the Boro 2021-22 season.**

Length type	Length (m)	Total area (ha)	Forward speed, S (km/h)	Total operating time (h)	Effective field capacity (ha/h)	Theoretical field capacity (ha/h)	Field Efficiency (%)
Sirajganj							
L1	28	0.02	4.32	0.08	0.25	0.86	28.9
L2	40	0.03	5.92	0.08	0.38	1.18	31.7
L3	50	0.08	6.43	0.12	0.67	1.29	51.8
L4	60	0.19	6.48	0.23	0.83	1.30	63.7
L5	65	0.20	6.95	0.23	0.87	1.39	62.6
$LSD_{0.05}$			0.1031		0.0794	0.1031	5.7447
% of cv			0.91		7.43	4.55	6.76
Habiganj							
L1	22	0.01	3.77	0.08	0.13	0.75	16.6
L2	38	0.03	5.20	0.08	0.38	1.04	36.1
L3	48	0.07	5.64	0.12	0.58	1.13	51.7
L4	55	0.17	5.71	0.23	0.74	1.14	64.7
L5	65	0.20	6.38	0.23	0.87	1.28	68.1
$LSD_{0.05}$			0.10		0.028	0.08	5.06
% of cv			1.03		2.76	4.16	5.64

Field performance of the combine harvesters in Aman 2022 season

*Head feed combine harvester (*Yanmar AG600A*)*

Field efficiency for the head feed combine harvester in Aman season was found to be 82.6 and 77.2% under the field length 61-70m in Sirajganj and Habiganj, respectively, whereas field length <30m had the significantly lowest field efficiency. Depending on the various field's length, the effective field capacity in Sirajganj and Habiganj, which were varied significantly, ranged from 0.192 to 0.52 ha/h and 0.19 to 0.51 ha/h while forward speed ranges from 2.98 to 4.3 km/h and 3.2 to 4.61 km/h, respectively (Table 6). Forward speed and effective field capacity of the head feed combine harvester (DR 150 A) were found 6.71 km/h and 0.33 ha/h, respectively in Amna season (Hasan *et al.,* 2019).

Table 6. Field performance of the head feed combine harvester (Yanmar AG600A**) in the Aman 2022 season.**

Length type	Length (m)	Total area (ha)	Forward speed (km/h)	Total operating time (h)	Effective field capacity (ha/h)	Effective cutting width, (m)	Theoretical field capacity (ha/h)	Field efficiency (%)
Sirajganj								
L1	24	0.05	2.979	0.250	0.19	1.5	0.45	44.8
L2	38	0.04	3.600	0.183	0.24	1.5	0.54	40.5
L3	42	0.09	3.844	0.217	0.39	1.5	0.58	71.9
L4	58	0.12	3.990	0.267	0.44	1.5	0.60	75.1
L5	65	0.08	4.307	0.150	0.52	1.5	0.65	82.6
$LSD_{0.05}$			0.1031		0.0827		0.0461	10.988
CV%			3.46		9.55		3.39	11.95
Habiganj								
L1	17	0.03	3.166	0.183	0.19	1.5	0.47	34.5
L2	32	0.06	3.388	0.267	0.24	1.5	0.51	44.2
L3	45	0.05	3.951	0.183	0.29	1.5	0.59	46.1
L4	55	0.11	4.097	0.267	0.42	1.5	0.61	67.0
L5	64	0.08	4.608	0.150	0.51	1.5	0.69	77.2
$LSD_{0.05}$			0.2455		0.0267		0.0322	7.6636
CV%			3.39		3.25		2.28	3.51

*Whole feed combine harvester (*FM World Ruilong*)*

Field efficiency for the whole feed combine harvester in Aman season was found to be 74.1 and 77.3% under the field length 61-70m in Sirajganj and Habiganj, respectively, whereas field length <30m had the significantly lowest field efficiency. Depending on the various field's length, the effective field capacity in Sirajganj and Habiganj, which are varied significantly, ranged from 0.32 to 0.90 ha/h and 0.29 to 0.70 ha/h respectively (Table 7). Forward speed, effective field capacity and field efficiency of the whole feed combine harvesters (new holland: CLAYSON 8080 and world star combine: WS7.0 PLUS) in large area were calculated 3.24 versus 4.10 km/h, 0.69 versus 0.53 ha/h and 64.3% versus 72.1% by (Suha Elsoragaby *et al.,* 2019.

