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Analyses of Productivity and Profitability in Boro Rice Cultivation within Blast-Affected Areas of Kushtia District

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ABSTRACT

This study evaluated the profitability dynamics of blast affected Boro rice cultivation within specific regions of Kushtia District of Bangladesh during the period of 2018-19. A total of 90 farmers, with 30 from each upazila, were selected randomly for participation in this study. The findings revealed substantial yield losses, with the most significant impact observed among11% farmers affected by a disease severity scale of 9 in BRRI dhan28, resulting in a yield loss of 3.92 t/ha. Similarly, a blast severity scale of 9 led to yield losses of 2.0 t/ha in BRRI dhan29, affecting 7% of farmers. The Miniket cultivar exhibited a yield loss of 1.70 t/ha among 56% of farmers with a severity scale of 5. Interestingly, Mirpur experienced devastating losses for both BRRI dhan28 and BRRI dhan29, while Kushtia Sadar suffered significant yield losses for the Miniket cultivar based on disease severity and yield impact. Application of Nativo 75 WG (0.40 Kg/ha) and Trooper 75 WP (0.50 Kg/ha) at the lowest (3%) disease incidence resulted in a remarkable 68.97% increase in yield for BRRI dhan29 in Bheramara. Conversely, spraying of Amistar Top 325 SC (0.56 l/ha) did not lead to increase yield. In Miniket cultivar at Bheramara, Nativo 75 WG (0.45 Kg/ha) and Amistar Top 325 SC (0.37 l/ha) resulted in a lower yield of 2.99 t/ha due to application at a higher (50%) disease incidence. Furthermore, a yield increase of 69.67% was observed with the application of Nativo 75 WG (0.34 kg/ha) in the Miniket cultivar at Kushtia Sadar. The highest gross return, gross margin, net return, and benefit-cost ratio were recorded in Bheramara, amounting to Tk 1,24,084/ha, Tk 46,037/ha, Tk 5,797/ha, and 1.05, respectively. Notably, BRRI dhan29 exhibited the maximum gross return and yield of Tk 1,32,435/ha and 6.14 t/ha, respectively, whereas BRRI dhan28 demonstrated the lowest gross return and net return of Tk 1,09,737/ha and (-) Tk 8,321/ha, respectively, due to higher blast disease incidence. Labor costs constituted the largest share (34.10%) of the total rice production expenses. Despite BRRI dhan28 exhibiting lower net and gross returns per hectare due to higher blast disease incidence, the highest yields in BRRI dhan29 were attributed to its comparatively lower disease infection rate among the three varieties. Evidently, the cultivation of the Miniket cultivar resulted in higher net returns due to its superior market price and quality, especially when disease incidence was lower compared to BRRI dhan28. This emphasizes the importance of blast management strategies and the use of resistant varieties with high yield potential and market value in ensuring sustainable productivity and profitability in Boro rice production.

Key words: Benefit-cost ratio, gross return, net return, profitability, boro rice, blast disease, yield

INTRODUCTION

Rice (*Oryza sativa* L.) stands as the cornerstone of sustenance in Bangladesh, serving as the staple food crop. The last three decades have witnessed a remarkable

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stride in agricultural development, specifically in rice production. Notably, rice not only serves as a vital food resource but also exemplifies Bangladesh's self-sufficiency (Mainuddin and Kirby, 2015; Timsina *et al.*, 2018). This sentiment is further echoed by the per capita consumption, with an average of 179.9 kg per annum in contrast to the global average of 53.5 kg per annum (FAO, 2020). Over the years, husked rice production has surged from 12.97 million tons in 1977 to 37.96 million tons in 2021, despite a population increase of 2.29 times during the same period (FAO, 2022). Among the three primary cropping seasons, rice asserts its dominance, constituting a significant portion of farmers' income and facilitating employment generation (Sarker *et al.*, 2012; Alam *et al.*, 2016). The vast expanse of approximately 11.70 million hectares contributes to the production of around 37.96 million tons of rice in Bangladesh (FAO, 2022). As the population projection for Bangladesh estimates an increase to 220 million by 2050 from the current 169 million (UNFPA, 2022), the importance of rice production becomes even more pronounced.

In a global context, the average rice yield per hectare is 3.18 t/ha, with the national average for Bangladesh slightly exceeding at 3.25 t/ha, yet notably trailing behind Japan (5.00 t/ha) and China (4.74 t/ha) (FAO, 2022). Within the Kushtia district, rice production occupies an area of 1.50 lakh hectares, yielding approximately 4.85 lakh tons in the 2019-20 period (BBS, 2021). While the district maintains an average yield of 3.28 t/ha (BBS, 2021), the Boro season's yield of 4.06 t/ha falls short in comparison to Japan and China. The factors contributing to this lower yield in Bangladesh, particularly in Kushtia district, are multifaceted. Intensive rice production practices have led to an increased use of high-yielding and hybrid Boro rice variants during the dry season, accompanied by heavy utilization of irrigation, fertilizers, pesticides, herbicides, and comprehensive crop management (Mainuddin *et al.*, 2021). However, the susceptibility of rice to blast pathogens during the Boro season exacerbates yield loss in comparison to the Aman and Aus seasons, emphasizing the urgent need to enhance Boro rice yield to meet escalating food demands (Mainuddin and Kirby, 2015).

Of the various rice diseases, rice blast (Pyricularia oryzae) emerges as a primary threat, significantly contributing to crop failure in Bangladesh and worldwide (Khan *et al.*, 2014; Ou, 1985; TeBeest *et al.*, 2007). Recognized as one of the ten major rice diseases (BRRI, 1999), blast disease poses a substantial challenge to rice production's sustainability and yield, consequently elevating production costs (Mottaleb and Mohanty, 2015). This rapid and destructive disease can decimate an entire crop in a remarkably short span (Groth and Hollier, 2016), leading to reduced grain size, increased sterility, and yield loss (Khan *et al.*, 2014). The prevalence of rice blast has been associated with yield losses ranging from 11.9% to 37.8% per hectare (Chuwa *et al.*, 2015).

