ISSN 1025-7330

BANGLADESH RICE JOURNAL

VOL. 26 NO. 2 December 2022

BANGLADESH RICE RESEARCH INSTITUTE
GAZIPUR-1701, BANGLADESH

BANGLADESH RICE JOURNAL
(Bangladesh Rice J.)

ISSN 1025-7330

VOL. 26 **NO. 2** **Dec 2022**

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Bangladesh Rice J. 26 (2): 1-18, 2022, doi.org/10.3329/brj.v26i2. 66729

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.

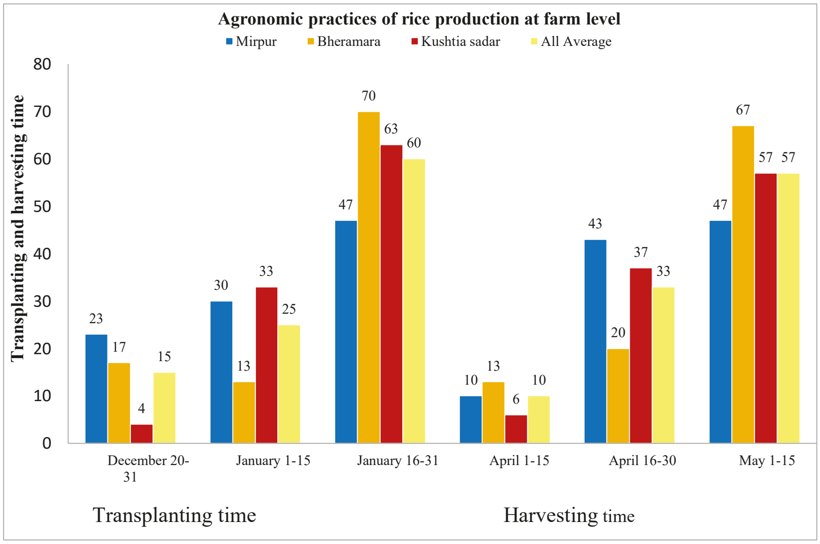

Fig. 1. Agronomic practices of Boro rice cultivation at study areas.

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.

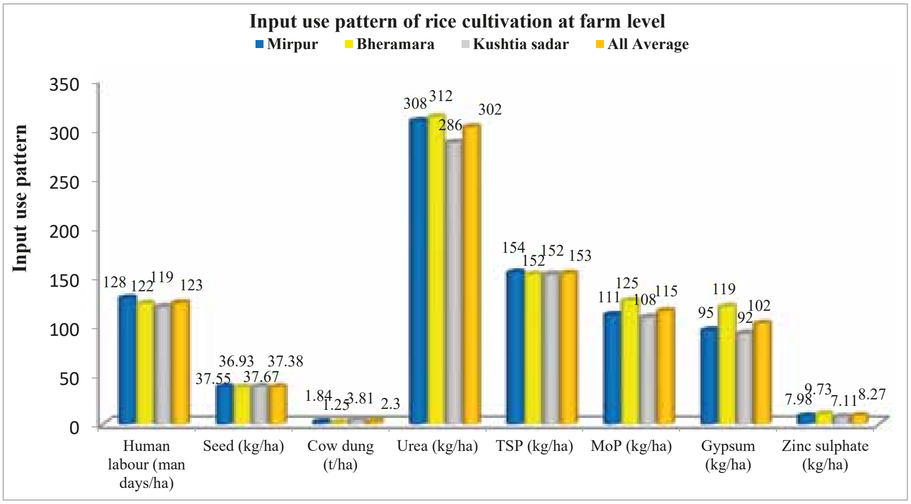

Fig. 2. Input use pattern of rice cultivation at farm level.

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.

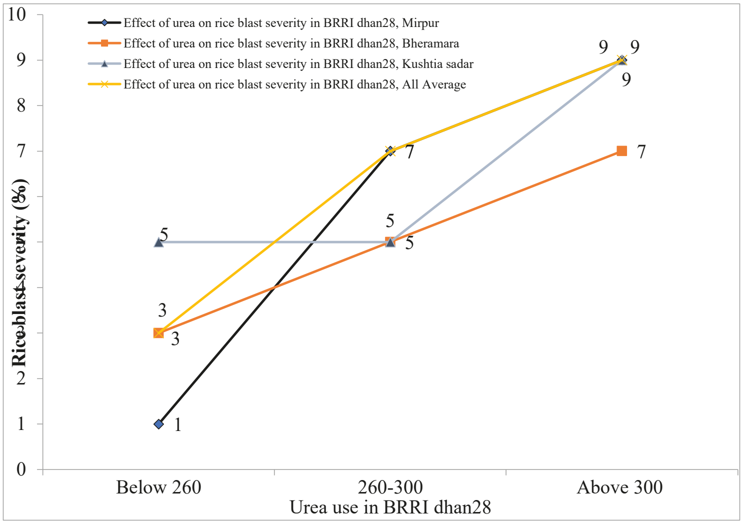

Fig. 3. Effect of urea on rice blast incidence in BRRI dha28.

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).

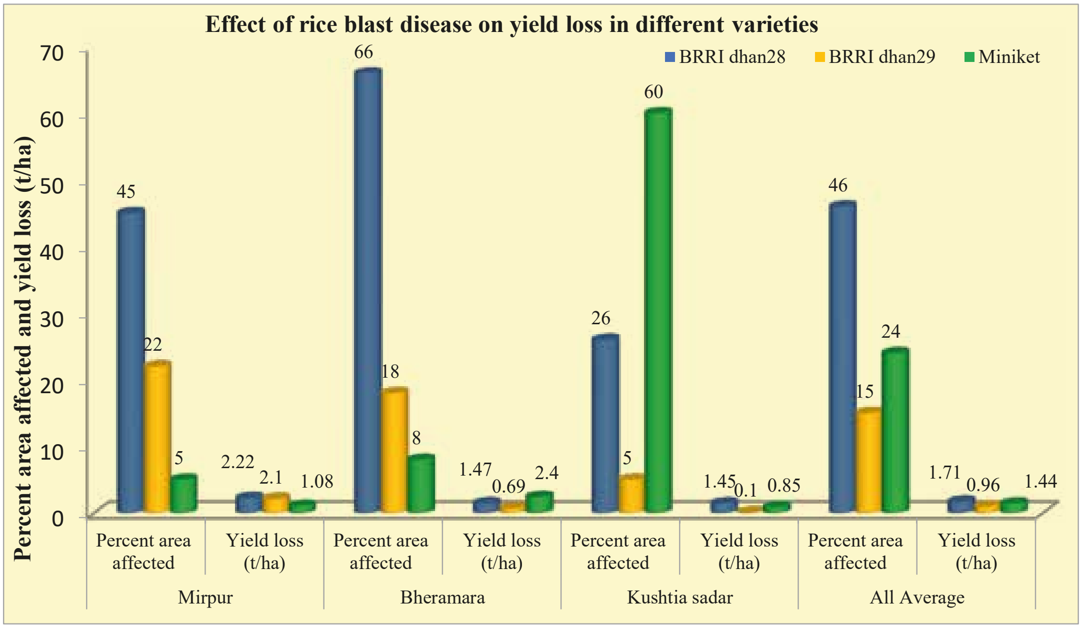

Fig. 4. Percent area affected by blast and yield loss.

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) Mean	Range	Yield (t/ha)	Spraying at severity scale
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.

FUNDING

This research was self-funded by the first author and did not receive any specific grants from public, commercial, or not-for-profit sectors.

DECLARATION OF INTERESTS

The authors declare no competing financial interests.

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Bangladesh Rice J. 26 (2): 19-39, 2022, doi.org/10.3329/brj.v26i2. 66731

Value Chain Analysis of Milled Rice Produce in Husking Rice Mill

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ABSTRACT

This study was aimed to identify the present status of rice milling, map and analyze milled rice along with associated constraints and recommend priority areas of interventions using primary and secondary data during the period of 2012-14. In a quantitative survey, stratified random sampling was used to identify respondents, while qualitative investigations involved focus groups and key informant interviews. About 15,500 husking mills, 650 semi-automatic mills, and 300 automatic rice mills are avaiable in Bangladesh. Husking mills still dominate the rice milling sector and it covers about 70% of total milled rice production. However, recent trends show that the husking rice mills fail to compete with modern automatic and semi-automatic rice mills in terms of quality finished products and market demand. In turn shifting to semi-automatic and automatic rice mills is going on. The milling capacity and capacity utilization of husking mills was found to be 0.8-1.0 th^{-1} and 34%, respectively. Milling cost, profit per ton of fine parboiled rice and BCR for husking were found to be Tk 2,601, Tk 3,637 and 1.4, respectively. The profit margin for parboiled fine rice processed in a husking mill was found to be 37.04%. Employment opportunities in terms of labour and staff requirement for husking mills were found to be 14.17 man hours per metric ton of paddy and 6.95 man hours per ton of paddy, respectively. Husking rice mills produce more broken, less head rice recovery and quality is less than automatic rice mills. Beside these, in husking mill bran and husk are mixed together that's not suitable for edible oil extraction and briquette production. In terms of quality of rice e.g. less broken rice, absence of stones and black kernels, brightness, colour etc, the rice mills having modern equipment produce higher quality rice, with higher market demand and higher profit making ability compared to rice mills having traditional equipment.

Key words: Value chain, husking rice mill, engelberg huller, BCR, technical performance.

INTRODUCTION

Rice is the most important crop, accounting for 80% of cropped land in Bangladesh and yielding approximately 36.60 million metric tons of clean rice from a total rice area of 11.40 million hectares (BBS, 2020). Different types of mechanized rice mills, popularly known as engelberg huller (traditional and husking rice mill), semi-automatic rice mills, and automatic rice mills process the majority of paddy produced in the country. The Directorate General of Food has classified three types of rice mills: husking, semi-automatic, and automatic rice mills, and enlisted with numbers to be 14239, 457, and 142, respectively (DG Food, 2007). In addition, the nation has about 100,000 traditional engelberg type rice huller mills. Traditional rice hullers, husking rice mills, semi-automatic rice mills and automatic rice mills employ a total of 1,00,000, 1,42,390, 13,710 and 6,248 workers, respectively. In Bangladesh, the rice milling sub-sector is still considered as an informal sector, with limited government facilities

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and incentives compared to the industrial sector.

Poor technical performance of milling machinery causes losses in the milling process, resulting in poor milling yields. About 90% of the produced paddy in Bangladesh is parboiled. The rubber-roll huller automatic and semi-automatic rice mill is processed about 20% parboiled and 10% of dry processed (unparboiled) paddy. Thirty per cent of the total paddy produced in the country is processed by households and does not come to market. The remaining 70% of paddy is processed in various types of medium to large rice mills (Dasgupta, 2001). The milling of rice in Bangladesh is mainly done by engelberg type steel huller and incurred a substantial amount of loss in recovery of head rice. In husking mills, bran and husk are also mixed in the milling process, and reduces the quality of rice bran. Instead of engelberg rice huller, the use of modern milling machinery could reduce 2-4 % of loss. Considering milling of about 27 million metric tons of paddy annually could increase the yiled of 0.648 million tons of milled rice that is almost a quarter of total whole rice import (Kabir, 2008). Baqui (2010) reported that there is a scope for saving food, on average 4.5 percent by using modern rubber roll milling technology. Hence, the total average national savings would be about 1.55 million tons per year.

Rice milling is an important sub-sector in Bangladesh, but very limited work has been done to determine the current status of this sub-sector in terms of business size, technology level and commodity value chains and processing machinery marketing chain. Over the last 40 years, Bangladesh's rice production increased significantly and this performance has been strongly linked to the high yielding varieties caused by the economic liberalisation of main input markets such as irrigation and fertilizers. (Ahmed, 2000; Hossain, 1998 and Hosain, *et al.*, 2006). Although rice production increased in recent years, resulting in self-sufficiency in rice food security, rice access to consumers has not yet been stabilized, and as a result, price fluctuations by days, hours and even minutes have become a common phenomenon. This means that the main concern of the rice supply chain is to determine the appropriate demand and meet it properly in a profitable manner. For effective sourcing, processing, distribution, and retailing, as well as meeting the customer requirements without facing any crises, a proper supply chain management framework is essential. The rice supply chain in Bangladesh is a focus for food security and climate change considerations. Bangladesh's rice supply chain is based on demand.

The implementation of a demand-driven supply chain is a difficult task (Selen and Soliman, 2002). Any consumer demand may trigger the execution of various activities by various contributors (Prahalad and Ramaswamy, 2000), making demand-driven supply chains highly dynamic and requiring various modes of cooperation, control, and coordination. Effective and sustainable supply chain management of rice milling systems should take into account not only total supply chain costs, but also inventory decisions and policy development.

The term "value chain" involves a wide range of activities required to take a product (or a service) from conception to delivery to final consumers and disposal after use (Kaplinsky, 1999; Kaplinsky and Moris, 2001). A systematic approach is urgently needed to analyze the rice milling value chains to identify the constraints and possible ways of improvement of the sub-sector and recommend a course of action for the policy makers. At this end, value chain analysis of the rice milling sub-sector would be an appropriate tool for

Rice is the most important crop, accounting for 80% of cropped land in Bangladesh and yielding approximately 38.86 million metric tons of clean rice from a total rice area of 11.677 million hectares (DAE, 2020). Different types of mechanized rice mills, popularly known as engelberg huller (traditional and husking rice mill), semi-automatic rice mills, and automatic rice mills process the majority of paddy produced in the country. The Directorate General of Food has classified three types of rice mills: husking, semi-automatic, and automatic rice mills, and enlisted with numbers to be 14,239, 457, and 142, respectively (DG Food, 2007). In addition, the nation has about 100,000 traditional engelberg type rice huller mills. Traditional rice hullers, husking rice mills, semi-automatic rice mills and automatic rice mills employ a total of 1,00,000, 1,42,390, 13,710 and 6,248 workers, respectively. In Bangladesh, the rice milling sub-sector is still considered an informal sector, with limited government facilities and incentives compared to the industrial sector.

Poor technical performance of milling machinery causes losses in the milling process, resulting in poor milling yields. About 90% of the produced paddy in Bangladesh is parboiled. The rubber-roll huller automatic and semi-automatic rice mill is processed about 20% parboiled and 10% of dry processed (unparboiled) paddy. Thirty per cent of the total paddy produced in the country is processed by households and does not come to market. The remaining 70% of paddy is processed in various types of medium to large rice mills (Dasgupta, 2001). The milling of rice in Bangladesh is mainly done by engelberg type steel huller and incurred a substantial amount of loss in recovery of head rice. In husking mills, bran and husk are also mixed in the milling process, and reduces the quality of rice bran. Instead of engelberg rice huller, the use of modern milling machinery could reduce 2-4 % of loss. Considering milling of about 27 million metric tons of paddy annually could increase the yieled of 0.648 million tons of milled rice that is almost a quarter of total whole rice import (Kabir, 2008). Baqui (2010) reported that there is a scope for saving food, on average 4.5 percent by using modern rubber roll milling technology. Hence, the total average national savings would be about 1.55 million tons per year.

Rice milling is an important sub-sector in Bangladesh, but very limited work has been done to determine the current status of this sub-sector in terms of business size, technology level and commodity value chains and processing machinery marketing chain. Over the last 40 years, Bangladesh's rice production increased significantly and this performance has been strongly linked to the high yielding varieties caused by the economic liberalisation of main input markets such as irrigation and fertilizers. (Ahmed, 2000; Hossain, 1998 and Hosain, *et al.*, 2006). Although rice production increased in recent years, resulting in self-sufficiency in rice food security, rice access to consumers has not yet been stabilized, and as a result, price fluctuations by days, hours and even minutes have become a common phenomenon. This means that the main concern of the rice supply chain is to determine the appropriate demand and meet it properly in a profitable manner. For effective sourcing, processing, distribution, and retailing, as well as meeting the customer requirements without facing any crisis, a proper supply chain management framework is essential. The rice supply chain in Bangladesh is a focus for food

Table 1. Sample distribution of rice mill for survey.

Rice mill	Covered			
	Dinajpur	*Kushtia*	Mymensingh	Total
Husking rice mill	*22*	*21*	22	65

Table 2. Sample distribution for main actor for survey.

Actor	Dinajpur	Kushtia	Mymensingh	Total
Paddy aratdar	10	08	10	28
Rice whole saler	12	10	08	30
Rice retailer	20	12	10	42

Survey questionnaire

Semi-structured questionnaires were prepared with active consultations of key informants, experts from the relevant areas and secondary information according to the objectives of the study. Two sets of semi-structured questionnaires were also developed to assess the status (services required, service providers, etc) of demand and supply side of Business Development Services (BDS). Furthermore, a checklist was developed for KIIs. The draft questionnaires and the checklist have been pre-tested and the required changes, additions and modifications have also been made.

Data collection method

Data were collected by personal interview through semi-structured questionnaires and Focus Group Discussions (FGD). During the interview each question was explained to the respondent clearly and tried to find out facts as much as possible. Appropriate participatory tools and techniques were used in FGDs.

Techniques applied

A simple descriptive statistical method was used for analyzing data. Data were analyzed in Excel format separately, computed the operational cost of rice mills from primary and secondary sources. The Excel format allows for quick and easy changes or refinements to any data, as well as the automatic calculation of operational costs for such changes or refinements in the Excel computation mode.

Data collection on present status of engelberg huller milling in Bangladesh

A semi-structured questionnaire was used to collect information on the current status of rice milling by engelberg huller. Ownership status, existing items, types of milling machineri used in the mill section, and overall cost of mill/mill section for commissioning were also collected. Cleaning, soaking, steaming, drying, milling, and other operations were also studied, as well as capacity utilization and rice milling recovery.

Capacity utilization

Capacity utilization is one of the important dimensions for assessment of market performance of any industry. An attempt is made to assess the performance by using the total processing capacity and the actual amount processed last year by the selected mills.

Capacity utilization of the selected mills of the paddy processing industry was computed by using the following formula:

$$\frac{\sum_{i=1}^{n}(PC)i}{\sum_{i=1}^{n}(AC)i}$$

Where

(PC)i stands for actual processing capacity of ith mill

(AC)i stands for installed capacity of the mill

n= number of rice mills

Value chain analysis

This study's value chain approach to rice milling in Bangladesh is designed into nine steps (Fig.1).