Table. 7. Field performance of the whole feed combine harvester (FM World Ruilong**) in the Aman, 2022 season.**

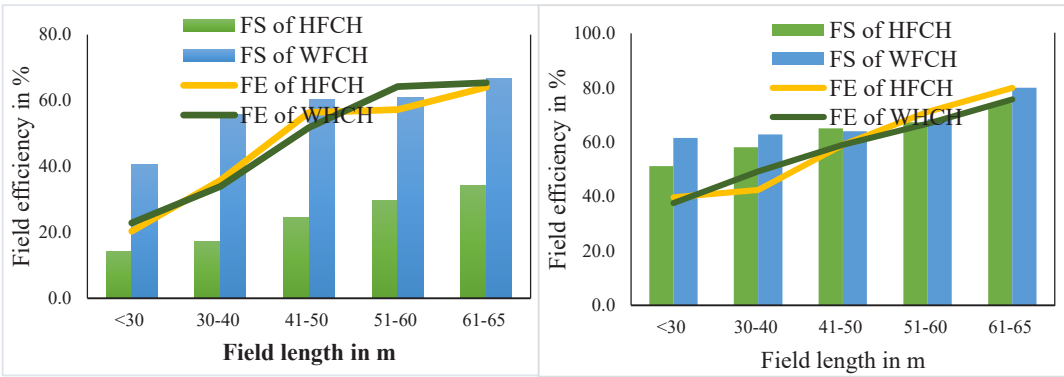
Length type	Length (m)	Total area (ha)	Forward speed (km/h)	Total operating time (h)	Effective field capacity (ha/h)	Effective cutting width (m)	Theoretical field capacity (ha/h)	Field Efficiency (%)
Sirajganj								
L1	29	0.058	3.773	0.183	0.32	2.2	0.83	38.2
L2	38	0.076	4.188	0.167	0.46	2.2	0.92	49.4
L3	44	0.088	4.659	0.15	0.59	2.2	1.02	57.2
L4	55	0.078	4.752	0.117	0.67	2.2	1.05	63.8
L5	62	0.075	5.54	0.083	0.90	2.2	1.22	74.1
$LSD_{0.05}$			0.1031		0.054		0.0639	5.1148
CV%			1.23		3.77		2.68	4.83
Habiganj								
L1	22	0.044	3.6	0.15	0.29	2.2	0.79	37.0
L2	39	0.078	3.343	0.217	0.36	2.2	0.74	48.9
L3	47	0.094	3.021	0.233	0.40	2.2	0.66	60.7
L4	54	0.08	3.471	0.15	0.53	2.2	0.76	69.8
L5	64	0.07	4.114	0.1	0.70	2.2	0.91	77.3
$LSD_{0.05}$			0.1203		0.0206		0.0734	2.3965
CV%			3.82		2.8		3.87	4.24

Forward speed and field efficiency of the head feed versus whole feed combine harvester

Forward speed and field efficiency increased with the increase of field length for the head feed and whole feed combine harvester in both Boro and Aman seasons while increasing rate varied with the machine type and seasons (Fig. 2). In Boro, 2021-22 season, forward speed of the head feed combine harvester increased 21 to 140% while it was increased 38 to 65% for whole feed combine harvester with the increase of field length based on the field length <30. Forward speed increased more for head feed combine harvester compared to whole feed combine harvester. In Aman, 2022 season, forward speed of the head feed combine harvester increased 14 to 45% while it was increased 2.2 to 30% for whole feed combine harvester with the increase of field length based on the field length <30m. Forward speed with the field length varied more for head feed combine harvester compared to the whole feed combine harvester because of complex mode of operation of the head feed combine harvester while overall variation was observed less in Aman season. Forward speed of the both type of harvesters was observed higher in Aman season as compared to Boro season which may be due to dryness of field during Aman season.