Remarkably, despite its reputation as a mega variety covering around 40% of the Boro season, BRRI dhan28 has experienced significant yield losses due to rice blast (Mahmud and Hossain, 2018). The wide distribution of the rice blast pathogen, coupled with favorable environmental conditions, underscores its destructive potential. Factors such as temperature, relative humidity, sunshine, rainfall, and wind speed intricately influence disease development and propagation (Rayhanul *et al.*, 2019). Developing blast-resistant varieties emerges as a critical strategy to combat this devastating disease, necessitating global collaboration among plant pathologists and rice breeders. Promisingly, the application of Nativo 75 WG 0.06% (Tebuconazole 50% +

Trifloxystrobin 25%) or Trooper 75 WP 0.08% (Tricyclazole 75%) through bi-weekly spraying during the heading and flowering stages has proven effective in controlling leaf and panicle infections (BRRI, 2018). Notably, Rabicide, Nativo, and Score have all contributed to reducing disease incidence (Ghazanfar *et al.*, 2009).

The rice cultivation sector serves as a reliable source of employment and income for countless households (Zeigler and Barclay, 2008). However, the escalating input prices and rising labor costs impede overall profitability, casting a shadow over rice production (Mottaleb and Mohanty, 2015). Achieving sustainable and socially beneficial rice production hinges on bolstering yields and profitability (Mottaleb *et al.*, 2013). Progress in rice production is intimately tied to higher yields, often influenced by fluctuations in market rice prices. In this context, Miniket cultivar and BRRI dhan29 emerge as durable choices for yield and profitability, as highlighted through probability and risk analyses (Mainuddin *et al.*, 2021). Conversely, the prevalence of rice blast disease precipitates lower yields and subsequently diminished market prices, undermining the profitability of rice production.

Despite extensive research on rice productivity and profitability in the country, a significant knowledge gap persists concerning blast-affected fields, the ensuing yield losses among various rice varieties, and their pathogenic interactions. The present study seeks to address this gap by scrutinizing blast incidence, its impact on yield across diverse varieties, evaluating the financial aspects of rice production, and identifying major constraints to Boro rice cultivation while offering potential remedies.

MATERIALS AND METHODS

Sampling Design: A multi-stage sampling technique was employed to select the study areas and sample households. The research was conducted across various upazilas within the Kushtia district, each chosen based on the degree of blast impact on rice production. Three specific upazilas, namely Mirpur, Bheramara, and Kushtia Sadar, were carefully chosen for the study. Subsequently, three Agricultural Blocks (AB), one from each selected upazila, were purposively selected in consultation with respective upazila extension personnel. A comprehensive list of rice growers was then compiled for each AB, from which 30 samples were randomly drawn for the study. Consequently, the total number of samples in the study amounted to 90.

Data Collection and Procedure: The dataset for this study was assembled through input from farmers, extension personnel, and scientists. Data collection involved interviews with selected rice farmers spread across various upazilas, utilizing a pre-designed and pre-tested interview schedule. These interviews took place after the Boro rice harvest during the period of July to August 2019. Researchers, in collaboration with trained enumerators, gathered data from the sampled households within the study areas. Farmers were individually queried using a structured questionnaire, with specific emphasis on their experiences and perceptions regarding blast-affected plots and associated losses. Information was gathered on a range of subjects, spanning the three chosen upazilas. Specific data points included details such as the rice varieties (BRRI dhan28, BRRI dhan29, and Miniket), application rates and costs of manures and chemical fertilizers, land lease values, irrigation costs, labor input and associated costs, disease incidence and severity, usage of fungicides and insecticides, costs of these agents, and mechanical expenses. Additionally, crop cutting exercises were conducted on blast-affected fields of 10 sqm (5m × 2m) for BRRI dhan28, BRRI dhan29, and Miniket cultivar, with estimated yield losses of (30 - 45%), (10 - 30%), and (10 - 30%) respectively across the three upazilas. Furthermore, the yield of blast-affected plots was assessed in crop cutting exercises of 10 sqm (5m × 2m) for control plots where no fungicides were applied.

Secondary data were sourced from various authorities, including the Department of Agricultural Extension (DAE), Bangladesh Rice Research Institute (BRRI), and Bangladesh Bureau of Statistics (BBS).

Analytical Techniques: The collected data underwent thorough editing, summarization, tabulation, and analysis, employing tabular and statistical methods to meet the study's objectives. A profit model was utilized to evaluate the profitability of rice cultivation.

Profitability Analysis: The profitability of rice cultivation was computed using the following equation, as proposed by Dillon and Hardaker (1980).

$\eta i= (Qp + Sq) – TC= (Qp+Sq) – (TVC+TFC)$

Where,

η = Net profit from rice production (Tk/ha)

Q = Amount of rice produced (kg/ha)

p = Average price of rice (Tk./kg)

S = Amount of straw (kg/ha)

q = Average price of straw (Tk./kg)

TC = Total cost of production (Tk./ha)

TVC = Total variable cost (Tk./ha)

TFC = Total fixed cost (Tk./ha)

DISEASE SEVERITY

The evaluation of neck blast incidence for mass assessment involved determining the count of panicles with lesions completely encompassing the node, neck, or lower section of the panicle axis. This assessment pertained to symptom types 7-9, as outlined in the Standard Evaluation System (SES) devised by IRRI (IRRI, 2013). To quantify panicle blast severity, the scale-specific count of panicles was utilized in the following manner:

Panicle blast severity scale (0-9) based on the incidence of severely infected plants.

0 = No incidence

1 = Less than 5%

3 = 5 - 10%

5 = 11-25%

7 = 26 – 50%

9 = More than 50%

RESULTS AND DISCUSSION

Agronomic Practices in Rice Production at the Farm Level

Regarding agronomic practices in rice production, the findings reveal noteworthy patterns. On average, the majority of farmers (60%) within the study area chose to transplant Boro rice during January 16-31. This was followed by transplantation occurring between January 1-15 (25%) and December 20-31 (15%) (Fig. 1). This trend held consistently across all upazilas, albeit with a minor deviation observed in Bheramara during January 1-15.

When it comes to the timing of harvesting, an interesting distribution emerges. The highest proportion of farmers (57%) conducted their harvesting activities during the May 1-15 period. This was followed by a significant presence during April 15-30 (33%) and a smaller contingent during April 1-15 (10%) across all study areas. This consistent trend was mirrored within each specific upazila. It is noteworthy that farmers in the study areas tended to transplant Boro rice later, which consequently led to a delayed harvesting period. This gradual shift towards later transplanting times corresponded directly to the extension of the harvesting period during the late season.