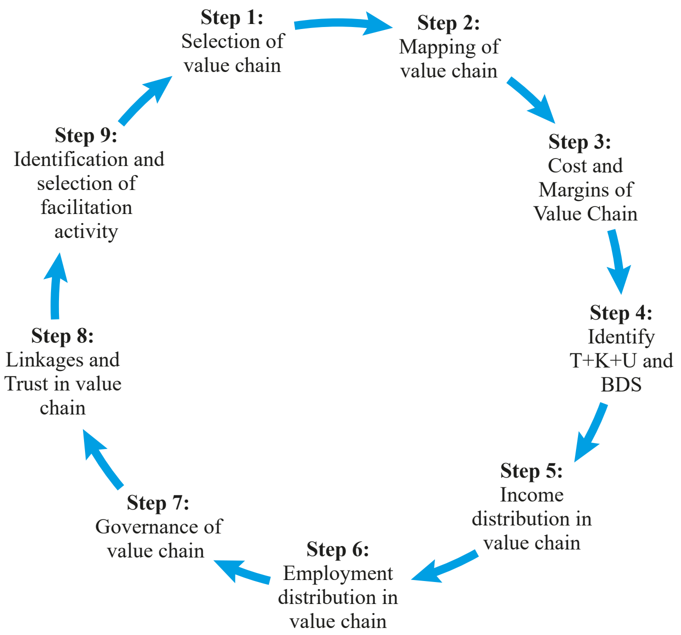

Fig. 1. Steps in value chain Business Service Approach to programme design.

The selection of value chains is the first step of the process. Step two starts with value chain mapping, which illustrates all of the major actors in rice milling value chains in a graphical format. Step three, analyzes the cost and margins of rice milling value chain. Step four, begins with the upgrading of knowledge, skill and technology. In this step, a detailed interview with relevant actors will identify different knowledge, technologies and skills, as well as constraints of actors at different levels of the value chain. Step 5 involves understanding the distribution of income in the value chain and the way income is distributed across actors in the value chain and identifying income generation opportunities. Step six, deals with employment distribution of value chain. Step seven and step eight, concerns the linkage and trust in identifying the reasons for the linkage, and whether the linkages are beneficial or not for the value chain for the rice milling. Step nine deals with the identification and selection of facilitation activities.

Identifying value chains for analysis

Selection of the value chain was done in active consultation with key informants such as, professor, researcher, rice mill owner/manager, rice mill machinery importer and manufacturer. The selected value chains are; fine rice value chain, coarse rice value chain. For value chain analysis one Engelberg huller mill was selected for in depth study and the rice mill situated in Gouripur of Mymensingh district. Selected rice mill was analyzed for cost and margin of fine rice and coarse rice value chain. In this case, milled rice products of individual mills was selected.

Mapping the value chains

A value chain map illustrates all of the major actors in the rice milling value chain in graphical form. It depicts the core processes, main actors involved in the processes, product flows, related knowledge and information flows, product volume, relationships and linkages among value chain actors. Focus group discussions (FGDs) and informal interviews with value chain actors were used to map value chains.

Analyzing costs and margins in the value chain cost analysis

In this study economic profitability of rice processing was estimated based on economic analysis considering the fixed cost (depreciation, interest, taxes, insurance etc of the machine and land) involve in rice milling were calculated by the following equation as described by Hunt (1995) and Kepner *et al.* (1978) and variable costs (labour, repair and maintenance, electricity, management cost, stuff salary etc.) also taken in consideration.

(a) Annual depreciation, $D = \frac{P - S}{L}$ (1)

Where, D = depreciation, Tk/yr, P = Purchase price of machine, Tk, S = Salvage value of machine, Tk and L= life of the machine, year. In this study, salvage value is assumed as 10 percent of the purchase price.

(b) Interest on investment, $I = \frac{(P + S)\,i}{2}$ (2)

Where, P= Purchase price, S = Salvage, i= Interest rate

Taxes

The cost of taxes was considered as 1.4% purchase price of the machine and equipment.

(c) Taxes, T = 1.4% of P (3)

Insurance

The cost of insurance was considered to be 0.25% of purchase price of the machine and equipment.

(d) Insurance, Ins. = 0.25% of P (4)

Where, Ins.=Insurance, Tk/yr, P=Purchase price of machine and equipment involved, Tk

Total fixed cost of machinery=*(a+b+c+d)* (5)

Benefit cost ratio

For profit contexts, a BCR may be used as a profitability measure. The benefit cost ratio (BCR) compares the amount of money saved by completing a project to the amount it costs to complete the project. BCR =Discounted value of incremental benefits/Discounted value of incremental costs.

Upgrading knowledge, skills, technology and business development services

The gap between the quality demanded by the consumer and the current quality offered to the consumer by various segments of producers was studied using this method. Additionally, an opportunity for upgrading knowledge, skill and technology was identified, as well as potential service providers to make the appropriate upgrading accessible and possible were mapped.

Analyze constraints related to knowledge, skills and technology in the processes of the value chain

In this stage different types of knowledge, technologies, and skills were used, as well as constraints faced by actors at various levels of the value chain were identified through in depth interview of the relevant actors. Technology/product growth, market access, input supply, management and organization, regulation, finance, and infrastructure were all classified as constraints.

Identification of business services

After identifying and noting a constraint during the interview, the interviewer asked the actor if there are any services that currently or theoretically, address that constraint. These services have been noted. Business services were defined in this way as being directly related to value chain

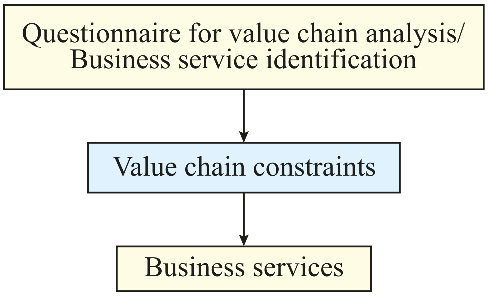

Fig. 2. Flow of information from the value chain questionnaire.

Selection of business services

The identified business services are shortlisted and prioritized in order to select those that will be subjected to a more detailed analysis. An "attractiveness" matrix tool was used to create short lists of business services. This matrix ranks business services based on two major criteria: a) the potential for the service to increase the target group's income, and b) the potential for the service to attract a significant number of customers. The highest priority was given to business services that fell within a pre-determined "attractive" range.

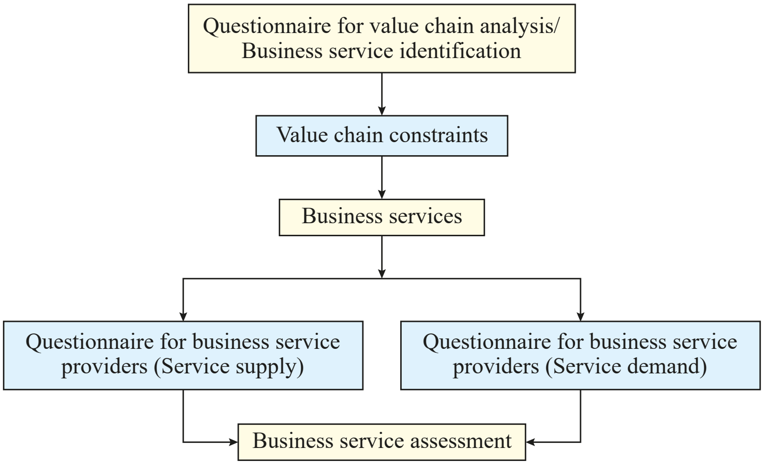

Fig. 3. Flow of information for Business Service Assessment

Regarding the selection of the business services to target, they are subjected to a more detailed investigation. Existing providers, market size and penetration, frequency of usage, demand and supply side constraints and opportunities, satisfaction with service, awareness of the service, proposed providers to aim for interventions and feasibility of the service were all compiled and analyzed for each targeted service (how costs for the service are covered). Fig. 3 depicts the method.

Analyzing Income distribution

Understanding how income was distributed through the value chain offers the requisite start to identify opportunities for income generation. An actor in value chain may be involved in several income generating activities within or different value chains. As a result, the sum of various actors' sources influences their livelihood strategies, and any analysis must take into account. The value chain study was compare income distribution of different actors in a value chain and different value chains.

Analyzing employment distribution

Understanding how employment were distributed throughout the value chain provides the necessary start to identify employment opportunities. The comparison of employment across various levels in a value chain will be carried out to provide an overview of the employment distribution and benefits for individuals at each level of the value chain.

Governance: Coordination, regulation and control

The goal of governance analysis is to look at the rules that regulate a value chain, as well as the system of coordination, regulation, and control that governs how value is created along the chain. Both the “official” laws that address output and the commercial imperatives of competition that influence how production is structured are referred to as governance. Types of rules and regulations, enforcement agencies and sanctions, knowledge and awareness gaps and BDS provisions will be identified through interview and FGDs with concern actors.

Linkages and trust

Linkage analysis involves not only determining which organizations and actors are linked to one another, but also determining why such linkages exist and whether they are beneficial or not. Actors in the value chain form links with one another primarily for the good of such relations. Business linkages are the most common within a value chain, and they may be formal or informal. The formal linkage is to the domain of social capital, where trust can play a key role. Interviews with related value chain actors will be conducted to determine their linkages and trustworthiness with other chain actors. First, a list of key actors in the value chain will be created. Second, a survey instrument was developed with a set of questions on linkages and trust.

Identification and selection of facilitation activities

The value chain approach used a one-day workshop with value chain actors (faria, bepari, aratdar, millers, wholesalers, retailers, and others) to identify facilitation interventions for selected business services. The workshop's key goals were to: 1) validate the assessment of business services in value chains, and 2) propose market-development interventions for those services. Following the development of a list of potential interventions, each intervention was assessed against specific criteria established by each implementing organization.

RESULTS AND DISCUSSIONS

Present status of rice milling

According to Rice Mills Owners Association there are about 17000 rice mills in the country. About 200 semi-automatic and automatic rice mills existed in 2005. In 2011, the number more than tripled, to about 600. The field survey of this research and Rice Mill Owners Association reveal that, there are 15,500 husking mills, and the number of semi-automatic and automatic rice mill in 2015 was estimated more than 950. Husking mills owner say, this mill at present have control over two-third of the market. Because of the increasing demand of automatic rice mill processed rice, it is projected that the share will be half of the total processed rice within couple of years.

Husking mill

Husking mills have drying floor for sun drying of rice, well-built godown, traditional drum boilers for steaming and boiling house. The process involves cleaning of paddy, soaking, steaming, steeping, sun drying, milling with engelberg huller, aerating and bagging. Boiler in husking mills is not standard. There was no system of measuring steam pressure and consequently, over and under steaming often affects the quality of rice. Steeping in this system consumes much time. Drying is not uniform as it is done on yard by sun. Engelberg huller produces more broken and under polished rice. Bran and husk are also mixed together. Rice produced in this system has less storage value and vulnerable to insect-pests and micro-organism, and off-coloured within a short period. Fig. 4 shows the low diagram.

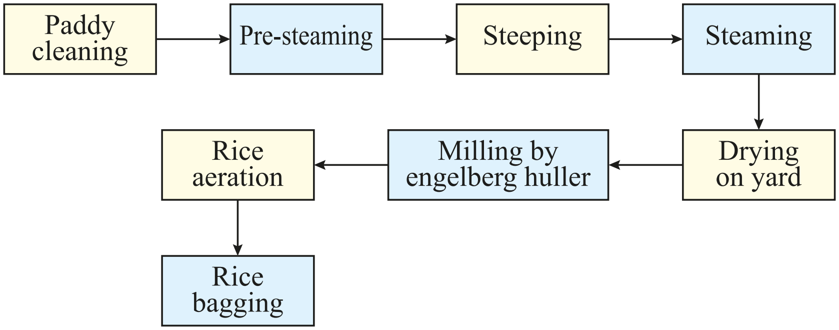

Fig. 4. Flowchart of a husking mill operation in Bangladesh.

Milling cost and recovery of rice for Husking rice mill

Table 3 shows the milling cost and recovery per ton of whole rice (fine and coarse).

Table 3. Milling cost and recovery of fine and coarse rice for engelberg huller rice mills

Type of rice mill	Type of rice	Milling cost, Tk /ton of rice	Whole rice recovery %
Husking	Fine rice	2601	65.0
	Coarse rice	2519	67.5

In Table 3, it was found that, fine rice processed in husking mill required Tk 2,601 to produce one ton of rice and whole rice recovery was 65%. Similar milling recovery (66%) was found in air blow type engelberg huller (BRRI, 2013-14) and (BRRI, 2015-16). However, the market price of rice processed in rice mill having modern equipment is higher than the other rice mills. The operating cost of husking mill was found Tk. 2601; this happened due to small amount of paddy is processed by husking mill. In Table 3, it was found that, for coarse rice, the operating cost for husking mill was Tk 2,519 and whole rice recovery was 67.5% for producing one ton of rice. Kibria (2018) reported that, automatic rice mill operating cost was found Tk 2,522 that's, almost same of the husking mill operating cost, because the capacity of husking mill is low compared to automatic rice mill.

Milling capacity of husking (engelberg) rice mill

Milling capacity indicates the amount of rice processed in a specified time. The capacity of mills is expressed in terms of clean rice. Table 4 shows the milling capacity of the husking rice mill.

Table 4. Milling capacity of husking rice mill.

Type of rice mill	Capacity (th^{-1})
Husking mill	0.8-1.0

Results showed that the capacity of husking rice mills were 0.8-1.0 th^{-1}. Baqui (2010) found that, the capacity of husking rice mills was found less than 1.0 t/h; similar results were observed for husking rice mill in BRRI (2013-14). Capacity depends on operator efficiency, machine efficiency and also feeding rate of materials.

Capacity utilization

Processing capacity utilization of rice mills was computed on the basis of average use in a year and table 5 shows the results.

Table 5. Capacity utilization of husking rice mills

Type of mill	No. of mills	Actual capacity (metric ton)	Capacity utilized (metric ton)	Capacity utilization (%)
Husking	20	38016	12672	34

The capacity utilization of husking rice mills was found to be 34% (Table 6). Raha *et al.* (2012) found that the capacity utilization of husking, semi-automatic and automatic mill was 54%, 52% and 56%, respectively. In case of husking and semi-automatic rice mills, it operates with a limited amount of paddy, does not operate round the year, technology varies from mill to mill, use of older technology, and inefficient operators may have influenced the capacity utilization.

Selection of value chain

There are several methods for selection of value chain, in this study, milled rice value chains were identified in active consultation with value chain practitioners, university professors, researchers from various organization, rice mill owners and rice mill association. In Bangladesh, 90% of total production of rice is parboiled and the rest 10% is un-parboiled including aromatic rice. Depending on the status of rice milling and consultation of the relevant two value stakeholders two value chains were identified for milled rice:

- Fine rice value chain
- Coarse rice value chain.

Mapping the core processes in the value chain

It includes major processes that raw materials go through before they enter the final consumption stage, such as the provision of raw material inputs. Paddy production was followed by paddy collection and trade, processors, wholesale marketing, retail marketing, and finally consumer marketing (Fig.5).

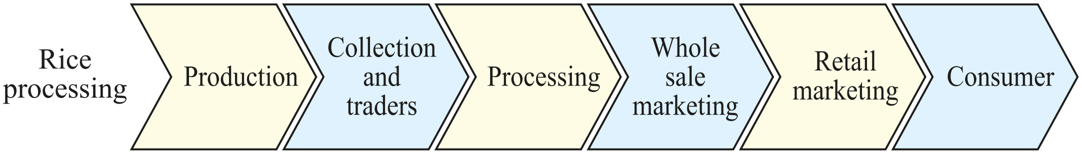

Fig. 5. Core process of fine and coarse rice value chain.

Identifying and mapping the main actors involved in the process

The people involved as main actors in the value chain were identified. The most obvious distinction was between categories of actors based on their main occupation. The main actors were identified and mapped based on their main occupation. The main actors for fine and coarse rice value chain are rice farmers, rice faria/ bepari/aratdar/commission agent, rice miller, rice wholesaler and rice retailer etc. (Fig.6).

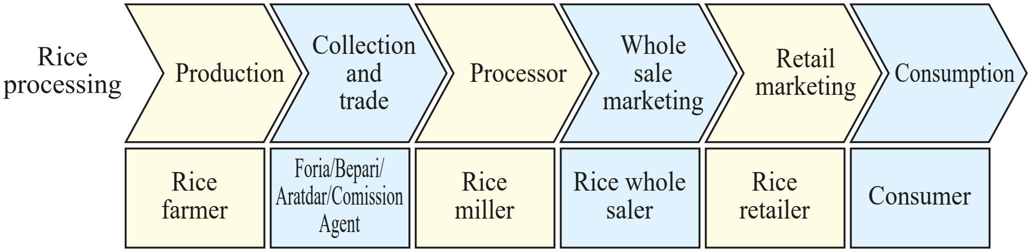

Fig. 6. Main actors in fine and coarse rice value chain.

Analyzing costs and margins of the value chains

In this study economic profitability of rice processing was determined based on economic analyses considering the fixed and variable costs involved in rice milling. Two types of value chains were analyzed, they are; fine rice value chain, course rice value chain;

Fine rice value chain

In the fine rice value chain husking rice mills were analyzed for the value addition considering every step of rice processing of fine rice.

Value addition of parboiled fine rice processing in husking mill

The value chain analysis of parboiled fine rice processed with husking mill indicated that husking miller (64.91%), retailing (15.41%) and wholesaling (14.55%) constituted the major value additions, while commission agent's value addition was only 4.72% (Fig. 7).