On contrary, field efficiency of the head feed combine harvester increased 76 to 215% and 7 to 101% during the Boro 2021-22 and Aman 2022 season, respectively with the

increase of the field length based on field length <30m. It was increased 49 to 187% and 31 to 101% of the whole feed combine harvester during the Boro 2021-22 and Aman 2022 season respectively with the increase of the field length based on field length <30m. In Bangladesh, the average field efficiency of combine harvester is around 50% and varied from 30 to 60% with a field length of 30 to 65 m (Hossen, 2022). According to Phetmanyseng *et al.* (2019) harvesting efficiency of the combine harvester as affected by rice field size and other factors.



Boro 2021-22 season

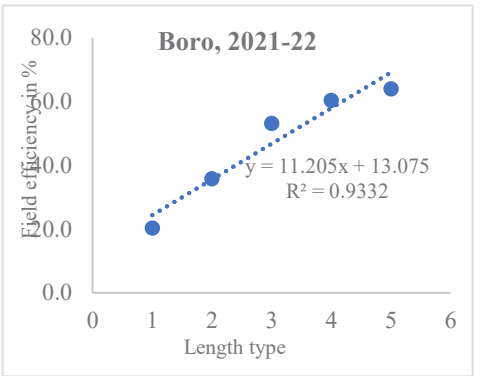
Aman 2022 season

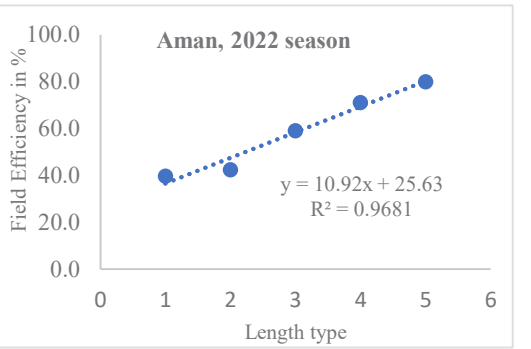
Note: FS: Forward speed, HFCH: Head Feed Combine Harvester, WHCH: Whole Feed Combine Harvester, FE: Field Efficiency

Fig. 2. Forward speed and field efficiency of the head feed versus whole feed combine harvester in Boro 2021-22 and Aman, 2022 season.

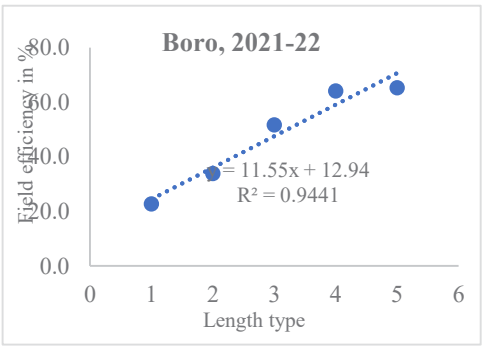
Effect of field length on field efficiency of the combine harvester

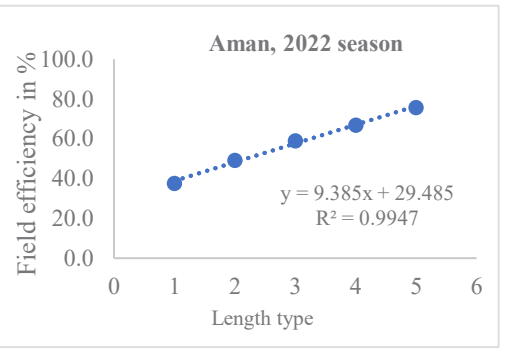
The field efficiency of both head feed and whole feed combine harvester was calculated with the length of the field which is presented in Tables 4-7. In all locations, the field efficiency of both the head feed and whole feed combine harvester increased with the increase in the field length. It is observed in the liner regression curve that the field performance of the head feed and whole feed combine harvester varied relatively in line with field length during Boro 2021-22 and Aman 2022 season respectively (R^2 = 0.93, R^2 = 0.94 and R^2 = 0.96 and R^2 = 0.99, respectively) (Fig. 3).