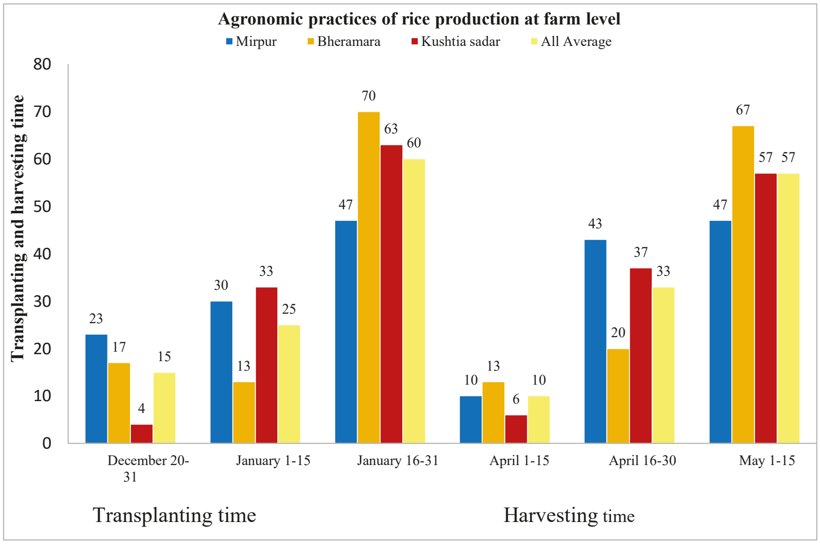

Fig. 1. Agronomic practices of Boro rice cultivation at study areas.

Input Utilization Patterns in Rice Cultivation at the Farm Level

The average inputs employed by farmers included 123 man-days/ha, 37.38 kg/ha of seed, 2.30 t/ha of cow dung, 302 kg/ha of urea, 153 kg/ha of Triple Super Phosphate (TSP), 115 kg/ha of muriate of potash (MoP), 102 kg/ha of gypsum, and 8.27 kg/ha of zinc sulfate (Fig. 2). The highest human labor utilization, at 128 man-days/ha, was observed in Mirpur, while the lowest was recorded in Kushtia Sadar, at 119 man-days per hectare (Fig. 2).

Seeding rates varied across the upazilas, with Kushtia Sadar leading at 37.67 kg/ha, followed closely by Mirpur (37.55 kg/ha) and Bheramara (36.93 kg/ha). Cow dung application peaked in Kushtia Sadar, reaching 3.81 t/ha, whereas Bheramara recorded the lowest application, at 1.25 t/ha. Notably, the highest urea application, totaling 312 kg/ha, occurred in Bheramara, whereas Kushtia Sadar exhibited the lowest, at 286 kg/ha. Triple Super Phosphate (TSP) fertilization displayed similar dosages across all three upazilas.

Muriate of potash (MoP) utilization revealed its highest rate of application, with 125 kg/ha in Bheramara, while Kushtia Sadar reported the lowest application at 108 kg/ha. In terms of gypsum, the maximum dose of 119 kg/ha was administered in Bheramara, followed by Mirpur (95 kg/ha) and Kushtia Sadar (92 kg/ha). Among farmers' practices, zinc sulfate recorded its highest usage at 9.73 kg/ha in Bheramara, whereas the lowest dose (7.11 kg/ha) was noted in Kushtia Sadar.

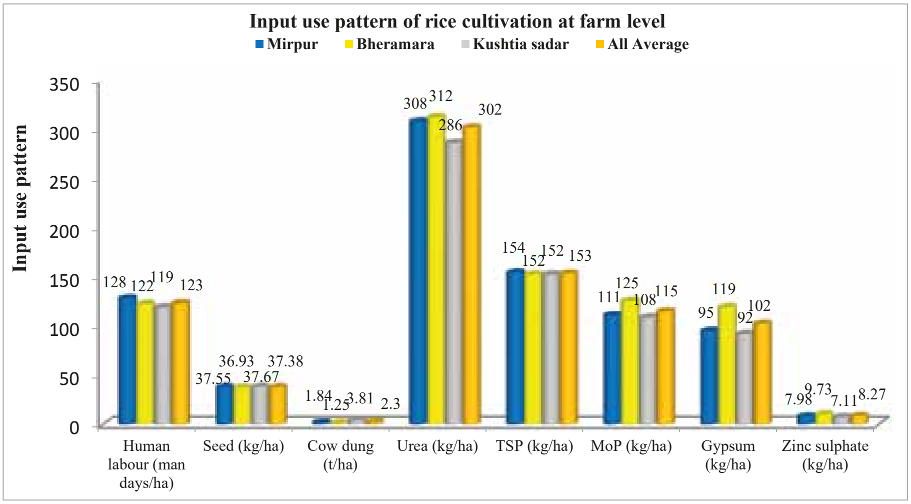

Fig. 2. Input use pattern of rice cultivation at farm level.

Effect of urea on rice blast incidence in BRRI dha28

TThe study revealed notable trends in disease severity in relation to urea application. On average, the highest disease severity scale (9) was observed among users applying above 300 kg/ha of urea. This was closely followed by a severity scale of 7 (260-300 kg/ha) and 3 (<260 kg/ha). Notably, the lowest disease severity scale was recorded in Bheramara, while Mirpur and Kushtia Sadar exhibited higher disease severity, attributed to the prevalence of rice blast disease (Fig. 3). The application of above 300 kg urea resulted in the maximum disease severity scale (9), followed by a severity scale of 7 (260-300 kg/ha), and 1 (<260 kg/ha) at Mirpur. Across all upazilas, a consistent trend emerged with higher disease severity corresponding to increased urea application.

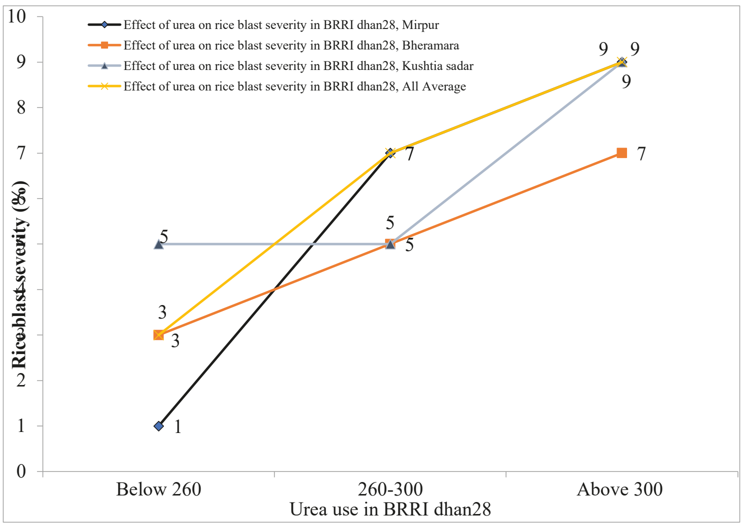

Fig. 3. Effect of urea on rice blast incidence in BRRI dha28.