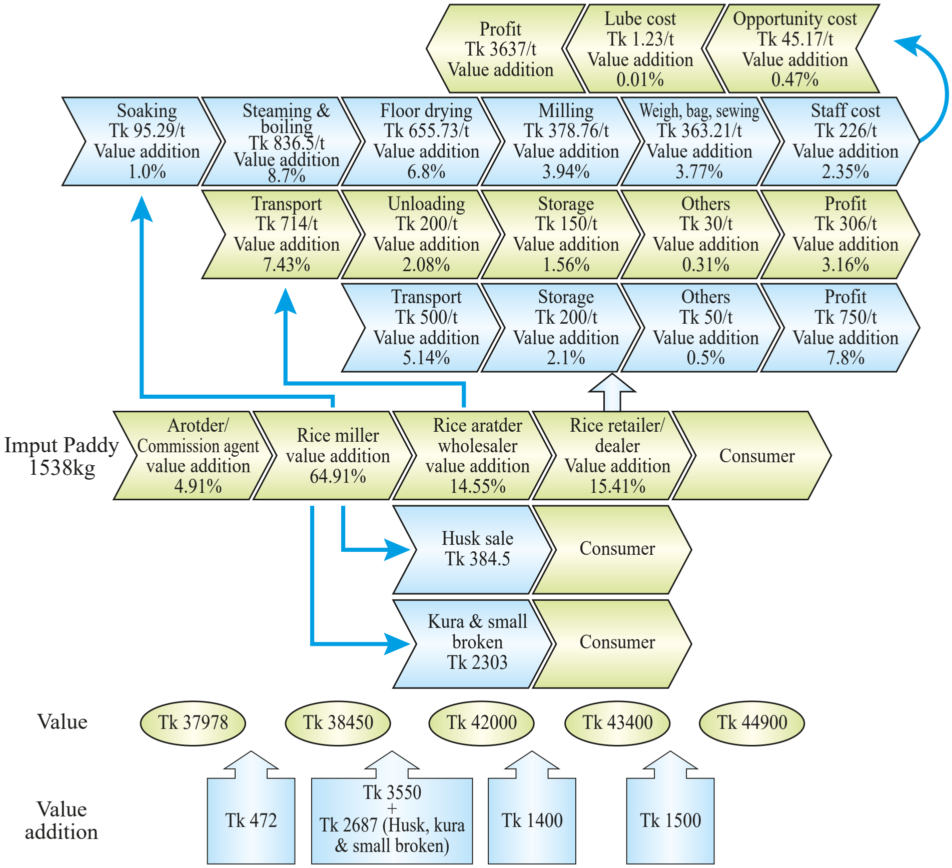

Fig. 7. Value addition of parboiled fine rice in husking mill.

The initial value of 1,538 kg paddy equivalent to one ton of clean rice was Tk 37978, and retailing price was Tk 44,900. Rice miller adds major value in the chain. The value addition at the husking mill consisted of Tk 3,550 in the processing and Tk 2,687 by selling husk, kura and broken rice. The value addition occurred 1% in soaking, 8.7 % in steaming and parboiling, 6.8 % in floor drying, 3.94% in milling, 3.77% in weighing, bagging and sewing, 2.35% in stuff cost, 0.47% in opportunity cost and 0.01% in lubrication cost.

Milling cost, by product selling cost and benefit-cost ratio of parboiled fine rice processing

Table 6 shows milling cost, by product selling price and benefit cost ratio of parboiled fine rice.

Table 6. Comparative milling cost, by product selling price and benefit cost ratio for parboiled fine rice.

Type of rice mill	Milling cost, Tk/ton of rice	Profit, Tk/ton of rice			BCR
		Rice milling	Byproducts' (husk, bran and broken rice)	Total	
Husking	2601	949	2688	3637	1.40

Milling costs and profit margin per ton of rice was found Tk. 2601 and Tk. 3667, respectively for traditional husking rice mills. Interestingly, by-products such as husk, bran and broken rice contribute significantly to the profit margin of the husking rice mills. The husk is being used as fuel for boilers and dryers in the rice mills, making briquette as bio-fuel and as poultry and dairy feed. The estimated BCR for husking rice mill was found to be 1.40.

Coarse rice value chain

In the coarse rice value chain husking rice mill was also analyzed for the value addition considering every step of rice processing of coarse rice.

Value addition in parboiled coarse rice process in husking mill

The value chain analysis of parboiled coarse rice processed with husking mill indicated that miller (64.50%), retailing (15.46%) and wholesaling (14.27%) constituted the major value additions. Value addition at commission agent was 4.55% (Fig. 8).

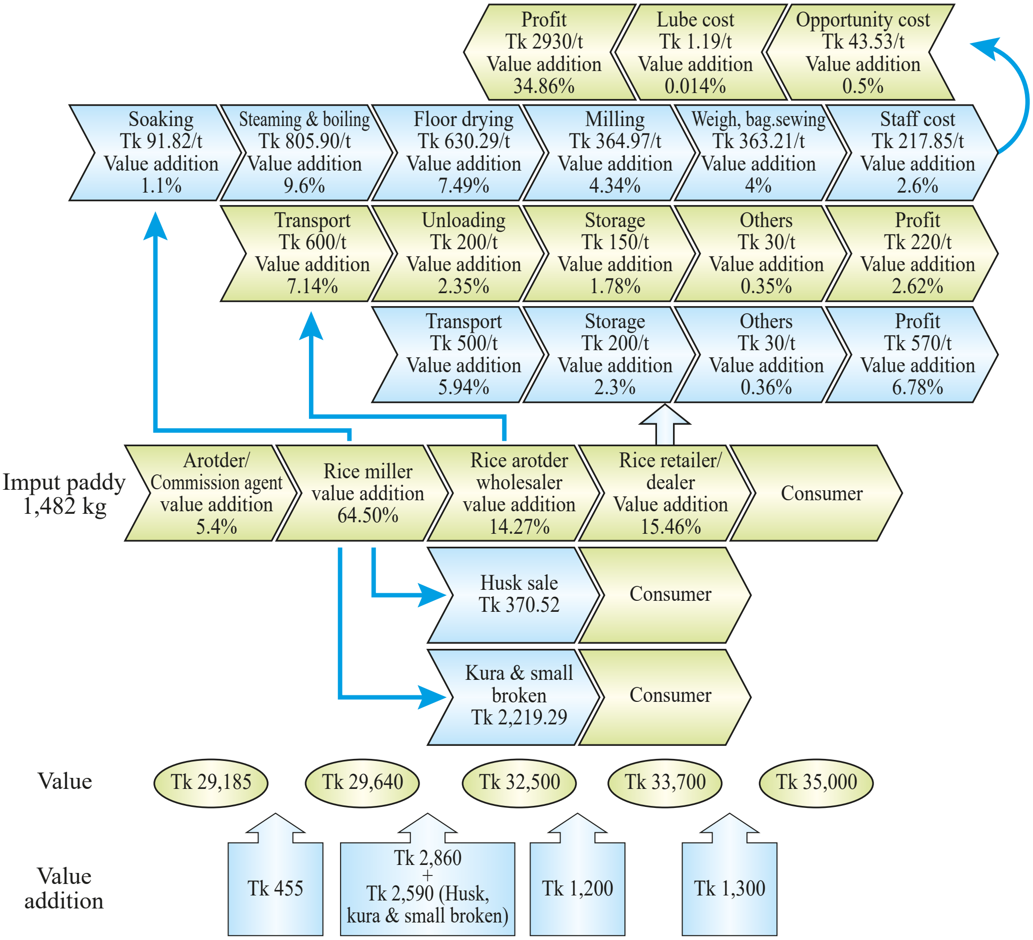

Fig. 8. Value addition of parboiled coarse rice in husking rice mill .

Price of 1,482 kg of paddy equivalent to one ton of clean rice was Tk 29,185, while the retailing price was Tk 35,000. Value additions at Miller's level were Tk 2,860 in the processing and Tk 2,590 by selling husk, kura and broken rice. Value addition contributed 1.09% in soaking, 9.6% in steaming and parboiling, 7.49% in floor drying, 4.34% in milling, 4% in weighing, bagging and sewing, 2.60% in stuff cost, 0.5% in opportunity cost and 0.014%in lubrication cost. Value addition at wholesale level consisted of 7.14% in transport, 2.35% for unloading and 1.78% in storage. The retailer value addition included 5.94% in transport, 2.3% in storage and 0.3% other cost.

Milling cost, by product selling cost and benefit-cost ratio of parboiled coarse rice processing

Table 7 shows omparative milling cost, by product selling price and benefit-cost ratio of parboiled coarse rice.

Table 7. Comparative milling cost, by product selling price and benefit cost ratio for parboiled coarse rice.

Type of rice mill	Milling cost, Tk t^{-1} of rice	Profit, Tk t^{-1} of rice			BCR
		Rice milling	Byproducts' (husk, bran and broken rice)	Total	
Husking	2519	341	2590	2930	1.16

Milling costs and profit margin per ton of rice in traditional husking rice mill was found Tk 2,519 and Tk 2,930, respectively. Interestingly, byproducts such as husk, bran and broken rice contribute significantly in profit margin of husking rice mill. The estimated BCR was found 1.16 in husking rice mill.

Constraints of rice mills

The major constraints that were identified through in-depth interviews of the sub-sector actors (traders, millers, wholesalers, retailers, government and non-government organizations, agencies and institutes) and key informant interviews are presented in the subsequent sections.

- Inadequate skilled manpower in operation and maintenance of rice mills; fabrication of rice mill machines and equipment, management and accounting at rice mill level resulting in poor sub-sector productivity: Due to change in market demand the husking rice mills are becoming inappropriate in terms of financial assessment
- Lack of market linkages for small farmers, traders, and processors with large urban markets
- lack of convenient access to the financial market by farmers, small traders, and processors resulting in little or no gains from economy of scale. Lack of adequate appropriate drying and storage facilities resulting loss of revenue from sales of rice by farmers' and traders' during harvesting season
- lack of steady electricity supply to rice mills' the production is hampered rice was hijacked and looted during transport, that demotivated the millers. Increased transport cost in peak season resulting in low profit margin to rice mill owners
- Lack of modern technology at husking and traditional rice mills resulting in huge loss of rice and poor quality of products

Business service provisions, providers, their constraints and opportunities

Business development services associated with the sub-sector are identified. The research further investigates the constraints associated with the business services and the results were summarized. The research identified the most potential BDSs to target for interventions. The public sector effort to encounter the sub-sector constraints is very insignificant. The public sector institutes such as, PTI, VTI, DYD, BRRI, BARI, BUET, BAU, RDA etc. are providing limited skill training and technological information. The emergence of this sub-sector is a recent event and the public sector institutes like PTI, VTI, and DYD etc are not aware of the requirement of this sub-sector. Therefore, these institutions have mobilized very limited resources to address the needs of this sub-sector. On the other hand, institutions like BRRI, BARI, BUET, BAU, RDA etc are mainly involved in research and education in the sub-sector, and lacking of adequate capacity for training a huge mass. Regarding dissemination of technological information, the institutes are lacking of adequate networking with the grass-root level entrepreneurs. Private sector repair and maintenance workshops are providing most of the skill mechanics through apprenticeship. However, these private workshops are lacking of modern technologies and related skills. Some private training institutes such as MAWTS (Dhaka), MATI (Bogura), CCTS (Jashore) and similar local enterprises are offering skill training on fabrication and machining, and operation, repair and maintenance of machinery and equipment, but their capacities are very limited. However, these programmers are lacking of continuity and mostly unable to fulfil the expectation of the sub-sector.

The entrepreneurs are also facing difficulty in recovery of credits, and frequently suffering from inadequacy of working capital. Market information is usually flow among the actors of the supply and value chains as embedded service, and mostly limited to product quality and market demand. Information related to new technologies, product development etc is still beyond the usual activities of these channels. The associations of manufacturers and traders are offering limited assistance to recovery credits, but these organizations are not strong enough to support whole range of credit recovery activities. NGOs, government and private banks are providing credits to the sub-sector actors, but the cumbersome processes of gaining credit keep most of the small size entrepreneurs away from such services.

Income distribution in parboiled fine and coarse rice value chain

Parboiled fine rice processed with husking mill, the profit margins were Tk 347 (3.61% value addition at this level) for aratdar, Tk 3,637 (37.84%) for miller, Tk 306 (3.18%) for wholesaler and Tk 750 (7.8%) for retailer (Table 8).

Table 8. Income distribution in parboiled fine rice value chain.

Type of rice mill	Type of Rice	Income (Tk)			
		Aratder	Miller	Wholesaler	Retailer
Husking	Fine	347 (3.61 %)	3637 (37.84 %)	306 (3.18 %)	750 (7.8 %)
	Coarse	335 (3.98 %)	2990 (34.86 %)	220 (2.62 %)	570 (6.78%)

Parentheses indicates percent of value addition.

Parboiled coarse rice processed with husking mill, the profit margins were Tk 335 (3.98% value addition at this level) for aratdar, Tk 2,990 (34.86%) for miller, Tk 220 (2.62%) for wholesaler and Tk 570 (6.78%) for retailer (Table 8).

Employment distribution in rice mill

Table 9 shows the employment distribution in husking rice mill.

Table 9. Employment distribution in husking rice mill.

Type of rice mill	Employment					
	Labour, Tk/ton of paddy	Staff cost, Tk/ton of paddy	Labour, man-hr/ ton of paddy	Labour, man-days/yr	Staff, man-hr/ton of paddy	Staff, man-days/yr
Husking	403	147	14.17	2232	6.95	1095

The cost of labour and staff per ton of paddy process in husking rice mill was estimated as Tk 403 and Tk 147, respectively (Table 9). Kibria (2018) reported that staff cost was found in modern automatic rice mills (Tk 101 per ton of paddy processing) mainly because of its higher capacity and automation. In terms of employment opportunity, a husking mill utilized 2232 man-days per year and labour requirement in husking rice mills was found 14.17 man-hr/ton of paddy processing (Table 9). On the other hand, employment in terms of staff, a husking mill utilized 1,095 man-days per year and required 6.95 man-hr/ton of paddy processing.

Governance: coordination, regulation and control

Mechanized rice milling started in this part of the sub-continent quite a long time back and is regulated by a similarly old legal instrument titled "The Bengal Rice Mills Control Order, 1943", which came into force on 20th December 1943. During that time single pass rice mills an adaptation of the "Engelberg " coffee hulled was popularly used for milling parboiled rice. In 2008, Food and Disaster Management ministry's, S.R.O. no. 217-law/2008 entitled "Control of Essential Commodities Act, 1956 (E.P. Act. No.1 of 1956) section 3, by dint of this act the government ordered a notification named "Rice procurement and control act 2008. These acts replace the "Bengal Rice mill control order-1943. In the act 2008, it was noticed that,

- Nobody can mill rice with power operated machinery, and cannot buy or sell paddy or rice or rice product without the license of government.
- Government time to time procures rice from licensed rice mills and millers are bound to supply rice as per its need.
- Licensed millers only mill paddy and cannot mill any other products without the prior permission of the government.
- Millers will report to district controller of food after every 15 days' interval about his milling amount, sell, storage and stock and he also report about the position of his store.
- Millers cannot change their business without the concern of government
- Millers buy paddy only the place which written in the license and they cannot buy paddy from other place.

The limitation of the notification "Rice procurement and control act 2008" is that there is no guide line about the quality of parboiled rice. Beside this, by this notification government fixed paddy buying areas in the license, which is not maintainable for the millers at present, rather they are buying paddy from all over the country. There is another issue in the notification that government would not buy rice from husking mills because of less quality and more loss during milling compared to semi-automatic and automatic rice mills that are operating in the country in large number. When government procures rice from mill, they prescribe in written form to the millers that rice should be well milled, no chalkiness in the belly of rice, well boiled, moisture content should be 14% or less, broken rice not more than 1%, dead or black rice not more than 1%, however, most millers unable to comply this. Moreover, the admissible moisture content (14%) is not suitable for long term storage. There are rice quality standards specified by BSTI, however, the millers do not follow the standard. They only separate very small broken rice and market it as dairy and poultry feed and as well for human consumption. The price of broken rice is almost half of the whole rice.

Policy intervention for improving rice milling sub-sector

The following interventions are suggested to achieve adequate benefit from rice mills

- Encourage use of modern postharvest processing technologies such as de-stoner, rubber roll de-husker, polisher, colour sorter etc for processing paddy.
- Considering the market, the husking mill should be modernized to semiautomatic/automatic rice mills. Profitable cases should be financed by institutional sources.
- Ensure regular and undisturbed power supply to the rice mill.
- C.C. loan bank rate should be reduced
- Make available spare parts of reasonable price with good quality.
- Installation of engelberg huller in the country should be banned. Neighbouring countries already banned engelberg huller since 30 years back.
- Vocational training institutes (VTI) may help to produce qualified operators for rice mills.
- Ensure optimum use of rice byproducts.

A good policy, on the other hand, will not help farmers unless it is properly implemented. Transparency and accountability for all stakeholders involved in the implementation, as well as good inter-departmental cooperation, are critical to the success of these policies/strategies.

Linkage and trust over the chain

Of the total 28 samples of Paddy aratdar, 13% have maintained informal linkage and 87% maintained verbal linkage arrangement with forward channel, i.e. millers. While at backward channel, 27% paddy aratdar had informal linkage with faria/bepari and 73% aratdar had verbal arrangement of linkage. The level of trust of such linkages by aratdar with faria/bepari was responded as no trust, little trust and some trust by 47%, 13% and 40% respondents, respectively.

Of the total 65 rice millers 40% had informal and 60% had verbal linkages with the rice wholesalers in forward linkage. Level of trust of business linkage by millers with rice wholesalers were recorded as no trust (60%), little trust (15%) and some trust (25%). At backward channel of rice millers 55% had informal linkage with aratdar and 45% had verbal arrangement. Level of trust by millers with wholesalers was recorded as some trust (60%), little trust (15%) and no trust (10%).

Of the total 30 rice wholesalers, 21% had informal and 79% had verbal linkages with the rice retailers in forward linkage. Level of trust on business linkage by rice wholesalers with rice retailers was recorded as no trust (76%), little trust (10%) and some trust (8%). At backward channel of rice wholesalers (56%) had informal linkage with millers and 44% had verbal arrangement. Level of trust by wholesalers with rice retailers was recorded as some trust (76%), little trust (16%) and no trust (8%).

Identification and Selection of Facilitation Activity

Short listing of service provisions for facilitation

Based on the information collected from the value chain actors and the key informants the probable business service provisions were narrowed below for priority intervention. The business services were judged by four important indicators such as, unmet market demand, potential for market growth, potential for employment generation and public sector interest with relative strength of 4x, 3x, 2x and 1x, respectively (Table 10). The indicators were identified in consultation with the key informants. Each business service was also given a score of 1 to 5 (with 1 being the lowest and 5 being the highest score) depending upon their relative weightage. The score of a business service was then the product of relative weightage and the strength. Then the business services were ranked based on the total score. The top five business services may be selected for immediate intervention.

Table 10. Ranking of service provisions for intervention.