Head Feed Combine Harvester





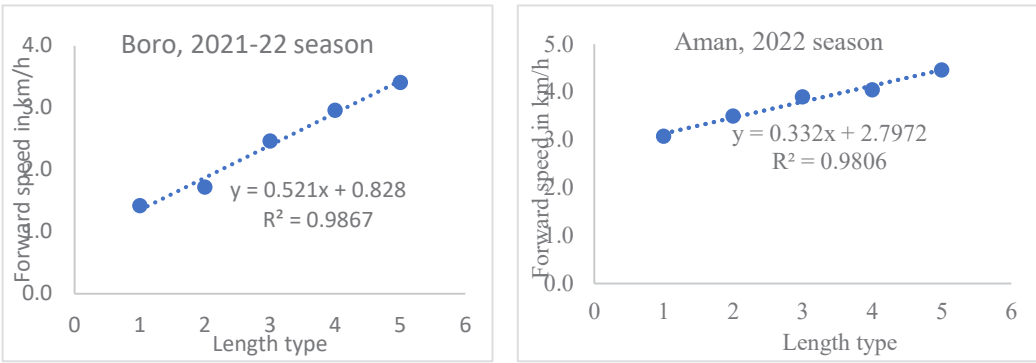
Whole Feed Combine Harvester

Note: Field length: L1≤30 m, L2: 31-40 m, L3: 41-50 m, L4: 51-60 m and L5: 61-70 m.

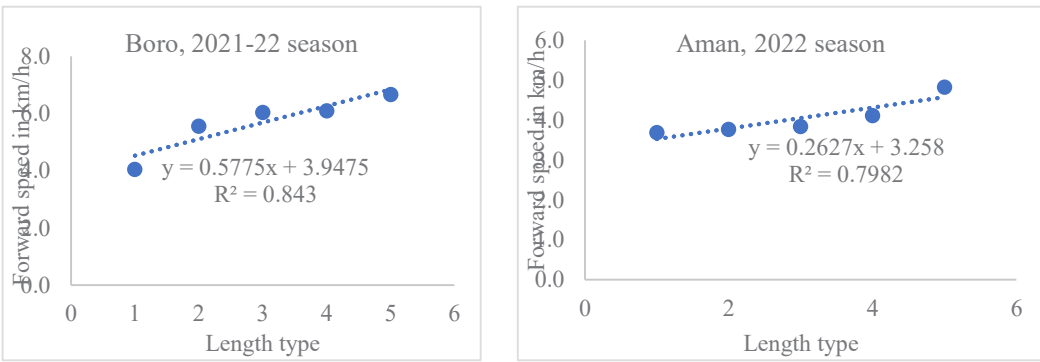
Fig. 3. Influences of field length on field efficiency of the combine harvesters.

Effect of field length on forward speed of the combine harvester

Forward speeds of both the types of combine harvester were determined with the length of the field which is presented in Table 4-7. It is observed in the liner regression curve that the forward speed of the head feed and whole feed combine harvesters varied relatively in line with field length in both Boro 2021-22 and Aman 2022 seasons respectively (R^2 = 0.91 and R^2 = 0.0.95, R^2 = 0.61 and R^2 = 0.95,) (Fig. 4).



Head Feed Combine Harvester



Whole Feed Combine Harvester

Fig. 4. Influences of field length on forward speed of the combine harvesters.

CONCLUSION

The study highlights the significant relationship between field size and the efficiency of combine harvesting operations. Larger field sizes tend to enhance operational efficiency by reducing the time and costs. Conversely, smaller fields lead to increased time and cost due to frequent turns and repositioning. Optimizing field sizes can lead to improved productivity and cost-effectiveness in harvesting practices using combine harvester, more specifically forward speed, effective field capacity, and field efficiency of both the head feed and whole feed combine harvesters varied linearly with the field size. The field length should not be less than 41-50 m for getting more than 50% field efficiency of the studied combine harvester in both the irrigated and non-irrigated seasons in Bangladesh. Additionally, recommendations for farmers and agricultural policymakers include considering field consolidation to maximize the benefits of mechanized harvesting. Further studies could explore the impact of other factors, such as crop type, logging condition, crop density, height of crop harvesting, field size and shape, plough pan depth, and on harvesting performance.

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AUTHOR'S CONTRIBUTION

M A Hossen generated the idea, design the experiment, developed the methodology, laid out the experiments, analyzed the data and prepared the report; Subrata Paul coordinated the field activities, S Islam and H Paul helped in data collection and tabulation for analysis according to the design; all authors read and approved the final manuscript.

AVAILABILITY OF DATA AND MATERIAL

Data used in this study are available from the first author upon request (dranwarhossenbrri@gmail.com).

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