Effect of rice blast disease on yield in different varieties

The study reveals the impact of rice blast disease on yield across various varieties. On average, blast disease affected approximately 46% of the cultivated area, resulting in yield losses of 1.71 t/ha in BRRI dhan28. Following this, around 24% of the area experienced yield losses of 1.44 t/ha in the Miniket cultivar within all study regions (Fig. 4). Notably, the most significant blast-affected area (66%) in Bheramara exhibited yield losses of 1.47 t/ha, while Mirpur displayed higher yield losses (2.22 t/ha) over an area where 45% was impacted by blast disease, specifically in BRRI dhan28.

Among the varieties, the highest yield loss of 2.10 t/ha was observed in the most severely affected area (22%) of Mirpur for BRRI dhan29. Conversely, the least affected area, accounting for 5%, demonstrated yield losses of 0.10 t/ha in Kushtia Sadar. The greatest yield losses (2.40 t/ha) were recorded in Miniket cultivar, within a less intensely affected area in Bheramara, while Kushtia Sadar, with a high blast-affected incidence (60%), incurred a yield loss of 0.85 t/ha.

This study highlights a notable disparity in urea application, with higher dosages used alongside lower dosages of Muriate of Potash, particularly during late transplanting when blast disease incidence escalated. These findings align with previous research by Piotti *et al.* (2005) and Groth and Hollier (2016). Piotti *et al.* (2005) indicated that excessive nitrogen fertilization contributed to the epidemic development of blast disease. Moreover, the progression of blast disease was influenced by thick plant growth and canopy density, often resulting from higher nitrogen applications and late transplanting, which were found to be particularly destructive under upland or drained conditions, as demonstrated by the study conducted by Groth and Hollier (2016).

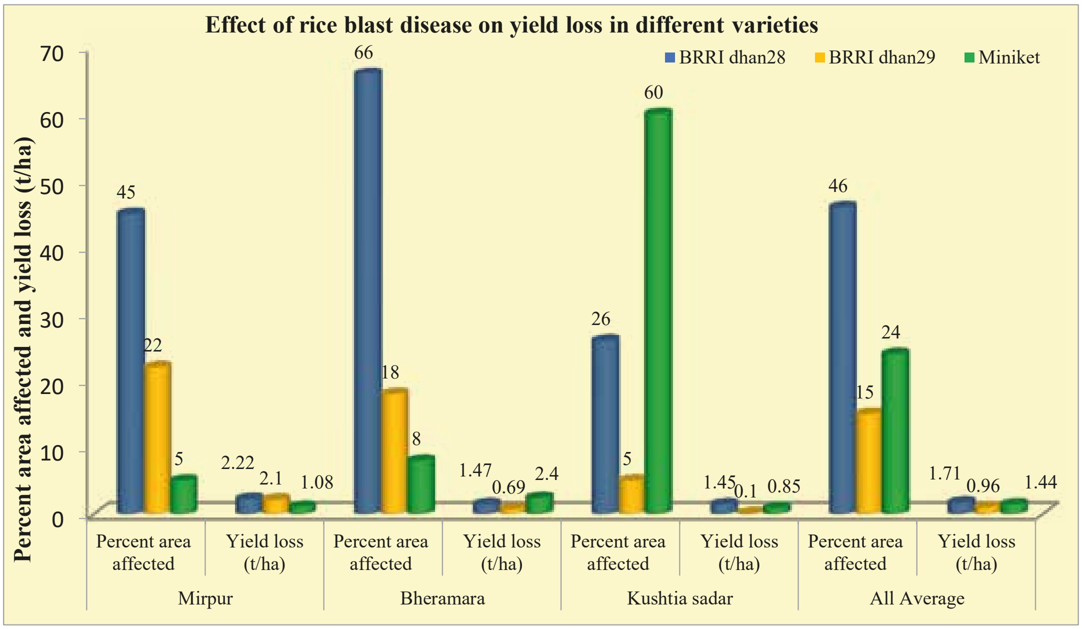

Fig. 4. Percent area affected by blast and yield loss.

Effect of Rice Blast Disease Severity on Yield Losses in Different Varieties:

BRRI dhan28

On average, a yield loss of 3.92 t/ha was observed among 11% of farmers at the highest disease severity scale (9), followed by 31% of affected farmers with yield losses of 2.18 t/ha at severity scale 7 across the three upazilas (Table 1). The most substantial yield losses of 4.13 t/ha were documented in 23% of affected farmers in Mirpur, with subsequent losses of 4.04 t/ha among 8% of affected farmers in Kushtia Sadar, and 3.59 t/ha among 3% of affected farmers in Bheramara, all within the disease severity scale of 9.

BRRI dhan29

Among the affected farmers, the highest yield loss of 2.0 t/ha occurred in 7% of cases at the highest disease severity scale of 9. This was followed by 1.50 t/ha among only 10% of farmers at severity scale 7. The most extensive impact, affecting 20% of farmers, resulted in yield losses of 0.85 t/ha at disease severity scale 5, considering the average of the three upazilas. Moreover, the most substantial yield loss of 5.99 t/ha occurred among 20% of affected farmers at disease severity scale 9. Meanwhile, the highest percentage (40%) of farmers experienced yield losses of 1.35 t/ha at disease severity scale 5 in the Mirpur upazila. This was followed by yield losses of 2.69 t/ha at disease severity scale 7 among 11% of farmers in Bheramara. In contrast, Kushtia Sadar witnessed lower yield losses (0.30 t/ha) at severity scale 3 (Table 1).

Table 1. Effect of disease severity of rice blast on yield loss in different varieties.