Business development services	Unmet market demand (4x)	Potential for market growth (3x)	Potential for employment generation (2x)	Public sector interest (1x)	Total score	Rank order
• Provisions for training on operation, maintenance and repair of rice mill to operators and technicians	16	12	8	4	40	1
• Provisions for training on fabrication of rice mill equipment to mechanics	12	9	4	1	26	10
• Provisions for training on management, accounting and marketing skill to management personnel	12	12	2	1	27	9
• Provisions for awareness building about modern technologies of semi-automatic and automatic rice mills among the husking rice mills owners	12	9	4	4	29	7
• Provisions for replacement of husking rice mills by semi-automatic and automatic rice mills	16	12	8	3	39	2
• Provisions for credit facilities for replacement of husking rice mills by semi-automatic and automatic rice mills	16	9	8	2	35	3
• Provisions for developing business model for replacement of husking rice mills	12	6	4	3	25	11

Table 10 (continued)

Business development services	Unmet market demand (4x)	Potential for market growth (3x)	Potential for employment generation (2x)	Public sector interest (1x)	Total score	Rank order
• Provisions for business model for incorporating modern technologies in older generation semi-automatic and automatic rice mills	16	9	6	1	32	6
• Provisions for credit facilities for replacing older generation technologies in semi-automatic and automatic rice mills	12	6	6	4	28	8
• Provisions of non-interrupted supply of electricity to producers and sellers	12	9	2	1	24	12
• Provisions for access to knowledge and skill to replace engelberg huller by rubber roll huller to husking and traditional rice mill owners	12	12	6	3	33	5
• Provisions for legislation to replace engelberg huller by rubber roll huller of husking and traditional rice mills	16	9	6	3	34	4

CONCLUSION

This research aimed to investigate the key problems and opportunities throughout the value chains for the growth of the husking rice milling sub-sector in Bangladesh. These issues are crucial for the improvement of the rice value chains, in terms of growth of this emerging sub-sector. Where possible, it also suggests policy implications and discusses some relevant interventions.

- Husking mills are still dominating in the rice milling sector; however, inappropriate technologies at husking and traditional rice mills resulting in improper milling, having large quantity of broken and black rice and not free from stones, thereby fail to compete with modern automatic and semi-automatic rice mills in terms of quality of rice and market demand. Even, byproducts such as husk and bran are remaining mixed and therefore, have less market demand and only used as local poultry and cattle feed. Therefore, husking rice mills need to be replaced by semi-automatic or automatic rice mills.
- Traditional husking mills operating all over rural Bangladesh need to be upgraded to improved air-blow type husking mills with small polisher or by rubber roll de-husker and a small polisher unless the milling sub-sector is fully automated.
- There are two major value chains of milled rice, fine rice value chain and coarse rice value chain. The share of parboiled milled rice is about 90% of the total milled rice production.
- The main actors of fine and coarse rice value chains are rice faria/Bepari/aratdar/commission agent, rice miller, rice wholesaler and rice retailer.
- In both fine and coarse rice value chains, major value addition and profit margin

take place at millers' level and dominating the whole chain. These rice millers control the paddy market through their employed agents and buy most of the paddy from beparies and farias in peak season and stockpile for rest of the season.

- "Rice procurement and control act 2008" is the major policy guide for controlling the rice milling sub-sector. However, there is no guide line for milled rice, and there is no instruction for the government not to procure rice from husking mill, as there are a number of semi-automatic and automatic rice mills already operating in the country which produce good quality milled rice with less loss.
- Due to high price fluctuation in rice market, mostly verbal linkages are maintained among the actors of rice value chain. In transactions, some to little trust are exists among miller, bepari and faria, however, no trust is existing among others actors.

RECOMMENDATIONS

The following priority recommendations for intervention by competent authorities are made on the basis of the above discussion:

- A special training institute on rice milling industry need to be establish to create skilled manpower for operation and maintenance of rice mills. Public sector institutes, especially the Ministry of Food and Disaster management can take initiative in this regard
- Establishment of a 'Rice Processing Hub (RPH)' on the outskirts of Dinajpur, Kushtia, Noagaon, Sherpur, and Mymensingh towns to accommodate existing and potential rice processing industries and manufacturers and to ensure infrastructural facilities such as non-interrupted electricity, gas, and water supplies.
- Long and mid-term credit facilities that are soft and flexible for capital equipment and working capital are to be accessible. The emergence of this sub-sector is a recent event and the public sector institutes like PTI, VTI, and DYD etc are not aware of the requirement of this sub-sector. Appropriate modules and courses need to be adopted in these institutes to meet the need of technical knowledge and skill of this sub-sector. Course and curriculum at tertiary level educational institutes (universities) to be strengthened for quality knowledge and business service provisions for rice milling sub-sector.

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Bangladesh Rice J. 26 (2): 41-49, 2022, doi.org/10.3329/brj.v26i2. 66733

Determination of Growth Stages of Some Rice Varieties as Affected by Sowing Time

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ABSTRACT

Identification of growth stages of rice is important for proper crop management and yield estimation. Appropriate planting time is a prerequisite for a decent harvest. The study aimed to determine the growth stages of different rice varieties and how they are affected by the sowing time. We evaluated four selected boro season rice varieties (BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89) under five sowing times for growth stage study and yield following a completely randomized block design (RCBD) with three replications. Each variety showed considerable variation in different growth stages and yield at various sowing dates. All tested rice varieties took 40 days to reach the seedling stage on 15 December sowing. With the advancement or preceding this sowing date, the days required to attain this stage decreased. In mid-November sowing, the maximum period (33-34 days) was needed for tiller development and then reduced with the advancement of sowing dates irrespective of variety. Among the rice varieties, BRRI dhan89 required the highest time for panicle initiation (PI) on all sowing dates. The other three rice varieties took more or less similar time for panicle initiation. Among the rice varieties, BRRI dhan89 needed the highest, and BRRI dhan86 needed the lowest degree days for PI and flowering. BRRI dhan81 and BRRI dhan89 produced a higher grain yield from 15 November and 1 December sowing. BRRI dhan88 produced consistent grain yield throughout the sowing time. The fluctuations in PI stages' commencement indicate varietal characteristics, environmental conditions, and interaction between variety and environment.

Key words: Sowing time, growing degree-days, rice growth stage, phenological development

INTRODUCTION

Rice is the leading food crop and the primary source of nutrition for 3,500 million people world wide (Vivek *et al.*, 2004, Mahadi *et al.*, 2006, Liu *et al.*, 2011). The population is predicted to reach 8000 million by 2030, necessitating a 50% boost in rice yield to fulfil rising global demand (Khush and Brar, 2002; Kim and Krishnan, 2002). Poverty alleviation and food security can be achieved through a rapid increase in rice production in Bangladesh. Understanding the effect of the environmental factors on rice growth stages is essential for optimizing rice production in Bangladesh.

An optimum date for rice planting is region specific and varies with genotypes and environmental interactions (Bashir *et al.*, 2010). Bruns and Abbas (2006) and Yoshida (1981) stated that rice plants need a specific temperature for their phenological development, such as panicle initiation, flowering, panicle exertion and maturity.

The phenological development of crops greatly influenced by heat accumulation is expressed as growing degree-days (GDD). GDD is a summation of the mean daily temperatures over a certain period of growth or development. Additionally, the amount of heat is needed for a variety to bloom. We cannot track rice plants' flowering and panicle initiation stage using

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calendar days because of large differences in temperature in different months within a year and year to year. The development of crops can be better followed and projected by the amount of heat accumulated during each growing period. Regardless of differences in temperatures from year to year, GDD predicts that a variety will flower and reach maturity. Rice seed sown before the optimum time typically has poor germination and seedling establishment, more damage from insects and diseases, and preharvest losses by rats and birds (Linscombe *et al.*, 1999). Due to higher disease and insect infestations, storm-related lodging and probable heat or cold damage during the heading and filling stages, rice grown after the recommended dates may result in poor yields (Groth and Lee, 2003 and Reza *et al.*, 2011). Seedling age during transplanting is vital for seedling establishment. If the seedling age is lower, the seedling may die due to transplanting shock. On the other hand, older seedlings may influence fewer productive and more unproductive tillers, resulting in a low yield. The prerequisites that allow the crop to complete its life phase in a timely and fruitful manner are proper seeding time and technique. (Vange and Obi, 2006). According to Khalifa (2009), an early sowing date is ideal for obtaining important characteristics like the maximum number of tillers, the highest number of panicles per square meter, the highest number of grains in each panicle, and finally grain yield. A high number of spikelets in panicle indicates a better response with an early sowing. Late planting minimizes the plant's growth cycle and reduces panicle length, and spikelet number and leaf area. According to Dhaliwal *et al.* (1986) and Bashir *et al.* (2010), the weight of one thousand grains decreased progressively with late planting time. Khakwani *et al.* (2006) explained that sowing time significantly influenced grain yield. Several studies investigated the effect of sowing time and GDD on rice growth stages in Bangladesh. Hossain *et al.* (2020) observed that some rice varieties performed better under early sowing conditions while others performed better under late sowing conditions.

So, using four recently released Boro rice varieties—BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89—we designed the current study to examine and assess the impact of different planting dates on phenological development and grain yield.

MATERIALS AND METHODS

Plant materials

Four popular Boro rice varieties: BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89, which were taken into account to conduct the experiment on five different sowing dates.

Growing rice plants in the field

We experimented in the Plant Physiology Division's research field located at Bangladesh Rice Research Institute (BRRI) farm Gazipur, Bangladesh, during Boro season in 2019. The latitude longitude coordinates for the experimental field were 23.98985°N, 90.40205°E. The soil of the experimental field was clay loam. Five different sowing dates were 15 November, 1 December, 15 December, 1 January and 15 January. When seedlings had five leaves, these were uprooted for transplantation after being nurtured in the ideal seedbed. After being transplanted most of the seedlings were destroyed by a flock of whistling duck at night when the seedlings of last set was transplanted (sowing was done on mid-January) in the main field. They destroyed the seedlings again and again when gap filling was done in the main field. So only the phenological data were taken from the remaining seedlings for mid-January sowing. Treatments consisted of five sowing dates and four rice varieties were laid out in a randomized complete block design with three replications. Each treatment was assigned to an experimental plot of 9 m^2. Urea, triple superphosphate, muriate of potash, and gypsum fertilizer were applied at the rates of 80-50-50-10 kg per hectare for N, P_2O_5, K_2O, and S, respectively. At the end of the land preparation process, full doses of triple superphosphate, muriate of potash, and gypsum were incorporated. The three equal splits of urea were applied concurrently at 15 days after transplanting, mid tillering and at PI stage. The intercultural operation was carried out as required during the period of growth. The experimental field was irrigated using flood irrigation, and the crop management practices were carried out following the BRRI recommended procedures.

Evaluation of agronomic traits

Observations were made on days taken from seed sowing to five-leaf stage, days taken from transplanting to 1st tiller formation, days to panicle initiation (PI), days to 1st heading, days to 50% flowering, and days to maturity. For determining PI stage, the mother tiller section was done every alternate day from the active tiller stage. Grain yield was measured from an area of 5m^2 and adjusted to 14% moisture level.

Measuring the heat accumulated over time provides a more accurate physiological estimate than counting calendar days. "Growing degree days" (GDD) is a way of assigning a heat value to each day. The temperature are added together to estimate the amount of seasonal growth of plants has achieved. A mathematical accumulation of daily mean temperatures above a predetermined threshold temperature is known as the GDD, also known as the accumulated degree days or effective heat unit. GDD was calculated following Iwata (1984).

$GDD = \Sigma [(Tmax+Tmin)/2-Tb]$.

$GDD = (Tmean - Tb)$

Where $Tmean = (Tmax + Tmean)/2$

Tmax = Daily maximum temp.

Tmin = Daily minimum temp.

Tb is the base temperature taken as 10.0 °C for rice (Yoshida, 1981)

Data analysis

The International Rice Research Institute's Statistical Tool for Agricultural Research (STAR), version 2.0.1, was used to analyze the data.

RESULTS AND DISCUSSION

Seedling stage: The days required to attain the seedling stage (5 leaves) varied from 30 to 40 days irrespective of varieties (Table 1). All the tested rice varieties took 40 days to reach the seedling stage when seeds were sown on 15 December. With the advancement or preceding this sowing date, the days required to attain this stage decreased. When sowing time was shifted from mid-December to mid-January, the seedling stage was shortened from 40 to 30 days for most of the varieties. The variation in the duration of the seedling stage was reflecting the temperature variation during that period. Vange and Obi (2006) observed the impact of early and late seeding dates on grain yield and several agronomic traits. These results suggested that the planting date had a big impact on the duration of seedling stage under variation of temperature.

Tiller formation: After transplanting, the time required for tiller formation varied from 17 to 34 days irrespective of variety (Table 1). In mid-November sowing, the highest time (33-34 days) was needed for tiller initiation and then decreased with the advancement of sowing dates irrespective of variety. Due to cold weather in January, under the 15 November sowing, seedling took more time to establish and tiller production. With the advancement of sowing date, The relatively warmer temperature in late January to February, seedling establishment and tiller production was much quicker. Mannan *et al.*, 2009 observed that plant height, tillers number, and days to tiller initiation varied significantly due to variation of transplanting dates.

Table 1. Effect of sowing time on the number of days required to reach different growth stage in boro season, Plant Physiology, BRRI, 2019.

Sowing date	Variety	Seedling stage (days required to grow 5 leaves)	Tiller formation (DAT)	PI (DAT)	1st Heading (DAT)	Days to 50% flowering (DAT)	Days to Maturity (DAS)
15 Nov 2019	BRRI dhan81	35	34	59	89	95	152
	BRRI dhan86	35	33	55	85	92	152
	BRRI dhan88	35	34	57	87	93	152
	BRRI dhan89	35	34	66	96	104	167
1 Dec 2018	BRRI dhan81	34	28	49	78	84	149
	BRRI dhan86	34	28	47	76	82	149
	BRRI dhan88	34	28	49	78	84	146
	BRRI dhan89	34	27	60	89	96	158
15 Dec 2018	BRRI dhan81	40	21	43	69	73	138
	BRRI dhan86	40	20	40	66	72	138
	BRRI dhan88	40	23	42	69	76	138
	BRRI dhan89	40	21	55	81	88	158
1 Jan 2019	BRRI dhan81	31	23	43	69	74	126
	BRRI dhan86	31	22	39	68	73	126
	BRRI dhan88	31	23	40	69	73	126
	BRRI dhan89	31	22	55	80	86	142
15 Jan 2019	BRRI dhan81	30	18	39	62	68	124
	BRRI dhan86	30	20	39	62	67	124
	BRRI dhan88	30	19	37	60	65	124
	BRRI dhan89	31	17	51	74	80	138

DAS: Days after sowing
DAT: Days after transplanting

Panicle initiation (PI) and heading stage: Irrespective of varieties, there was a decrease in days requiring the panicle initiation in the progress of sowing time. Among the rice varieties, BRRI dhan89 took the highest time for panicle initiation on all sowing dates. The other three rice varieties took more or less similar time for panicle initiation. The time needed for heading varied markedly. It was the highest during mid-November sowing and the lowest when seeded in mid-January (Table 1). Biswas *et al.*, 2019 reported that late planting causes significant variation in agronomic traits like PI, days to flowering, and days to maturity

Flowering stage and growth duration: With the advancement of the sowing date from mid-November to onward, days to flowering decreased gradually irrespective of variety (Table 1). The highest time for flowering was exhibited by BRRI dhan89 in all sets of sowing. In mid-November sowing, all rice varieties took the highest days for flowering. As the sowing date was shifted from mid-November to mid-January, the reduction of flowering time (from transplanting) was 27, 25, 28, and 24 days for BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89, respectively. These findings agreed with those of Wani *et al.* (2016), who found that the time required to attain flowering and harvest varied significantly between sowing dates. Growth duration followed the same trend. The growth duration ranged from 124 to 152 days in BRRI dhan81, BRRI dhan86, BRRI dhan88, and 138 to 167 days in BRRI dhan89 over sowing dates (Table 1). In mid-November sowing, growth duration was the highest in all tested varieties. As sowing dates were advanced, the growth duration decreased gradually irrespective of rice variety. With the advancement of sowing dates, rice crops' elevated temperature affects the crop duration by attaining the phenological stages earlier.

Growing degree-days (GDD): Degree-days expresses the influence of mean temperature on the developmental rate. We used GDD for phenological forecasting of a rice crop. Tables 2 and 3 present the phenology of four rice varieties at the four sowing times. Results indicated that phenology was significantly influenced by the interaction effect of sowing time and varieties. The tested varieties varied in growing degree days (°Cd) requirements for panicle initiation and flowering (Tables 2 and 3). Among the rice varieties, BRRI dhan89 needed the highest, and BRRI dhan86 needed the lowest degree-days for both PI and flowering in all sowing dates. The results reflected that heat requirement for phenological development was the highest for BRRI dhan89 and for BRRI dhan86 it was the lowest. Mid November sowing needed the highest Degree days (°Cd) requirements for panicle initiation and flowering and decreased gradually when sowing dates were shifted onward. The required GDD from PI (from (transplanting) were 959 ± 39.9, 912.8 ± 42.6, 935.8 ± 42.7, 1121.3 ± 22.3 while for flowering (from transplanting) 1492.5 ± 43.2, 1466.5 ± 32.3, 1483.5 ± 33.6, 1712.8 ± 22.2 for BRRI dhan81, BRRI dhan86, BRRI dhan88 and BRRI dhan89, respectively.

Table 2. Requirement of degree-days (°Cd) for panicle initiation (from transplanting) of some rice varieties in Boro season, Plant Physiology, BRRI, 2019.

Variety	Sowing date			
	15-Nov-18	1-Dec-18	15-Dec-18	1-Jan-19
BRRI dhan81	1076 b	932 b	933 b	895 b
BRRI dhan86	1027 c	906 b	897 c	821 c
BRRI dhan88	1050 bc	932 b	917 bc	844 c
BRRI dhan89	1169 a	1145 a	1102 a	1069a

Means with the same letter are not significantly different.

Table 3. Requirement of degree-days (°Cd) for flowering (from transplanting) of some rice varieties in Boro season, Plant Physiology, BRRI, 2019.