Severity scale	Mirpur		Bheramara		Kushtia Sadar		All Average	
	% farmer affected	Yield loss (t/ha)	% farmer affected	Yield loss (t/ha)	% farmer affected	Yield loss (t/ha)	% farmer affected	Yield loss (t/ha)
BRRI dhan28								
0	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-
3	14	0.70	7	0.30	4	1.80	8	0.93
5	23	1.38	43	1.08	54	1.37	40	1.28
7	40	2.13	37	2.23	15	2.17	31	2.18
9	23	4.13	3	3.59	8	4.04	11	3.92
BRRI dhan29								
0	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-
3	-	-	16	0.80	33	0.30	16	0.37
5	40	1.35	21	1.20	-	-	20	0.85
7	20	1.80	11	2.69	-	-	10	1.50
9	20	5.99	-	-	-	-	7	2.00
Miniket				-				
0	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-
3	-	-	-	-	58	0.77	19	0.26
5	60	1.80	100	2.40	8	0.90	56	1.70
7	-	-	-	-	17	1.95	6	0.65
9	-	-	-	-	-	-	-	-

MINIKET CULTIVAR

On average, the blast disease affected a maximum of farmers (56%) with the highest yield losses of 1.70 t/ha at a severity scale of 5 across the three upazilas. This was followed by yield losses of 0.65 t/ha among 6% of affected farmers with the highest severity scale (7). Additionally, yield losses of 1.95 t/ha were observed among 17% of affected farmers with a severity scale of 7 in Kushtia Sadar. Meanwhile, the highest yield loss (0.77 t/ha) was found in the most affected farmers (58%) at a disease severity scale of 3. Notably, the most significant yield losses per hectare (1.80 and 2.40) were recorded among 60% and 100% of affected farmers at the severity scale of 5 in Mirpur and Bheramara, respectively. Comparatively, Kushtia Sadar exhibited the highest yield loss in the Miniket cultivar in comparison to the other upazilas (Table 1).

Our findings underscore a clear correlation between higher disease incidence and increased yield losses, with lower yields associated with higher disease incidence. Among the widely cultivated varieties, BRRI dhan28 displayed a disease incidence of 29.6%, and BRRI dhan29 had a disease incidence of 25.9%. Regardless of location and cropping sequence, a higher disease incidence of 39.8% was noted in BRRI dhan29, while BRRI dhan28 exhibited a disease incidence of 20.3%, consistent with the findings of Hossain *et al.* (2017). They also reported yield losses of 37.9% in BRRI dhan29 and 19.3% in BRRI dhan28. Yield losses ranging from 20% to 100% were documented by Khush and Jena (2009) as well as Pinheiro *et al.* (2012). Khan *et al.* (2014) highlighted that neck blast infection alone caused a significant yield loss of 42.52% in Bangladesh. These observations were in line with the studies conducted by Chuwa *et al.* (2015) and Khan *et al.* (2014), who reported that neck blast disease led to reduced grain size, yield losses, compromised seed quality, and increased grain sterility. However, the incidences of panicle rice blast were found to be strongly and positively correlated with grain yield losses, in agreement with the findings of Chuwa *et al.* (2015).

Effect of Fungicides on Yield in Different Varieties

BRRI dhan28: The application of Nativo at 0.30 kg/ha and Amistar Top at 0.50 l/ha during the heading and flowering stage resulted in the highest yield of 4.39 t/ha, marking an impressive increase of 46.33% over the control. This was followed by the combination of Trooper at 0.60 kg/ha and Amistar Top at 0.37 l/ha during the booting and heading stage, resulting in a yield of 3.89 t/ha and an increase of 29.66% in Mirpur. Similarly, the maximum yield of 4.98 t/ha was achieved using Nativo at 0.42 kg/ha, showing a substantial yield increase of 60.65% over the control. Trooper (0.47 kg/ha) also displayed a higher yield of 3.82 t/ha in Bheramara when applied at the heading stage.

Farmers observed that Trooper and Amistar Top were employed in fields with higher disease incidence (50%) at the ripening stage, leading to lower yield compared to Nativo treatment due to failed recovery of the rice field. In Sadar upazila, the application of Nativo at 0.37 kg/ha and Amistar Top at 0.37 l/ha during the heading and flowering stage resulted in the highest yield of 5.39 t/ha, showcasing a yield increase of 63.33%. Similarly, the use of Trooper at 0.37 kg/ha during the heading stage and the combination of Trooper at 0.37 kg/ha and Amistar Top at 0.37 l/ha during the heading and flowering stage also yielded 5.39 t/ha. Notably, the spraying of Nativo at 0.22 kg/ha and Seltima at 0.75 l/ha during the booting and heading stage led to a significant yield increase of 26.97% over the untreated control (Table 2).

BRRI dhan29: At Mirpur, a higher yield of 4.79 t/ha was achieved with a yield increase of 27.73% through the application of Trooper at 0.37 kg/ha and Filia at 0.37 l/ha during the heading and flowering stage, compared to control. This was followed by the use of Nativo at 0.40 kg/ha, resulting in a yield of 4.49 t/ha and an increase of 19.73%. An impressive yield increase of 68.97% (6.59 t/ha) was achieved with the application of Nativo at 0.40 kg/ha at the lowest (3%) disease incidence during the heading stage over control. Similarly, the use of Trooper at 0.50 kg/ha in the same disease incidence during the heading stage led to a highest yield of 6.59 t/ha in Bheramara. However, Amistar Top at 0.56 l/ha displayed a lower yield of 3.79 t/ha when applied at the ripening stage under higher disease severity scale (7). In Kushtia Sadar, a yield of 3.59 t/ha was observed with Folicur at 0.50 l/ha when applied at 40% disease incidence during the heading stage. Therefore, based on farmers' observations, Amistar Top and Folicur did not exhibit significant effectiveness in controlling rice blast disease (Table 2)."

Table 2. Effect of fungicides in increasing yield over control in different varieties.