Variety	Sowing date			
	15-Nov-18	1-Dec-8	15-Dec-18	1-Jan-19
BRRI dhan81	1619 b	1476 b	1445 c	1430 b
BRRI dhan86	1563 c	1443 b	1432 c	1428 b
BRRI dhan88	1580 bc	1476 b	1450 b	1428 b
BRRI dhan89	1771 a	1722 a	1688 a	1670 a

Means with the same letter are not significantly different.

Grain yield: The interaction between sowing dates and varieties was significant on grain yield by the ANOVA test. Among the rice varieties, BRRI dhan81 and BRRI dhan89 produced the highest grain yield at 15 November seeding whereas BRRI dhan86 at early December and BRRI dhan88 at mid-December seeding (Fig. 1). With the advancement of sowing dates, the grain yield decreased remarkably for BRRI dhan81and BRRI dhan89. Although BRRI dhan88 produced the highest grain yield (6.18 tha^{-1}) at mid-December seeding, which was statistically similar to all the seeding dates. BRRI dhan86 produced the highest grain yield in early December seeding, and seeding before or after early December sharply decreased grain yield. BRRI dhan86 produced the lowest crop yield at mid-November seeding.

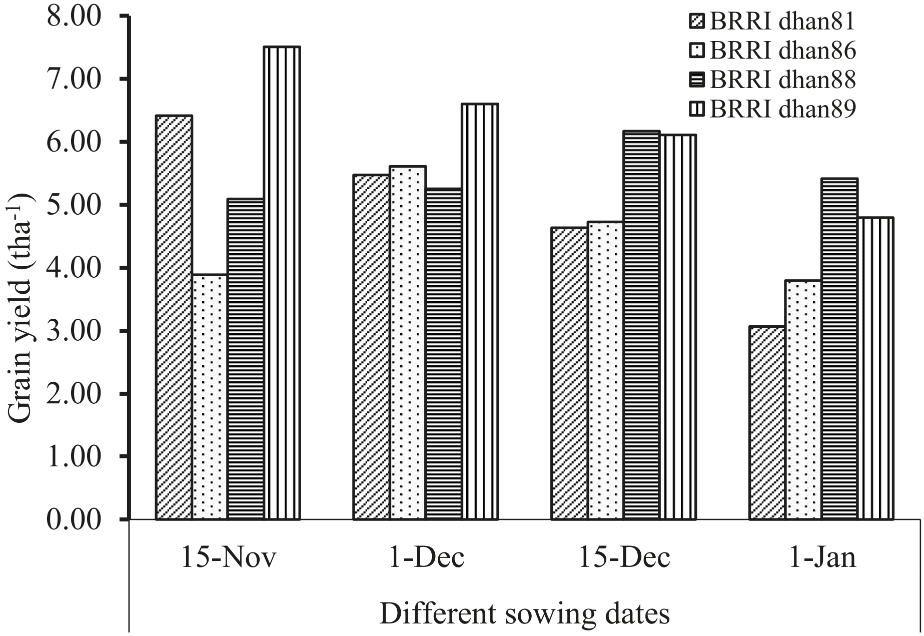

Fig. 1. Grain yield (tha^{-1}) of four rice varieties as affected by different sowing dates in Boro season.

Planting rice after the optimal dates may result in lower grain yield due to poor vegetative growth, higher disease and insect incidence, and possible heat or cold damage during heading and grain filling (Groth and Lee, 2003; Reza *et al.*, 2011; Biswas *et al.*, 2019).

Yield components

The interaction between variety and sowing date was not significant except for sterility. Among the varieties, the highest panicle number per unit area (310) was found in BRRI dhan88 and the lowest (260) in BRRI dhan81 (Table 4). BRRI dhan89 had the highest number of grain per panicle (114) and BRRI dhan86 had the lowest (92).The highest 1000-grain weight (23.62 g) was observed in BRRI dhan89 and the lowest (21.55 g) in BRRI dhan88. Number of panicle per unit area was the highest when seeds were sown at the beginning of January and the lowest when sowing date was mid-December (Table 5). Number of filled grain per panicle was the highest when seeds were sown at the beginning of December and decresed with the advancement of sowing date. Similar trend was observed for 1000 grain weight.

Table 4. Effect of different varieties on yield component, Plant Physiology, BRRI, 2019.

Variety	No. of panicle m^{-2}	No filled grain $panicle^{-1}$	1000 grain wt (g)
BRRI dhan81	260.42 c	100.75 bc	22.63 b
BRRI dhan86	273.75 bc	92.25 c	23.26 ab
BRRI dhan88	309.75 a	111.58 ab	21.55 c
BRRI dhan89	290.42 b	114.17 a	23.62 a
CV(%)	7.71	13.74	4.16

Means with the same letter are not significantly different.

Table 5. Effect of different sowing dates on yield component, Plant Physiology, BRRI, 2019.

Sowing date	No. of panicle m^{-2}	No. of filled grain $panicle^{-1}$	1000 grain wt (g)
15 Nov	275.50 b	112.25 a	23.16 a
1 Dec	278.75 b	115.75 a	23.60 a
15 Dec	272.75 b	99.42 b	22.98 a
1 Jan	307.33 a	91.33 b	21.32 b
CV(%)	7.71	13.74	4.16

Means with the same letter are not significantly different.

Table 6. Interaction effect of variety and sowing dates on sterility percent, Plant Physiology, BRRI, 2019.

	15 Nov	1 Dec	15 Dec	1 Jan
BRRI dhan81	14.54 b	25.80 a	36.31 a	43.05 a
BRRI dhan86	30.01 a	23.77 a	32.20ab	34.06 ab
BRRI dhan88	21.73 ab	23.50 a	15.75 c	28.64 b
BRRI dhan89	19.98 ab	23.40 a	22.07 bc	38.99 ab
		CV% = 24.69		

Means with the same letter are not significantly different.

Irrespectictive of varieti highest sterility was observed when seeds were sown at the beginning of January. Due to high sterility grain yield reduced irrespective of varieti and when critical stage (flowering stage) faced high temperature due to shifted sowing date. It is the number of filled spikelets and the spikelet size that govern grain yield of rice (Yoshida, 1981). BRRI dhan81 and BRRI dhan89 showed the lowest sterility when seeds were sown on mid November; while BRRI dhan86 and BRRI dhan88 showed lowest sterility when seeds were sown at the beginning of December and mid December, respectively.

CONCLUSION

Among the four seeding dates, significant variation of evaluated growth stage and yield indicated higher variability in tested rice varieties' performance. Among the rice varieties, BRRI dhan81 and BRRI dhan89 produced a higher harvest from 15 November and 1 December sowing. BRRI dhan88 produced consistent yield throughout the sowing time. BRRI dhan86 did not perform well under low-temperature conditions. So BRRI dhan86 should not be cultivated in cold prone northern part and haor region of the country. The variation in the occurrences of PI stages, heading of different varieties, and sowing dates indicated the dependence of PI and heading stages on varietal characteristics, environmental conditions, and variety × environment interaction. The rice varieties showed a wide variation in degree-days' requirement to develop panicle initiation and flower for sowing time. The adverse effects of late planting were reflected in the lower yield in Boro season. The study highlights the importance of selecting appropriate sowing time for a variety to obtain maximum yield.

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Influence of Cultivation Techniques on Dry Matter Partitioning, Nitrogen Distribution Pattern and Yield of Super Hybrid Rice Liangyoupeijiu

M A Badshah[1*], M Ibrahim[2] and T N Mei[3]

ABSTRACT

Liangyoupeijiu was grown under different crop cultivation techniques viz conventional tillage and transplanting (CTTP), no tillage and transplanting (NTTP), conventional tillage and direct seeding (CTDS) and no- tillage and direct seeding (NTDS) during 2011 and 2012. Results showed that, CTTP had higher leaf dry weight than NTTP. Maximum leaf dry weight reduced in direct seeded than transplanted rice. Shoot dry weight reduced by 6% both in transplanted and direct seeded rice from heading to 12 days after heading (DAH) in both the years. No tillage and transplanting had higher export percentage of dry matter and transport percentage of dry matter among the cultivation techniques in both the years. At heading, leaf nitrogen concentration (%) and nitrogen uptake (g m^{-2}) were higher in transplanted than direct seeded rice and significantly higher nitrogen uptake was observed under conventional tillage and transplanting in both the years. The physiological nitrogen use efficiency was higher in no-tillage than conventional tillage in both the years. Total nitrogen (kg ha^{-1}) uptake was higher in conventional tillage than no tillage either in transplanted or in direct seeded rice and was higher under conventional tillage and transplanting among the cultivation techniques in both the years. Grain yield was closely associated with uptake of total nitrogen at heading. Although, direct seeded rice had more than 23% higher panicle number than transplanted rice, conventional tillage and transplanting produced higher grain yield due to higher uptake of nitrogen by grain at maturity and bigger sink size.

Key words: Crop establishment method, dry matter partitioning, N distribution pattern, super hybrid rice

INTRODUCTION

The productivity of cereal depends on the accumulation of dry matter and effective partitioning. Dry matter translocation to grain is critical for satisfactory grain yield when plants experience with nitrogen deficiency during grain filling period (Ladha *et al.*, 1998). Accumulation and translocation of pre-anthesis assimilates to grain is more important in direct seeding rice because of high plant density (Farooq *et al.*, 2011). Rice yield is the function of biomass production before heading and translocation to grains after heading (Yang *et al.*, 2008). Sink size, spikelet filling percentage and grain weight are the determining factors for rice yield and sink size is the primary determinant (Kropff *et al.*, 1994). Sink size could be improved by increasing higher number of panicle or more spikelet per panicle or both (Ying *et al.*, 1998). A higher yield is generally achieved either by increasing panicles per unit land area (Lin *et al.*, 2002; Wu *et al.*, 2007) or more number of panicle (Chen *et al.*, 2008; Lu *et al.*, 2008). Sink size could be increased by enhancing sink formation efficiency per unit biomass at flowering (Yang *et al.*, 2008). So, this study was

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undertaken to evaluate the effect of cultivation techniques on dry matter partitioning and nitrogen distribution pattern in relation to grain yield of Liangyoupeijiu.

MATERIALS AND METHODS

The experiment was conducted in the research farm of Hunan Agricultural University, Hunan, China during 2011-2012 (May to September).

MEASUREMENT AND METHODS

Nitrogen concentration (%) It was measured by micro-Kjeldahl digestion, distillation, and titration (Bremneret al., 1982).

Nitrogen translocation ratio (NTR) Nitrogen translocation ratio was calculated following Ying et al., (1998).
NTR = (Nvo – Nstraw)/Nvo
Where, Nvo= N uptake by vegetative organ (leaf and shoot) at heading
Nstraw = N uptake by straw at maturity.

Export percentage of dry matter (EPMCS) was calculated as EPMCS (%) = (dry weight of leaf and shoot at heading - dry weight of straw at maturity) / dry weight of leaf and shoot at heading×100

Transformation percentage of dry matter (TPMCS) was calculated as TPMCS (%) = (dry weight of leaf and shoot at heading - dry weight of straw at maturity)/dry weight of panicle at maturity × 100

RESULTS

Dry matter partitioning

Leaf dry weight There was significant difference in leaf dry weight among the treatments at all growth stages of crop in both years. Leaf dry weight gradually increased up to booting stage and then decreased with advancement of time. Direct seeding had higher leaf dry weight than transplanting at panicle initiation, booting and heading stage during 2011 but was higher with transplanting than direct seeding in 2012. At booting stage, conventional tillage and transplanting produced higher leaf dry weight than no tillage and transplanting in both the years. Similarly, no tillage and direct seeding had higher leaf dry weight than conventional tillage and direct seeding in 2011 but CTDS and NTDS had statistically similar in 2012 (Fig. 1).

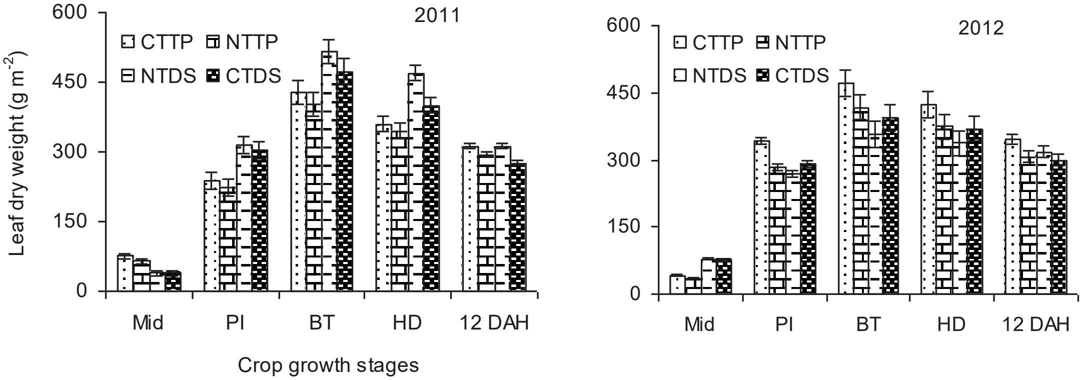

Fig. 1. Leaf dry weight of Liangyoupeijiu at different growth stages. Bar represents Standard Error (SE).

Shoot dry weight Shoot dry weight varied significantly at all sampling dates in both the years except 12DAH in 2012. Shoot dry weight increased up to heading stage and slightly decreased at 12DAH. Direct seeding had higher shoot dry weight than transplanting at all growth stages except at mid tillering stage in 2011 but was higher in transplanting than direct seeding during 2012. At heading stage, significantly higher shoot dry weight was observed in CTDS among the cultivation techniques in 2011 but NTTP produced higher shoot dry weight in 2012. Conventional tillage and transplanting produced higher shoot dry weight than NTTP almost all sampling dates in both the years. Conventional tillage and direct seeding produced higher shoot dry weight than NTDS at heading and 12DAH stage during 2011 but was higher at panicle initiation and booting stage during 2012 (Fig. 2).

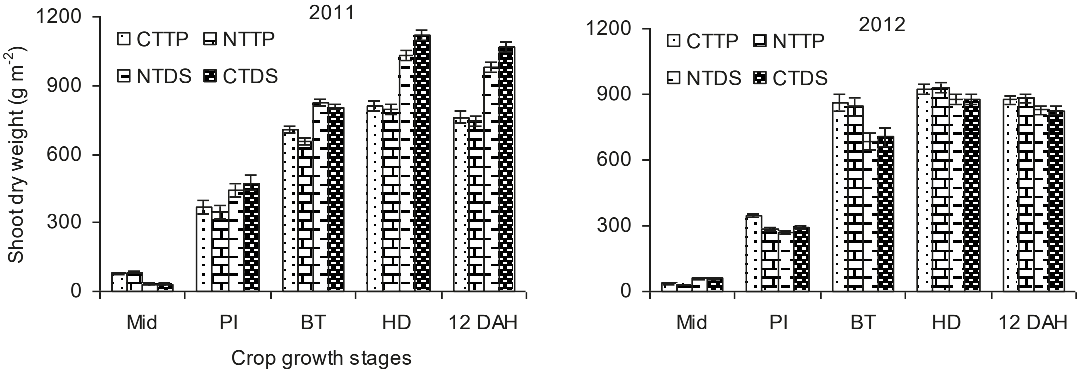

Fig. 2. Shoot dry weight of Liangyoupeijiu at different growth stage. Bar represents SE.

Dry weight of panicle It increased with advancement of time and varied significantly among the cultivation techniques at all growth stages of crop except booting in 2011 and at 12DAH in 2012. At heading, it was significantly higher in direct seeding than transplanting in 2011 but transplanting had higher panicle dry weight than direct seeding in 2012. At 12DAH, statistically similar panicle dry matter was observed in conventional tillage and transplanting, no tillage and direct seeding, conventional tillage and direct seeding during 2011 but was significant difference in 2012 (Fig. 3).

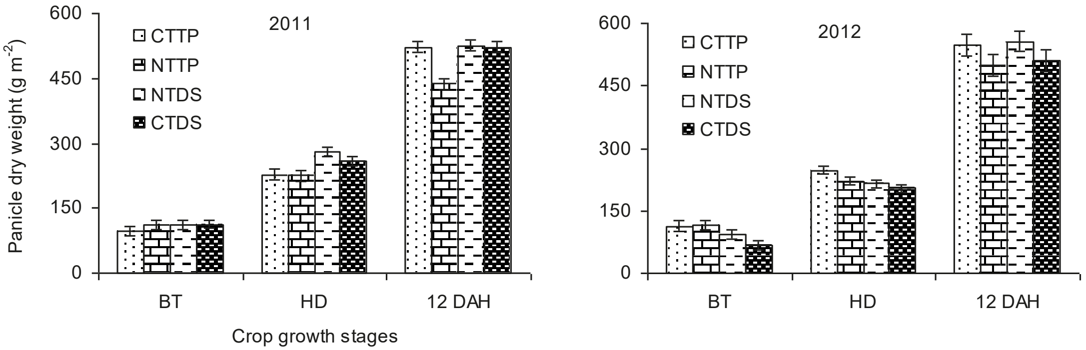

Fig. 3. Panicle dry weight of Liangyoupeijiu at different growth stage. Bar represents SE.

Export percentage of dry matter (EPMCS) and transport percentage of dry matter (TPMCS)

Export percentage of dry matter varied significantly among the cultivation techniques in both the years but not in transport percentage of dry matter. The EPMCS and TPMCS were higher in transplanting than direct seeding in both the years. Export percentage of dry matter was higher in no tillage system either in transplanting or direct seeding in both the years but transport percentage of dry matter was higher in conventional tillage than no tillage. No tillage and transplanting had higher EPMCS and TPMCS among the cultivation techniques in both the years (Fig. 4).

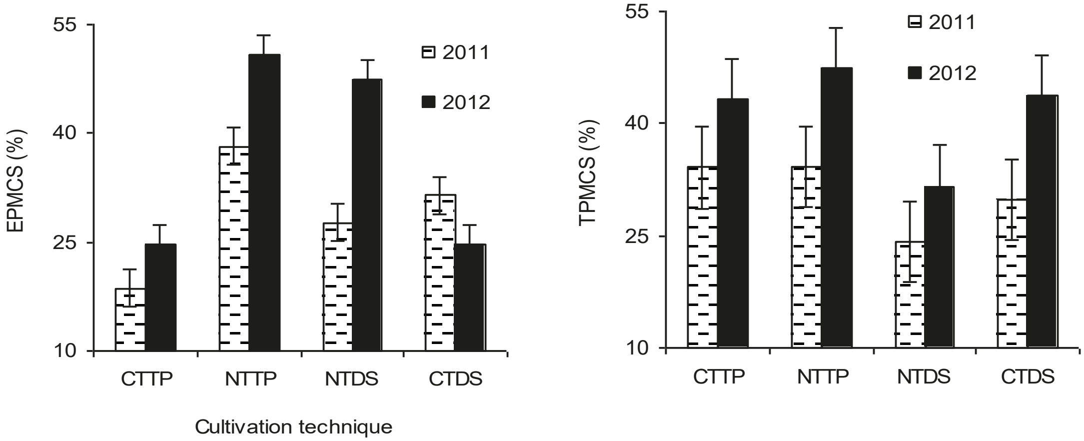

Fig. 4. Influence of cultivation techniques on export percentage of dry matter (EPMCS) and transport percentage of dry matter (TPMCS). Bar represents SE.