Location/ Varieti	Fungicide	Quantity applied (kg/ha & l/ha)		Yield (t/ha)	Spraying at severity scale
		Mean	Range		
BRRI dhan28:					
Mirpur	Nativo 75 WG	0.37	0.30-0.45	3.57 (19.00)	5
	Nativo 75 WG & Amistar Top 325 SC	0.30 & 0.50	0.30 & 0.37-0.75	4.39 (46.33)	3
	Trooper 75 WP & Amistar Top 325 SC	0.60 & 0.37	0.45-0.75 & 0.37	3.89 (29.66)	5
	Control (No fungicide used)	-	-	3.00	7
Bheramara	Nativo 75 WG	0.42	0.22-0.60	4.98 (60.65)	3
	Nativo 75 WG & Amistar Top 325 SC	0.45 & 0.37	0.45 & 0.37	3.59 (15.81)	5
	Trooper 75 WP	0.47	0.37-0.75	3.82 (23.23)	5
	Control (No fungicide used)	-	-	3.10	7
Kushtia Sadar	Nativo 75 WG	0.33	0.22-0.60	4.34 (31.52)	5
	Nativo 75 WG & Amister Top 325 SC	0.37 & 0.37	0.37 & 0.37	5.39 (63.33)	3
	Nativo 75 WG & + Seltima	0.22 & 0.75	0.22 & 0.75	4.19 (26.97)	5
	Trooper 75 WP	0.37	0.37	5.39 (63.33)	3
	Trooper 75 WP & Amistar Top 325 SC	0.37 & 0.37	0.37 & 0.37	5.39 (63.33)	3
	Control (No fungicide used)	-	-	3.30	7
BRRI dhan29:					
Mirpur	Nativo 75 WG	0.40	0.30-0.45	4.49 (19.73)	5
	Trooper 75 WP & Filia 525 SE	0.37 & 0.37	0.37 & 0.37	4.79 (27.73)	5
	Control (No fungicide used)	-	-	3.75	7
Bheramara	Nativo 75 WG	0.40	0.30-0.45	6.59 (68.97)	1
	Trooper 75 WP	0.50	0.37-0.75	6.59 (68.97)	1
	Amistar Top 325 SC	0.56	0.37-0.75	3.79 (-2.83)	7
	Control (No fungicide used)	-	-	3.90	7
Kushtia Sadar	Folicur	0.75	0.75	3.59 (-5.53)	7
	Control (No fungicide used)	-	-	3.80	7
Miniket:					
Mirpur	Nativo 75 WG	0.34	0.34	4.19 (35.16)	5
	Seltima	0.75	0.75	3.59 (15.81)	5
	Control (No fungicid used)	-	-	3.10	7
Bheramara	Nativo 75 WG & Amistaer top 325 SC	0.45 & 0.37	0.45 & 0.37	2.99 (-3.54)	7
	Control (No fungicide used)	-	-	3.10	7
Kushtia Sadar	Nativo 75 WG	0.34	0.34	5.09 (69.67)	3
	Nativo 75 WG & Amistar Top 325 SC	0.45 & 0.37	0.45 & 0.37	3.99 (33.00)	5
	Amistar Top 325 SC	0.56	0.56	3.00 (0.00)	7
	Trooper 75 WP	0.37	0.37	4.79 (59.67)	5
	Nativo 75 WG & Seltima	0.22 & 0.75	0.22 & 0.75	4.94 (64.67)	5
	Control (No fungicide used)	-	-	3.00	7

Percentages of share on increased yield over control in parentheses were shown.

Miniket cultivar: The yield experienced a notable increase of 35.16% with the application of Nativo at 0.34 kg/ha during the heading stage, closely followed by Seltima at 0.75 l/ha which exhibited a yield increase of 15.81% over the control in Mirpur (Table 2). However, spraying Nativo at 0.45 kg/ha and Amistar Top at 0.37 l/ha during the ripening stage resulted in a lower yield of 2.99 t/ha in Bheramara, where the severity scale was at 7.

In Kushtia Sadar, the application of Nativo 75 WG at the heading stage with a severity scale of 3 showed the highest yield of 5.09 t/ha. Similarly, the spraying of Nativo at 0.22 kg/ha and Seltima at 0.75 l/ha during the heading stage led to a remarkable yield increase of 64.67%. Among the fungicides used, Trooper 75 WP exhibited a significant effect in boosting yield, showing an increase of 59.67% over the control plot. Conversely, the application of Amistar Top at 0.56 l/ha during the heading stage resulted in a lower yield of 3.0 t/ha, and as the fungicide did not demonstrate a significant effect in controlling rice blast disease, the yield was reduced compared to other fungicides (Table 2).

It's worth noting that fungicides were applied in the rice field at the booting stage and then again at the flowering stage, with a 10-day interval between applications.

Efficacy of different fungicides against neck blast under field conditions and their impact on rice yield exhibited notable variations

Significant differences were observed among the fungicides in terms of the percentage of disease incidence of blast disease, and in most cases, all the fungicides contributed to reducing blast disease incidence. Notably, Nativo 75 WG (0.40 kg/ha) and Trooper 75 WP (0.50 kg/ha) demonstrated a profound ability to control rice blast disease when timely spraying was conducted. However, in certain instances, the number of sprayings and the appropriate dosages, along with accurate timing in relation to the growth stages of the rice plants, were not consistently executed, resulting in unsynchronized and less effective outcomes in fungicide application.

Singh *et al.* (2019) reported that spraying of Amistar Top 29.6 SC (0.13%), Nativo 75 WG (0.07%), Folicur 250 EC (0.06%), and Score 250 EC (0.06%) twice at a 15-day interval showed promising effectiveness in reducing disease incidence. Among these, Nativo 75 WG exhibited the lowest disease intensity at 11.46%, followed by Amistar Top 29.6 SC at 12.85% disease intensity. Notably, the highest grain yield of 4.10 t/ha was achieved with the application of Nativo 75 WG (0.07%), followed by 3.97 t/ha with Amistar Top 29.6 SC (0.13%). Similar findings were corroborated by Ghazanfar *et al.* (2009), Mohan *et al.* (2011), and Nirmalkar *et al.* (2017). Mohan *et al.* (2011) and Nirmalkar *et al.* (2017) highlighted that the application of tebuconazole 50% and trifloxystrobin 25% (WG), along with tebuconazole 25.9% (EC), exhibited a significant effect in controlling neck blast disease in paddy under field conditions.

Moktan *et al.* (2021) conducted a study in Nepal during 2017, where Tricyclazole 75% WP was sprayed five times at weekly intervals in rice fields, resulting in effective control of rice blast disease with minimal blast incidence (27.85%). These findings were further supported by the research of Magar *et al.* (2015).

Cost of rice cultivation at farm level

The total cost of rice cultivation was calculated based on both total variable costs and total costs, as detailed in Table 3. The average total cost and total variable cost of rice cultivation across all study areas were determined to be Tk. 118,398/ha and Tk. 78,425/ha, respectively. Among the study areas, Mirpur had the highest total cost of rice cultivation, amounting to Tk.

120,341/ha. The primary contributor to the total cost was human labor (34.10%), followed by the rental value of land (20.12%), irrigation expenses (13.62%), and mechanical costs (11.81%).

In terms of irrigation costs, Bheramara incurred the highest expense of Tk. 17,764/ha, while Kushtia Sadar had the lowest at Tk. 14,471/ha. Notably, the data indicated that the farmers in Kushtia Sadar allocated a significant portion of their budget to irrigation, largely due to the substantial area recommended under the Ganges Kobadak irrigation project. This finding highlights the pronounced impact of irrigation costs on the overall expenditure in rice cultivation.

Table 3. Cost of rice cultivation at farm level.

Item	Mirpur (Tk/ha)	Bheramara (Tk/ha)	Kushtia Sadar (Tk/ha)	All Average (Tk/ha)
Hired labour	24775 (20.59)	23832 (20.15)	24056 (20.64)	24221 (20.46)
Mechanical	14159 (11.77)	13498 (11.41)	14246 (12.22)	13968 (11.80)
Seed	1777 (1.48)	1692 (1.43)	2123 (1.82)	1864 (1.57)
Manure	3216 (2.67)	1622 (1.37)	4878 (4.18)	3239 (2.74)
Fertilizer	12784 (10.62)	13640 (11.53)	12285 (10.54)	12903 (10.90)
Irrigation	16149 (13.42)	17764 (15.02)	14471 (12.41)	16128 (13.62)
Pesticides	5781 (4.80)	5354 (4.53)	5230 (4.49)	5455 (4.61)
Interest on operating capital @4% for 5 months	655 (0.54)	645 (0.55)	644 (0.55)	648 (0.55)
Total variable cost	79296 (65.89)	78047 (65.98)	77933 (66.86)	78425 (66.24)
Family labour	16516 ((13.72)	15888 (13.43)	16038 (13.76)	16147 (13.64)
Rental value of land	24529 (20.38)	24352 (20.59)	22595 (19.38)	23825 (20.12)
Total fixed cost	41045 (34.11)	40240 (34.02)	38633 (33.14)	39973 (33.76)
Total cost	120341	118287	116566	118398

Percentages of share on total cost of production in parentheses were shown.

Productivity and Profitability of Rice Cultivation at the Farm Level

An average yield of 4.55 t/ha was achieved across all study areas (Table 4). The highest yield (5.06 t/ha) was observed in Bheramara, whereas the lowest yield (4.18 t/ha) was recorded in Mirpur due to a blast disease outbreak. The average gross return from rice cultivation was calculated as Tk 1,14,549/ha in all study areas. The highest gross return (Tk 1,24,084/ha) was achieved in Bheramara, primarily due to a higher yield, followed by Kushtia Sadar (Tk 1,15,456/ha) and Mirpur (Tk 1,04,107/ha).

The average gross margin and net return or profit from rice cultivation were determined to be Tk 36,124/ha and (-) Tk 3,849/ha, respectively, across all study areas. Bheramara stood out with the highest net profit of Tk 5,797/ha among all study areas, driven by its higher yield. Conversely, Mirpur experienced the lowest net profit (-) Tk 16,234/ha due to higher costs, lower yield, and a severe blast disease outbreak. The highest gross margin (Tk 46,037/ha) was observed in Bheramara, attributed to its higher yield, followed by Kushtia Sadar (Tk 37,523/ha).

The average benefit-cost ratio (BCR) was calculated at 0.97 across all study areas, with the highest BCR (1.05) achieved in Bheramara. The rice yield was significantly affected by blast disease infection and increased production costs, influencing the net return per hectare. Furthermore, blast disease significantly curtailed yield in Mirpur, leading to reduced profitability.

The labor-intensive stages of rice

production were transplanting and harvesting, accounting for approximately 34.10% of the total production cost. These findings align with the research of Rashid *et al.* (2009) and Alam *et al.* (2018). The cost of rice was highest in Mirpur (Tk 28.79/kg), resulting in a lower BCR of 0.87, whereas the lowest price was observed in Bheramara (Tk 23.38/kg).

Table 4. Productivity and profitability of rice cultivation at farm level

Item	Mirpur	Bheramara	Kushtia Sadar	All Average
Yield (t/ha)	4.18	5.06	4.40	4.55
Price (Tk/kg)	20.43	19.96	21.14	20.51
Cost of rice/Kg	28.79	23.38	26.49	26.02
Rice straw (Tk/ha)	18712	23078	22455	21415
Gross return (Tk/ha)	104107	124084	115456	114549
Total cost (Tk/ha)	120341	118287	116566	118398
Total variable cost (Tk/ha)	79296	78047	77933	78425
Gross margin (Tk/ha)	24811	46037	37523	36124
Net return (Tk/ha)	(-)16234	5797	(-)1110	(-)3849
Benefit cost ratio (TC basis)	0.87	1.05	0.99	0.97
Benefit cost ratio (TVC basis)	1.31	1.59	1.48	1.46

Productivity and Profitability of Rice Cultivation at the Farm Level

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The labor-intensive stages of rice production were transplanting and harvesting, accounting for approximately 34.10% of the total production cost. These findings aligned with the research of Rashid *et al.* (2009) and Alam *et al.* (2018). The cost of rice was highest in Mirpur (Tk 28.79/kg), resulting in a lower BCR of 0.87, whereas the lowest price was observed in Bheramara (Tk 23.38/kg).

Table 5. Productivity and profitability of rice cultivation in different variety.

Item	BRRI dhan 28	BRRI dhan29	Miniket
Yield (t/ha)	4.29	6.14	4.24
Price (Tk/kg)	20.57	17.99	23.58
Cost of rice/kg	27.52	20.87	28.56
Rice straw (Tk/ha)	21505	21987	19960
Gross return (Tk/ha)	109737	132435	119945
Total cost (Tk/ha)	118058	128160	121080
Total variable cost (Tk/ha)	77569	84428	80379
Gross margin (Tk/ha)	32168	48007	39566
Net return (Tk/ha)	(-)8321	4275	(-)1135
Benefit cost ratio (TC basis)	0.93	1.03	0.99
Benefit cost ratio (TVC basis)	1.41	1.57	1.49

Productivity, cost and return of rice cultivation in different variety

The yield of BRRI dhan28, BRRI dhan29, and Miniket cultivar was found to be 4.29 t/ha, 6.14 t/ha, and 4.24 t/ha, respectively (Table 5). The total cost of BRRI dhan28, BRRI dhan29, and Miniket cultivar for rice cultivation was recorded at Tk. 1,18,058/ha, Tk. 1,28,160/ha, and Tk. 1,21,080/ha, respectively (Table 5). The total cost of BRRI dhan29 was higher due to increased labor, fertilizer, and irrigation costs. The highest gross return was estimated for BRRI dhan29 (Tk. 1,32,435/ha) owing to its higher yield, followed by Miniket cultivar (Tk. 1,19,945/ha) and BRRI dhan28 (Tk. 1,09,737/ha). The maximum gross margin (Tk. 48,007/ha) was obtained for BRRI dhan29 due to its higher yield, followed by Miniket cultivar (Tk. 39,566/ha) with its better pricing and fine quality.