Nitrogen distribution pattern at heading

leaf Nitrogen concentration (%) and uptake (g m^{-2}) varied significantly in both the years. Conventional tillage either in transplanting or direct seeding had significantly higher nitrogen concentration than no tillage in 2011 but CTTP, NTTP and NTDS had higher nitrogen concentration during 2012. Nitrogen uptake was higher in transplanting than direct seeding and significantly higher N uptake was observed in CTTP in both the years (fig. 5).

Shoot Nitrogen concentration (%) and uptake (g m^{-2}) varied significantly among the cultivation techniques and CTTP, NTTP and CTDS had statistically similar nitrogen concentration and NTDS had the lowest nitrogen (%) during 2011. Conventional tillage and direct seeding had higher nitrogen (%) in 2012. Nitrogen uptake was higher in 2012 than 2011 and significantly higher N uptake was observed under CTDS in both the years (Fig. 5).

Panicle Grain nitrogen concentration (%) was higher in direct seeding method compare to transplanting. Nitrogen uptake varied significantly in the year 2011. Nitrogen uptake was significantly higher in CTDS in both the years and difference between direct seeding and transplanting during 2012 was lower (Fig. 5).

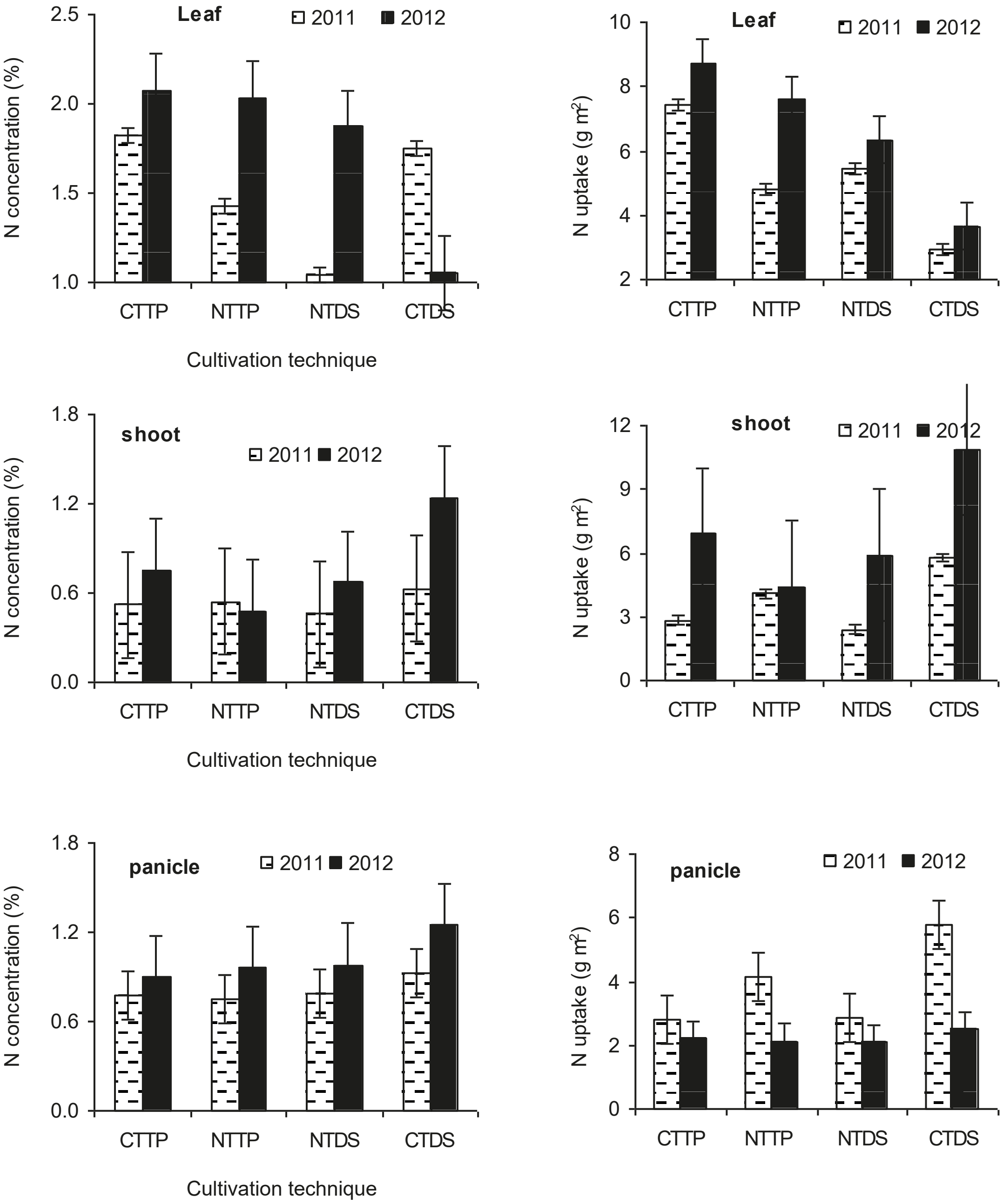

Fig. 5. Nitrogen concentration and uptake by Liangyoupeijiu at HD stage. Bar represents SE.

Nitrogen distribution pattern at maturity

Nitrogen concentration (%) in grain and straw varied significantly for cultivation techniques in 2011 but not in 2012. Nitrogen concentration (%) was higher in conventional tillage than no tillage in both the years. Conventional tillage and transplanting had significantly higher nitrogen (%) among the cultivation techniques in 2011 and had higher nitrogen (%) in straw during 2012. In grain, NTDS had significantly higher nitrogen (%) among cultivation techniques in 2011 and CTDS in 2012. No tillage had higher nitrogen (%) than conventional tillage in both the years (Fig. 6).

In straw, nitrogen uptake (kg ha^{-1}) was significantly higher in CTDS in 2011 and CTTP in 2012. In grains, nitrogen uptake (kg ha^{-1}) was similar in CTTP, NTTP and NTDS during 2011 and CTTP, NTTP and CTDS in 2012 (Fig. 6).

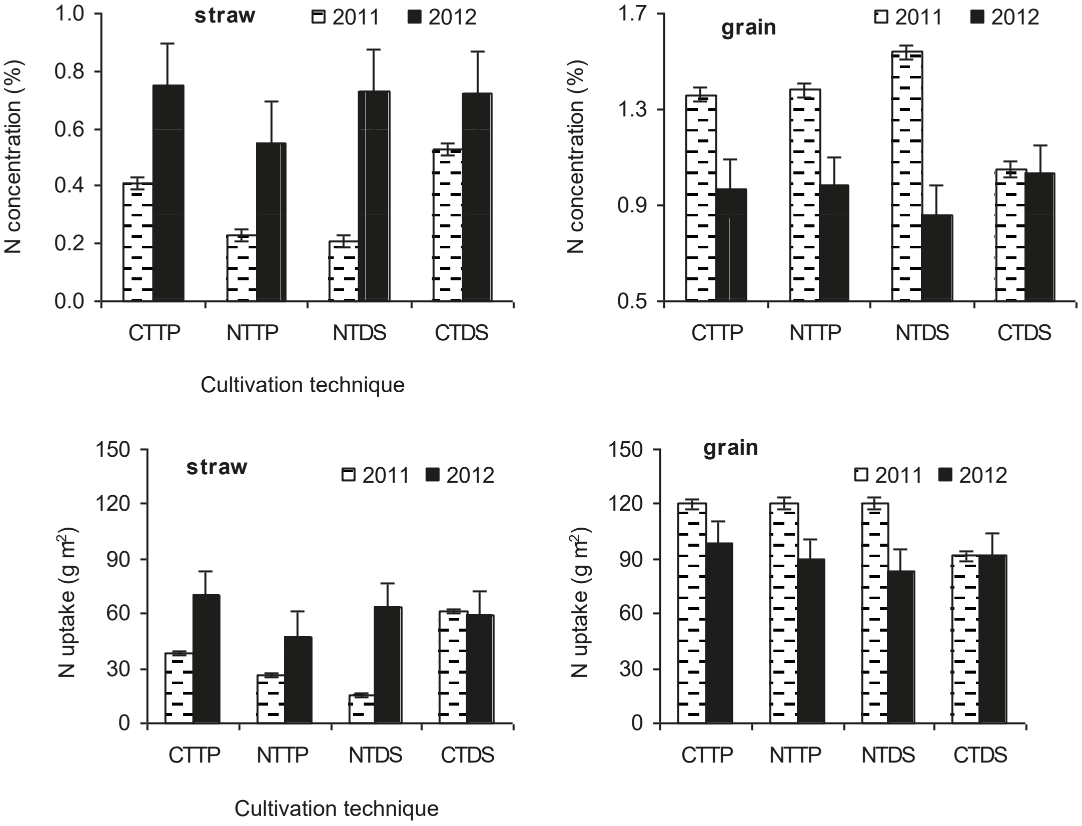

Fig. 6. Nitrogen concentration and uptake by Liangyoupeijiu at MA stage. Bar represents SE.

Nitrogen translocation ratio (NTR)

Nitrogen translocation ratio varied significantly due to cultivation techniques in 2011 and higher amount of nitrogen was translocated from NTDS and the lowest amount was in CTDS. In 2012, it had higher in CTTP and NTTP among the cultivation techniques. It was also higher in transplanting than direct seeding, similarly no tillage than conventional tillage in both the years (Fig. 7).

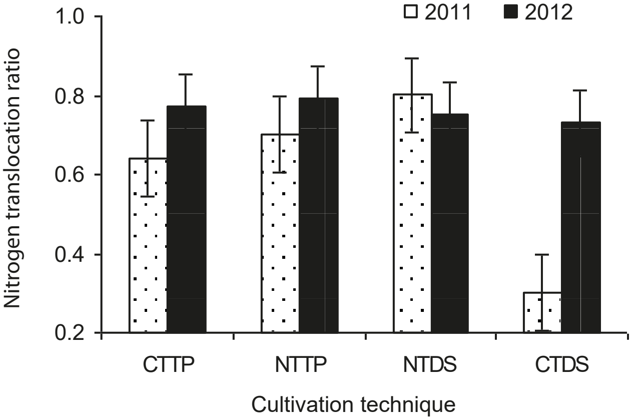

Fig. 7. Influence of cultivation technique on nitrogen translocation ratio (NTR) of Liangyoupeijiu. Bar represent SE.

Physiological N use efficiency (kg kg^{-1})

Physiological nitrogen use efficiency varied significantly among the cultivation techniques in 2011 but not in 2012. It varied significantly between conventional tillage and no tillage and NTTP, NTDS and CTDS were statistically similar in physiological nitrogen use efficiency in 2011. The physiological nitrogen use efficiency was higher in no tillage than conventional tillage in both the years (Fig. 8).

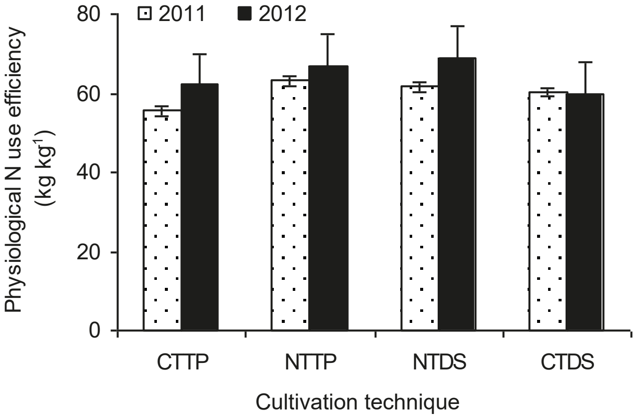

Fig. 8. Physiological N use efficiency of Liangyoupeijiu. Bar represents SE.

Total nitrogen(kg ha^{-1}) uptake at maturity

Total nitrogen uptake was higher in conventional tillage than no tillage either in transplanting or direct seeding in both the years and CTTP had higher among the cultivation techniques in both the years (Fig. 9).

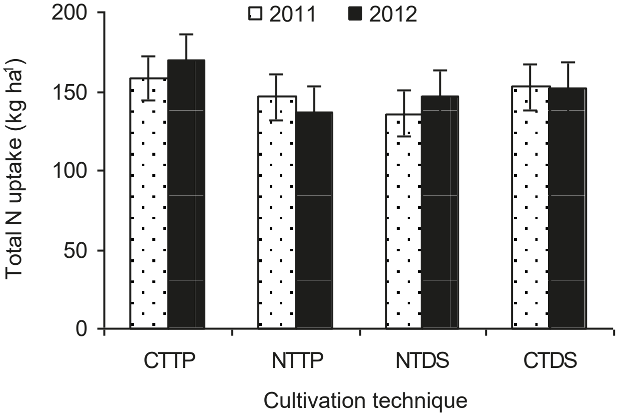

Fig. 9. Influence of cultivation technique on total N uptake of Liangyoupeijiu. Bar represents SE.

Relationship of grain yield and total nitrogen uptake at heading and maturity

Grain yield was positively associated with uptake of total nitrogen at heading (Fig. 10).

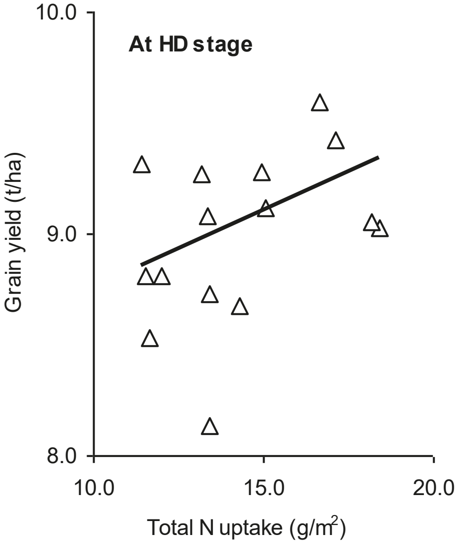

Fig. 10. Relationship of grain yield and total N uptake by Liangyoupeijiu at heading and maturity

RELATIONSHIP BETWEEN GRAIN YIELD AND YIELD COMPONENTS

Panicle (m^{-2}) Panicle number varied significantly among the cultivation techniques and directed seeded either in conventional tillage or no tillage produced more number of panicles than transplanting. No tillage and direct seeding produced higher number of panicle and was lower in NTTP in both the years.

Total spikelet (m^{-2}) Total number of spikelet varied significantly among the cultivation techniques and bigger sink size was observed in transplanting than direct seeding. Conventional tillage and transplanting produced significantly higher number of spikelet in both the years.

Grain yield Conventional tillage produced higher economic yield than direct seeding and was higher under CTTP followed by CTDS but cultivation techniques were insignificant in 2011. Similarly, CTTP had significantly higher grain yield followed by NTDS in 2012. The difference between transplanting and direct seeding in grain yield was lower but conventional tillage had higher grain yield than no tillage in 2011. Conventional tillage and transplanting produced higher grain yield due to bigger sink size in both the years (Table 1).

Table. 1. Yield and yield components of super hybrid rice Liangyoupeijiu, Hunan, China.

Treatment	Panicle (m^{-2})	Total spikelet (m^{-2})	Grain yield (t ha^{-1})
2011			
CTTP	261 bc	47529 a	8.82
NTTP	242 c	44367 c	8.54
NTDS	333 a	42119 d	8.30
CTDS	297 ab	45664 b	8.73
Analysis of variance			
Establishment method (A)	*	*	NS
Tillage (B)	NS	*	NS
A X B	*	*	NS
SE (0.05)	16.47	481.31	0.359
2012			
CTTP	238 b	52736 a	10.30 a
NTTP	220 b	45001 b	9.10 b
NTDS	325 a	45198 b	9.70 ab
CTDS	306 a	40228 c	9.00 b
Analysis of variance			
Establishment method (A)	*	*	NS
Tillage (B)	NS	NS	NS
A X B	*	*	*
SE (0.05)	19.02	1387.3	0.30

DISCUSSION

Translocation of pre-anthesis reserve to grain is more important in direct seeded rice because of high plant density (Farooq *et al.*, 2011). Leaf dry weight gradually increased up to booting stage and CTTP had 7% -12% higher leaf dry weight than NTTP owing to more number of tillers per unit land area. Badshah *et al.*, (2013) reported that, tiller number was always higher under CTTP than NTTP from maximum tillering to maturity stage. Maximum leaf dry weight reduced in direct seeding than transplanting due to high population caused by mutual shading (Monneveux *et al.*, 2008) and a consequent acceleration in leaf senescence (Baylis and Dicks, 1983). Shoot dry weight increased up to heading stage and slightly reduced at 12DAH due to translocation of reserved materials to sink. Rice yield is the function of biomass production before heading and translocation to grains after heading (Yang *et al.*, 2008). Direct seeded rice produced more shoot biomass than transplanted rice at heading and was 26% higher than transplanted rice in 2011 but was 6% higher under transplanting in 2012. Shoot dry weight reduced about 6% both in transplanting and direct seeding from heading to 12DAH in both the years due to translocation of reserved materials to sink. Higher grain yield depends on higher dry matter accumulation and translocation that influence by numerous factors like cultural practices, climate and genotype (Dingkuhn *et al.*, 1990a). At 12DAH, direct seeding had about 9 % more panicle dry weight than transplanting in 2011 due to more number of tillers per unit land area. At heading, leaf nitrogen concentration (%) in transplanted rice was 31% and 75% and nitrogen uptake (g m^{-2}) was 32% and 39% higher than direct seeding during 2011 and 2012 respectively. Direct seeding had lower leaf nitrogen content due to greater mutual shading of canopy (Dingkuhn *et al.*, 1990b). In shoot, nitrogen concentration in transplanting and direct seeding was similar in 2011 but direct seeding had about 36% higher nitrogen (%) than transplanting in 2012. Nitrogen uptake was higher in direct seeding than transplanting and was 16% and 33% higher in direct seeding due to rapid leaf area development and dry matter accumulation but growth rates and N uptake decreased during the grain filling period. In panicle, direct seeding had slightly higher nitrogen (%) than transplanting in 2011 but was 17% higher nitrogen (%) than transplanting in 2012. Nitrogen uptake was 19% higher in direct seeding than transplanting in 2011 but difference between direct seeding and transplanting in 2012 was lower. In straw, transplanted rice had 14% and 11% higher nitrogen (%) than direct seeded rice and conventional tillage had 53% and 13% higher nitrogen (%) than no tillage during 2011 and 2012 respectively. Nitrogen uptake (kg ha^{-1}) was 16% higher in direct seeding than transplanting during 2011. In grain, NTDS had significantly higher nitrogen (%) among the cultivation techniques during 2011 and was higher under CTDS in 2012. Transplanted rice had 6% and 3% higher nitrogen (%) than direct seeded rice and no tillage had 18% and 8% higher nitrogen (%) than conventional tillage in 2011 and 2012 respectively. Nitrogen uptake (kg ha^{-1}) was higher in transplanted than direct seeded by 12% and 7% during 2011and 2012 respectively. The physiological nitrogen use efficiency was higher in no tillage than conventional tillage in both the years due to total nitrogen uptake was lower but grain yield was close to conventional tillage. Nitrogen translocation ratio was higher in no tillage than conventional tillage due to source–sink relationship. The export percentage of dry matter and transport percentage of dry matter were higher in no tillage either in transplanted or direct seeded in both the years due to higher sink-source ratio. No tillage direct seeding produced higher number of panicle and NTTP was lower in both the years. Direct seeding rice had more number of panicle than transplanting due to more tillers per unit area. Badshah *et al.*, (2013) showed that at maximum tillering and maturity stage, direct seeded showed 22% more tiller than transplanted irrespective of tillage system. Sink size (more number of spikelet) was bigger in transplanting than direct seeding and CTTP produced significantly higher number of spikelet in both the years due to longer panicle and more number of spikelet per inch of panicle. Badshah *et al.*, (2013) reported that, transplanted rice had about 12% longer and larger sink (heavier panicle) than direct seeded rice. Conventional tillage and transplanting had higher economic yield because of bigger sink size in both the years caused by total uptake of nitrogen at maturity.