The highest net return was observed at Tk. 4,275/ha for BRRI dhan29, while the lowest net return was found for BRRI dhan28 at (-) Tk. 8,321/ha, primarily due to its lower yield affected by blast disease. The highest benefit-cost ratio was recorded at 1.03 for BRRI dhan29, followed by Miniket cultivar (0.99) and BRRI dhan28 (0.93) based on the total cost. Clearly, rice cultivation of all varieties showed lower net returns/profits for BRRI dhan28. Furthermore, rice yield was significantly reduced by blast disease in all three varieties in each upazila, leading to decreased net returns per hectare. It is worth noting that the most severe yield loss occurred in BRRI dhan28 due to the devastating blast disease, resulting in decreased profitability.

Similar findings were observed by Mainuddin *et al.* (2021), highlighting the significant impact of market fluctuations in rice prices on overall profitability. The complementary effects of increased yield and profitability in rice cultivation were evident, as indicated in the study by Sayeed *et al.* (2018), underscoring the importance of enhancing profitable rice cultivation. Our study also underscores the substantial reduction in yield caused by rice blast disease, leading to severe losses.

Furthermore, Pasha *et al.* (2013) reported a significant 80% reduction in yield in severe cases of susceptible rice varieties, with 100% yield loss reported in Brazil (Prasad *et al.* 2009). These consistent findings were supported by Khush and Jena (2009) and Pinheiro *et al.* (2012). Naznin *et al.* (2019) conducted a study in the south-western region and estimated the average total cost of production for BRRI dhan50 at 105,815.62 ± 927.84 BDT/ha, with gross returns of 125,383.9 ± 3073.08 BDT/ha in Khulna district, focusing on cost and return analysis. Chanda *et al.* (2019) carried out a comparative analysis of rice production in Boro rice crop, reporting an average cost of production at Tk. 94009.67/ha, average yield of 5.96 t/ha, average gross returns of Tk. 196562/ha, and net returns of Tk. 102553/ha. Dash *et al.* (1995) also presented a similar pattern of analysis. These outcomes aligned with the results of Chanda *et al.* (2018), who conducted a study on Boro rice cultivation in Sirajganj district. The variations in rice production costs across locations can be attributed to factors such as land rent and labor costs, while gross returns were influenced by market rice prices. The higher benefit-cost ratio (BCR) observed was due to increased production of high-yielding varieties (HYVs) of rice in that specific area. However, our results differed from these findings, likely due to the combination of lower yield, lower prices, and higher production costs at the farm level.

Conversely, our study highlighted that in highly blast-affected areas of the three varieties across the three upazilas, both yield and production were achieved at a lower level, resulting in a reduced BCR.

MAJOR CONSTRAINTS TO RICE PRODUCTION AND MARKETING

Farmers were significantly impacted by the elevated costs of production, including labor, pesticides, irrigation, and the transplanting and harvesting systems. These escalated costs served as discouraging factors for rice production on their farms. Additionally, insufficient knowledge and skills in disease management, lack of mechanization, and a shortage of farm laborers emerged as prominent constraints affecting rice production. Among these, rice blast stood out as a particularly destructive disease, posing a major threat to rice cultivation and leading to substantial yield losses.

The challenge of securing fair and equitable prices for their rice in the face of the existing marketing system remained a constant struggle for farmers. The unpredictability of input prices in the market, along with concerns about adulteration, introduced a high level of risk to the reliability and sustainability of rice production for farmers. Furthermore, in certain areas of Kushtia district, farmers faced frustration due to inconsistent irrigation support provided by the Ganges Kobadak irrigation project, which hampered their rice production efforts.

Efforts to address these constraints and promote successful rice production would need to focus on mitigating cost burdens, enhancing disease management skills, implementing mechanization where feasible, and ensuring a more reliable and equitable marketing system.

CONCLUSIONS

Kushtia district holds a significant role in the country's Boro rice production. Variability was observed in Boro rice yield, production costs, gross benefits, and gross income, influenced by factors such as rice varieties, fertilizers, pest management, and labor expenses. Our study examined yield, productivity, and profitability of Boro rice across three upazilas, as well as among three varieties in areas heavily impacted by blast disease.

Evidently, Mirpur and BRRI dhan28 exhibited the lowest net returns per hectare and gross returns per hectare. Despite the severe blast disease impact, BRRI dhan29 emerged with the highest yield among the three varieties. Intriguingly, this variety displayed comparatively better yield and gross income due to reduced blast disease incidence. Miniket, another cultivar, demonstrated higher net returns attributed to its superior price and quality, particularly in cases of lower infection compared to BRRI dhan28.

Our findings underscore the pressing challenges of sustainable Boro production in the area, including elevated production costs, lower rice prices, and the destructive influence of blast diseases. Labor costs, constituting a lion's share of production expenses, primarily stem from transplanting and harvesting, accounting for about 34.10% of the total cost. This highlights the need to emphasize mechanization in these operations, offering profitability to rice production.

The study strongly emphasizes the paramount importance of blast-resistant rice varieties and effective blast disease management strategies for ensuring farmers' profitability and the long-term sustainability of rice cultivation. Simultaneous implementation of stable inputs and a resilient marketing system stands as essential steps for maintaining profitable rice production in Kushtia.

However, it is worth noting that the current study's scope is limited in assessing the effect of fungicides on blast disease management. Future endeavors should involve comprehensive economic analyses of blast-affected rice varieties and in-depth laboratory and field studies of rice blast pathogens to further refine our understanding and management of this critical disease.

AUTHORS' CONTRIBUTIONS

H M: Contributed to research design, data collection, and writing.
M S R: Played a role in methodology development, data analysis, and draft preparation.
M F A: Contributed to data evaluation and review.
U U: Involved in data compilation and sequencing.
I H: Contributed to manuscript writing, review, and editing.
All authors read and approved the final manuscript.

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The authors declare no competing financial interests.

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