CONCLUSION

Nitrogen translocation ratio and physiological nitrogen use efficiency were higher in no tillage over conventional tillage in both the years. Although, direct seeded rice had more than 23% higher panicle than transplanting but higher grain yield was observed in CTTP in both the years due to higher uptake of nitrogen by grain at maturity and bigger sink size (more number of spikelet per unit land area).

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Bangladesh Rice J. 26 (2): 63-72, 2022, doi.org/10.3329/brj.v26i2. 66918

Effect of Nitrobenzene on the Growth and Yield of Rice

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ABSTRACT

A field experiment was conducted at two locations (Gazipur and Satkhira) during the Boro (dry) season in 2020 to study the performance of Nitrobenzene on the growth and yield of rice. Four different concentrations of Nitrobenzene (2.0 mL L^{-1}, 2.5 mL L^{-1}, 3.0 mL L^{-1} and 3.5 mL L^{-1}) as foliar spray with recommended chemical fertilizer (RF) were tested on BRRI dhan89 under wetland condition. Application of Nitrobenzene at different concentrations with RF showed significant effect on rice growth and yield. At both the locations, foliar application of Nitrobenzene (2 mL L^{-1}) + RF produced higher number of tiller/m^2, panicle/m^2 and grain/panicle over RF. At Gazipur site, Nitrobenzene (2 mL L^{-1}) + RF resulted in significant increase of grain and straw yield of BRRI dhan89 over the RF only whereas, at Satkhira site, no significant yield benefit with Nitrobenzene was found over RF. In terms of rice growth, yield and economic point of view, foliar application of Nitrobenzene at low concentration (2 mL L^{-1}) with recommended fertilizer showed positive effect on the growth and yield of BRRI dhan89 in this study. However, since Nitrobenzene is a new type of plant stimulant, detailed studies on its mode of action, interaction with other plant growth hormones and environmental effects are required to get an insight on rice response to Nitrobenzene and its widespread application in rice cultivation.

Key words: Rice growth, rice yield, foliar spray, economic benefit

INTRODUCTION

In Bangladesh, farmers generally use chemical fertilizers with little or no use of organic manures to meet the rice nutrient requirement, which results in degraded soil health and decreased rice yield (Sarkar *et al.*, 2016). Farmers could not use sufficient organic manures as they are required in bulk amount and are less available. Therefore, to curtail chemical fertilizer use as well as to increase rice yield an efficient and sustainable alternative is imperative. To solve this problem, plant growth regulator could be an efficient option. Plant growth regulators are widely used for their ability to increase crop growth and yield. Among the plant growth regulators, nitrobenzene found as effective in improving crop production in some studies (Aziz and Miah, 2009; Kohombange *et al.*, 2017; Kohombange *et al.*, 2019). Nitrobenzene is a combination of nitrogen and plant growth regulators, extracted from sea weeds that act as plant energizer, flowering stimulant and yield booster. Nitrobenzene is quickly absorbed into the plants and it influences the biochemical pathway of plants to uptake more nutrients from the soil. It also promotes vegetative growth and yield by increasing nutrient use efficiency, flowering and retention of flower and fruits (Deb *et al.*, 2009). The use of plant growth regulators like nitrobenzene in rice in Bangladesh is very limited. It is imperative to properly understand the effects of Nitrobenzene on rice growth and yield before its widespread use in rice

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cultivation. Therefore, this study was conducted to evaluate the performance of Nitrobenzene on the growth and yield of rice as well as to assess the profitability of Nitrobenzene application in rice cultivation.

MATERIALS AND METHODS

A field experiment was conducted at two locations: one at Bangladesh Rice Research (BRRI) farm, Gazipur under AEZ 28 and the other one at BRRI farm, Satkhira under AEZ 13 in Boro (dry) season, 2020 (Fig. 1). Table 1 presents the initial soil properties of the experimental locations. Soil pH, organic matter, total N, available P, exchangeable K, available S and available Zn were analyzed following the methods described by Tedesco *et al.*, 1995, Walkley and Black, 1934; Bremner and Mulvaney 1982, Sparks *et al.*, 1996; Black *et al.*, 1965; Fox *et al.*, 1965 and Olsen and Ellis, 1982, respectively. Fig. 2 presents the weather data (temperature and rainfall) of the experimental locations during the crop growing period. In this study, the efficacy of Nitrobenzene (Nitrobenzene 20% w/w obtained by the trade name Flora) was tested in five treatment combinations: T_1= Recommended chemical fertilizer only (RF), T_2 = RF + Nitrobenzene @ 2.0 mL L^{-1}, T_3 = RF + Nitrobenzene 2.5 mL L^{-1}, T_4 = RF + Nitrobenzene 3.0 mL L^{-1}, and T_5 = RF + Nitrobenzene 3.5 mL L^{-1}. The recommended rates of nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and zinc (Zn) were 138, 21, 75, 18 and 4 kg ha^{-1} respectively, at both the locations. The treatments were assigned in randomized complete block design with three replications. The N, P, K, S and Zn nutrients were applied as urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulfate, respectively. Full dose of TSP, MoP, gypsum and zinc sulfate were applied at the time of final land preparation. Urea was applied into three equal splits: 1/3rd after 12 days of transplanting, next 1/3rd at maximum tillering stage and the remaining 1/3rd at panicle initiation stage. Nitrobenzene of different doses were sprayed five times on the rice plant during the growing period according to the spray schedule (Table 2). At both the locations, thirty-five days old 2-3 seedlings/hill of BRRI dhan89 were transplanted with 20 cm × 20 cm spacing. Weeding, pesticide application and other necessary intercultural operations were done when required. At maturity, the crop was harvested from the centre 5 m2 area of each plot and the grain yield was adjusted to 14% moisture content. The data of plant height, tiller and panicle number per meter, filled grain number per panicle, thousand grain weight, grain and straw yields and harvest index were recorded.

Harvest index (HI) was estimated based on grain and straw yields using the following formula:

$$Harvest\ index = \frac{Grain\ yield}{Biological\ yield} \dots\dots\dots\dots (1)$$

where, Biological yield = grain yield + straw yield.

The grain and straw samples were analyzed for N concentration by micro-Kjeldahl method (Nelson and Sommers, 1973) and P and K concentrations were anlyzed by nitric-perchloric acid digestion method (Yamakawa, 1992) to calculate the total N, P and K uptake by the rice crop. The nutrient uptake was calculated as:

$$Nutrient\ uptake\ (kg/ha) = \frac{Nutrient\ concentration\ (\%) \times Yield\ (kg/ha)}{100} \dots\dots\dots\dots (2)$$

The data related to rice crop growth and yield were subjected to analysis of variance (ANOVA) to determine the treatment effects. Least Significance Difference (LSD) at the 5% level of probability was used to separate the means for treatments effect. All the analyses were performed using Statistical Tool for Agricultural Research (STAR 2.0.1, International Rice Research Institute, Manila, the Philippines).

Economic analysis was done to estimate added return, net return and marginal benefit cost ratio (MBCR) according to the following equations:

$$Added\ return = Gross\ return_{Flora\ treated\ plot} - Gross\ return_{Flora\ control\ plot} \ldots\ldots\ldots (3)$$

$$Net\ return = Gross\ return - Total\ variable\ cost \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$MBCR = \frac{Gross\ return_{Flora\ treated\ plot} - Gross\ return_{Flora\ control\ plot}}{Total\ variable\ cost_{Flora\ treated\ plot} - Total\ variable\ cost_{Flora\ control\ plot}} \ldots\ldots\ldots\ldots (5)$$


Location: BRRI Farm, Gazipur (23.9903, 90.39956)

Location: BRRI Farm, Satkhira (23.9903, 90.39956)

Fig. 1. Study locations.

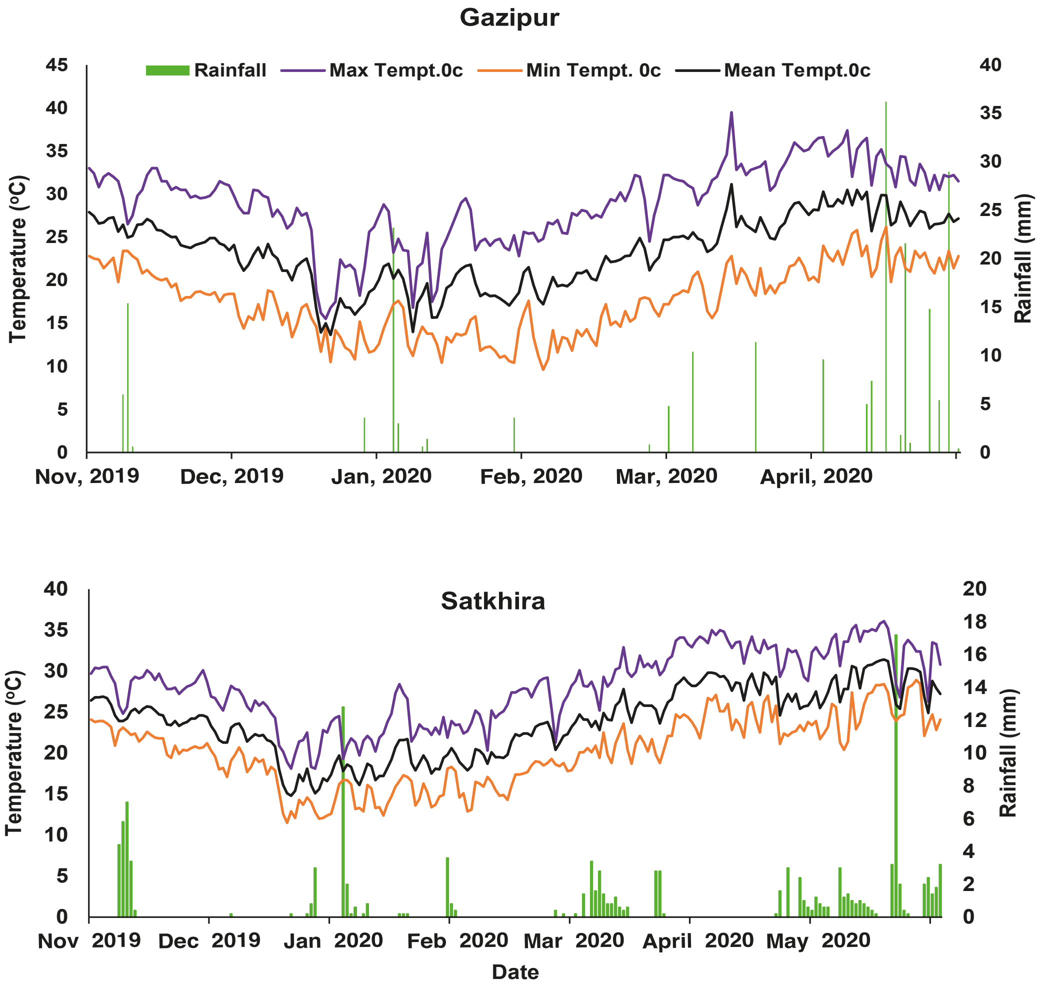

Fig. 2. Temperature and rainfall data of the study locations during crop growing period.

Table 1. Initial soil characteristics of the study locations.

Parameter	BRRI farm, Gazipur	BRRI farm, Satkhira
pH (1 : 2.5)	6.80	7.30
Organic C (%)	1.20	1.40
Total N (%)	0.11	0.13
Available P (mg/kg)	8.20	11.00
Exchangeable K (cmol/kg)	0.17	0.20
Available S (mg/kg)	19.00	30.00
Available Zn (mg/kg)	3.70	1.10

Table 2. The spray schedule of Nitrobenzene.

Spray schedule	Spray time
First spray	7 days before transplanting
Second spray	25 days after transplanting
Third spray	50 days after transplanting
Fourth spray	75 days after transplanting
Fifth spray	100 days after transplanting

RESULTS AND DISCUSSION

Effect of foliar application of Nitrobenzene on growth parameters

Foliar application of Nitrobenzene at different rates showed no significant effect on plant height of BRRI dhan89 at Gazipur and Satkhira sites. However, at both the locations the tiller number m^{-2} varied significantly with Nitrobenzene spray of varying rates. At both the locations, T_2 (RF + Nitrobenzene @ 2 mL L^{-1}) produced the highest tiller number m^{-2} compared to other treatments. The T_2 treatment increased tiller number m^{-2} by 11% and 10% over the recommended chemical fertilizer (T_1) at Gazipur and Satkhira sites, respectively (Table 3). In this study, foliar application of Nitrobenzene in combination with chemical fertilizer showed positive effect on tiller number of BRRI dhan89 at the study locations at low concentration (2 mL L^{-1}). The enhanced plant growth with Nitrobenzene may be attributed to synergistic relationship between Nitrobenzene and other plant hormones namely gibberellins, auxin and cytokinin (Kohombange *et al.*, 2019). Gibberellins and auxin influence stem elongation while auxin and cytokinin influence lateral growth of parenchyma cells in stem so that the plant girth increases (Nickell, 1982). Moreover, Nitrobenzene promotes plant nutrient uptake from the soil and nutrient use efficiency by influencing the biochemical pathway of the plant resulting in improved plant growth (Deb *et al.*, 2012). However, in our study at both locations the total uptake of N, P and K showed no significant variation with the treatments applied.

Table 3. Effects of foliar application of Nitrobenzene on growth and yield parameter of BRRI dhan89.

Treatment*	Plant height (cm)		Tiller m^{-2}	
	Gazipur	Satkhira	Gazipur	Satkhira
T_1	102.67	110.44	301 b	288 bc
T_2	102.67	110.00	335 a	318 a
T_3	103.00	112.56	284 b	301 b
T_4	101.00	110.44	314 ab	298 bc
T_5	101.00	107.33	304 b	284 c
$LSD_{0.05}$	2.00	4.00	31	16
CV (%)	1.03	2.00	*5.31*	*3.83*

*T_1= Recommended chemical fertilizer (RF), T_2= RF + Nitrobenzene (2.0 mL L^{-1}), T_3= RF + Nitrobenzene (2.5 mL L^{-1}), T_4 = RF + Nitrobenzene (3.0 mL L^{-1}), T_5 = RF + Nitrobenzene (3.5 mL L^{-1}).

Effect of foliar application of Nitrobenzene on yield parameters

Table 4 presents the effect of different treatments on yield components of BRRI dhan89. Application of Nitrobenzene at different rates in combination with recommended fertilizer significantly influenced the panicle number m^{-2}. At Gazipur site, the highest panicle number m^{-2} (329) were recorded with T_2 (RF + Nitrobenzene @ 2 mL L^{-1}), which was statistically similar to T_4 (RF + Nitrobenzene @ 3 mL L^{-1}). At Satkhira site, the T_2 treatment also produced the highest number (308) of panicles m^{-2} compared to the other treatments. The T_2 treatment increased panicle number m^{-2} by 12% and 9% over the recommended fertilizer only (T_1) at Gazipur and Satkhira sites, respectively. The number of grains per panicle and sterility (%) differed significantly with varying levels of Nitrobenzene spray at both the locations. At Gazipur site, the highest number (147) of filled grain per panicle was found with T_2 treatment which was statistically similar with T_3 and T_4 treatments. At Satkhira site, the highest number (133) of grain per panicle was found with T_2 than the other treatments. At both the locations the grain sterility (%) significantly reduced with the T_2 treatment and was higher with T_5. The thousand grain weight of BRRI dhan89 did not differ with the applied treatments. Number of panicle m^{-2} and filled grain were significantly higher with Nitrobenzene sprayed at 2 mL L^{-1} compared to only chemical fertilizer, which indicates that Nitrobenzene might have positive effect on rice flowering and grain filling. The application of Nitrobenzene and its immediate transport to the auxiliary buds would have resulted in a better sink for the quick mobilization of photo-assimilates. The increased number of filled grain might be influenced by triggering of such metabolic processes and the increased accumulation of carbohydrates into the rice grain which resulted in reduced grain sterility. The sterility of BRRI dhan89 was comparatively higher in Satkhira than that of Gazipur, which might be due to the variation in climatic condition between the two locations.

Table 4. Effects of foliar application of Nitrobenzene on yield parameters of BRRI dhan89.

Treatment*	Panicle m^{-2}		Grain/panicle		1000 grain wt.		Sterility %	
	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira
T_1	294	282	134	116	23.34	24.02	11	20
T_2	329	308	147	133	23.04	23.52	10	18
T_3	278	288	138	117	23.01	23.31	10	18
T_4	304	288	125	113	22.90	23.65	13	21
T_5	296	274	114	112	23.27	24.12	15	31
$LSD_{0.05}$	*31*	*15*	*17*	*17*	*1.10*	*1.20*	*4*	*4*
CV (%)	*5.53*	*3.63*	*6.94*	*7.40*	*2.78*	*2.45*	*19*	*10*

*T_1= Recommended chemical fertilizer (RF), T_2= RF + Nitrobenzene (2.0 mL L^{-1}), T_3= RF + Nitrobenzene (2.5 mL L^{-1}), T_4 = RF + Nitrobenzene (3.0 mL L^{-1}), T_5 = RF + Nitrobenzene (3.5 mL L^{-1}).

Effect of foliar application of Nitrobenzene on grain and straw yield

The grain and straw yields of BRRI dhan89 significantly differed with the different treatments and table 5 presents the results. At Gazipur site, the T_2 (RF + Nitrobenzene @ 2 mL L^{-1}) treatment produced the highest grain and straw yields than the other treatments. The T_2 treatment increased grain yield by about 11% over recommended fertilizer only (T_1). At Satkhira site, the highest grain yield was found with T_2 (RF+ Nitrobenzene @ 2 mL L^{-1}) which was statistically identical to T_1, T_3 and T_4 treatments. The T_2 treatment increased grain yield by about 5% over T_1. The highest straw yield was found with T_3 (RF+ Nitrobenzene @ 2.5 mL L^{-1}) which was statistically similar to T_1, T_2 and T_5 treatments. Irrespective of location the harvest index of BRRI dhan89 varied between 0.50-0.53 and there was significant variation among the different treatments. The increased grain yield of BRRI dhan89 with Nitrobenzene sprayed at a concentration of 2 mL L^{-1} was attributed to the higher number of tiller, panicle and filled grain with this treatment. Deb *et al.*, 2012 and Kohombange *et al.*, 2019 reported that Nitrobenzene increased flowering and fruit sets in tomato and cucumber, respectively which support our findings. However, the significant yield increase was observed only at Gazipur site indicating that effect of Nitrobenzene may vary with locations because of variation in initial soil fertility (Table 1). Our study clearly indicate that application of flora at concentration above 2 mL L^{-1} showed no significant effect on rice plant growth and yield. Guo *et al.*, 2010 found that in solution culture the growth of soybean seedlings increased at low concentration of 5 mg L^{-1} and after 10 mg L^{-1} showed genotoxic effects. Moreover, higher concentrations of nitrobenzene in water bodies are hazardous to aquatic organism and plants by irrigation (Guo *et al.*, 2010).

Table 5. Effects of foliar application of Nitrobenzene on grain and straw yield (t/ha) of BRRI dhan89.

Treatment*	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest index		% Grain yield increased over recommended chemical fertilizer	
	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira
T_1	6.79 b	6.67ab	6.19 b	6.54ab	0.52	0.50		
T_2	7.53 a	6.99 a	6.85 a	6.86 a	0.52	0.50	10.82	4.66
T_3	6.93 b	6.84 ab	6.33 b	6.87 a	0.52	0.50	2.01	2.44
T_4	6.82 b	6.54 ab	6.25 b	6.24 b	0.52	0.51	0.46	-2.04
T_5	6.85 b	6.44 b	6.17 b	6.52 ab	0.53	0.50	0.91	-3.52
$LSD_{0.05}$	*0.43*	*0.28*	*0.46*	*0.49*				
CV (%)	*4.27*	*4.69*	*3.35*	*4.95*				

*T_1= Recommended chemical fertilizer (RF), T_2= RF + Nitrobenzene (2.0 mL L^{-1}), T_3= RF + Nitrobenzene (2.5 mL L^{-1}), T_4 = RF + Nitrobenzene (3.0 mL L^{-1}), T_5 = RF + Nitrobenzene (3.5 mL L^{-1}).

Effects of foliar application of Nitrobenzene on nutrient uptake of BRRI dhan89

Application of Nitrobenzene at different concentrations showed no significant effect on the total uptake of nitrogen (N), phosphorus (P) and potassium (K) by BRRI dhan89 at both the locations. At Gazipur site, the total uptake of N, P and K ranged between 108.63 – 126.70 kg ha^{-1}, 20.69 – 23.80 kg ha^{-1} and 99.47 – 113.73 kg ha^{-1}, respectively. At Satkhira site, the total uptake of N, P and K ranged between 109.78 – 120.72 kg ha^{-1}, 17.77 – 21.09 kg ha^{-1} and 84.70 – 95.11 kg ha^{-1}. respectively.

Economic analysis

Tables 6 and 7 present the calculated total variable cost (TVC), gross return, added return, net return and marginal benefit cost ratio (MBCR) of BRRI dhan89 with different treatments. The total variable cost was calculated considering the cost for fertilizer, fertilizer application, Nitrobenzene spray and labour for the additional products (Table 6). At both the locations, foliar application of Nitrobenzene (2mL L^{-1}) with the recommended fertilizer resulted in the highest gross return, added return and net return. Moreover, application of Nitrobenzene at higher rates was not profitable as the added and net returns were much lower with higher rates of Nitrobenzene. At both the locations, similar results were also found for MBCR (Table 7).

Table 6. Economic analysis of foliar application of Nitrobenzene on BRRI dhan89 at two different locations of Bangladesh.

Total variable cost (TVC) in Tk/ha

Treatment*	Fertilizer cost		Fertilizer application cost		Nitrobenzene spray cost		Labor cost for additional products		Total variable cost (BDT ha^{-1})	
	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira
T_1	14560	14560	800	800	0	0	0	0	15360	15360
T_2	16180	16180	800	800	2000	2000	5580	2534	24560	21514
T3	16585	16585	800	800	2000	2000	1134	1975	20519	21359.8
T4	16990	16990	800	800	2000	2000	359.6	0	20149.6	19790
T5	17395	17395	800	800	2000	2000	184.4	0	20379.4	20195

*T_1= Recommended chemical fertilizer (RF), T_2= RF + Nitrobenzene @ 2.0 mL L^{-1}, T_3= RF + Nitrobenzene @ 2.5 mL L^{-1}, T_4 = RF + Nitrobenzene@ 3.0 mL L^{-1}, T_5 = RF + Nitrobenzene @ 3.5 mL L^{-1}. Fertilizer cost included price of chemical fertilizer and Nitrobenzene. Urea = Tk 16/kg, TSP = Tk 22/kg, MoP= Tk15/kg, Gypsum= Tk 25/kg, Zinc= Tk 200/kg, Nitrobenzene (Flora) = Tk 810/lit.
Labor wage= Tk 400/day. Two additional man days/ha are required for applying fertilizer, ten-man days/ha for per ton additional products and five-man days/ha for spraying Nitrobenzene.

Table 7. Gross and net return in Tk/ha and marginal benefit cost ratio (MBCR)

Treatment*	Yield				Total variable cost		Return						MBCR	
	Grain		Straw				Gross		Added		Net			
	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira
T_1	6.79	6.67	6.19	6.54	15360	15360	188989	186631	-	-	173629	171271	-	-
T_2	7.53	6.99	6.85	6.86	24560	21514	209421	195359	20432	8729	184861	173845	2.22	1.42
T_3	6.93	6.84	6.33	6.87	20519	21360	192830	191535	3841	4904	172311	170175	0.74	0.82
T_4	6.82	6.54	6.25	6.24	20150	19790	189918	182484	929	-4147	169768	162694	0.19	-0.94
T_5	6.85	6.44	6.17	6.52	20379	20195	190557	180494	1568	-6137	170178	160299	0.31	-1.27

*T_1 = Recommended Fertilizer (RF), T_2 = RF + Nitrobenzene @ 2.0 mL L^{-1}, T_3 = RF + Nitrobenzene @ 2.5 mL L^{-1}, T_4 = RF + Nitrobenzene @ 3.0 mL L^{-1}, T_5 = RF + Nitrobenzene @ 3.5 mL L^{-1}; GS = Gazipur site, SS = Satkhira Site. Rice grain price = Tk 26/kg, Rice straw price = Tk 2/kg.

CONCLUSION

Foliar application of Nitrobenzene significantly affected the growth and yield of BRRI dhan89. Among different concentrations of Nitrobenzene tested, Nitrobenzene sprayed at a concentration of 2 mL L^{-1} with recommended chemical fertilizer (RF) resulted in significantly higher tiller and panicle number and grain number. Compared to only RF, combined application of nitrobenzene (2mL L^{-1}) with RF produced significant yield benefit of BRRI dhan89 only at Gazipur site. Irrespective of location, application of Nitrobenzene at higher rates showed no significant advantages on the growth and yield of BRRI dhan89. In this study, foliar spray of Nitrobenzene with a rate of 2mL L^{-1} performed better in terms of plant growth and yield of BRRI dhan89. However, this study was a single season experiment and conducted only at two locations, thus multilocational trials with long term study which is reqiured to draw a concrete conclusion on rice response to Nitrobenzene.

ACKNOWLEDGEMENTS

The authors wish to thank anonymous reviewers for their suggestions, which significantly improved this article.

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Bangladesh Rice J. 26 (2): 73-82, 2022, doi.org/10.3329/brj.v26i2. 66919

Long Term Rice-Rape Seed Cropping Effects on Weed Seed Bank Size and Composition

M A Badshah[1*], M Ibrahim[2] and T N Mei[3]

ABSTRACT

To study the long term rice-rape cropping effect on weed seed bank size and composition, soil samples were collected from a long term (2004–2012) experiment under the cultivation techniques of conventional tillage transplanting (CTTP), no-tillage transplanting (NTTP), conventional tillage direct seeding (CTDS), and no-tillage direct seeding (NTDS) at a various soil depths of 0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm during 2011- 2012. Results indicate that, the highest weed seed accumulation of most species was in the 0-5 cm soil depth. More than 60% (% to total weed seeds) seeds were germinated at 20 days after placement of tray (DAP). The seed bank size of *Echinochloa crus-galli*(L) under direct seeded was 53% higher than transplanted in both years irrespective of tillage system. It decreased 67% under CT and 87% under NT from 0-5 to 5-10 cm soil depth in 2011. The ranked of weed species were grass > broad leaf > sedge based on their number per unit area in both years. The rank of *Echinochloa crus-galli*(L) was CTDS > NTTDS > NTTP > CTTP among the treatments at 0-5 cm soil depth in both years. *Monochoria vaginalis* (Burm.f) Kunth, *Fimbristylis miliacea* and *C. iria* L were fewer in number. The pressure of germination of weed seeds was more at 20 DAP at 0-5 cm soil depth. Total number (up to 60 DAP) of *Echinochloa crus-galli* was higher in CTDS at 0-5 cm soil depth in both the years and drastically reduced under no tillage than under conventional tillage towards deeper horizon of soil.

Key words: Rice-rape cropping, weed seed bank

INTRODUCTION

Weed seed bank in the soil is mainly influenced by tillage system, weed management options and crop rotation. Secondary weed could be converted to become a primary weed by changing the tillage system. Direct seeded rice occupied many areas of the world and needs less aggressive tillage and a greater use of herbicides. This cultivation practice increases annual weed problems and a shift in the spectrum of annual weeds. Shrestha *et al.*, (2002) reported that, conventionally tilled land faces greater weed pressure than in no-tillage systems. Tillage system plays an important role to influence the depth distribution, abundance and species composition of seeds in the soil. Weed seeds that accumulate close to soil surface in no-till and are more or less uniformly distributed with depth by moldboard plowing in combination with disking (Ball, 1992; Yenish *et al.*, 1992). These differences in seed burial depth affect weed community composition and emerge at or near the soil surface tend to increase in reduced tillage systems (Buhler, 1995). Perennial weeds may increase after several years of reduced tillage (Barberi *et al.*, 1998; Cardina *et al.*, 1991; Triplett and Lytle, 1972; Wicks *et al.*, 1994).Weed seed bank size and composition in soil influences to a much greater by tillage systems than crop rotation (Barberi and Cascio, 2001). Higher number of annual dicot weed seed has been reported in 5-15

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cm deep in conventional tillage than in minimum tillage or reduced tillage (Vanasse and Leroux, 2000). Some information is available about weed seed bank size and composition caused by tillage system. Therefore, this study has been taken to evaluate the long term rice-rape cropping effect on weed seed bank size and composition.

MATERIALS AND METHODS

The experiment was conducted in a long term rice-rape cropping pattern research farm of Hunan Agricultural University, Hunan, China during 2004-2012 (May to September). Data were taken from 2011-2012. The experiment was laid out in a RCB (Randomized complete block) design with four replications. Factor A was tillage system; conventional tillage (CT) and no-tillage (NT), factor B was crop establishment method; transplanting (TP) and direct seeding (DS). So, crop cultivation techniques were conventional tillage and transplanting (CTTP), conventional tillage and direct seeding (CTDS), no-tillage and transplanting (NTTP) and no-tillage and direct seeding (NTDS). Animal-drawn plowing was done in conventional tillage followed by harrowing and non- selective herbicide and flooding was used in no-tillage. Twenty-five-day-old seedlings were manually transplanted at a spacing of 20 x 20 cm with one seedling per hill on 8th June in case of transplanting. Pre-germinated seeds were manually broadcasted on the soil surface at a seeding rate of 22.5 kg per ha on 24th May in case of direct seeding.

Weather condition during study period: During 2011, the highest and the lowest temperatures gradually increased from 20 - 40 days after placement (DAP) of pot and then slightly decreased at 60 DAP. During 2012, the highest temperature slightly decreased but the lowest temperature slightly increased from 20 - 60 DAP (Fig.1). Average sunshine hour (h) gradually decreased from 20 - 60 DAP in 2011. During 2012, sunshine hour sharply decreased from 20 - 40 DAP and then slightly decreased up to 60 DAP. Average rainfall sharply decreased from 20 - 40 DAP and then slightly decreased at 60 DAP during 2011. But rainfall sharply increased from 20 - 40 DAP and then sharply decreased at 60 DAP during 2012 (Fig. 2).

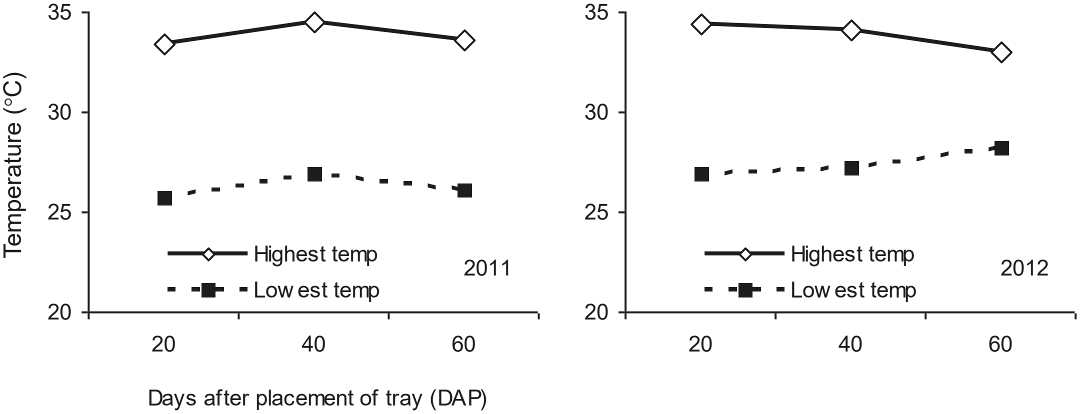


Fig. 1. Highest and lowest temperature during weed seed bank study, Hunan, China.

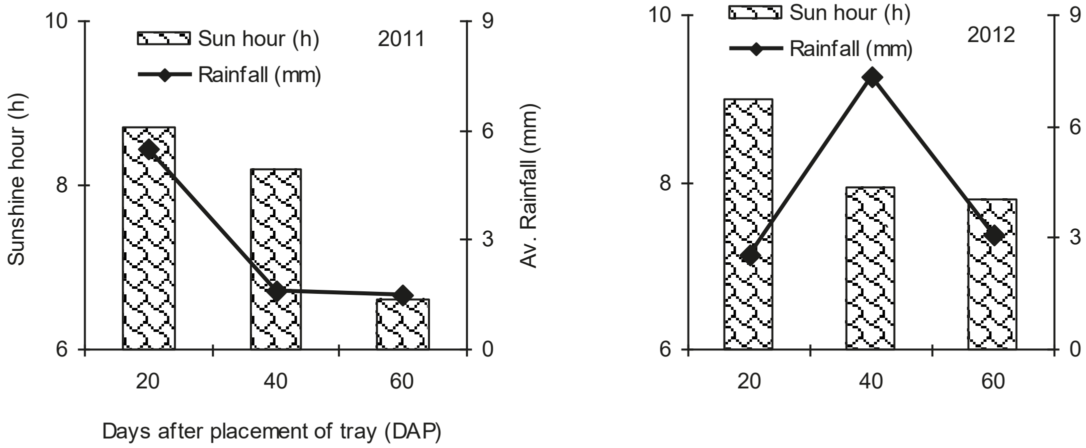
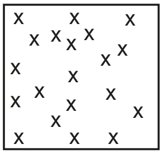
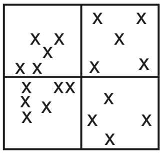


Fig. 2. Sunshine hour and rainfall during weed seed bank study, Hunan, China

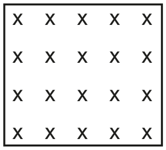
Time and method of soil sampling: After harvesting of rape but before rice planting, soil samples were taken from each of the 0-5 cm, 5-10 cm, 10-15 cm and 10-20 cm soil layers of each plot. The systematic sampling plan was used in this study because it has been widely accepted, straightforward and potentially increases the accuracy of the study.



Simple Random



Stratified Random



Systematic

Working procedure of weed seed bank study During 2011 and 2012, soil cores were taken from 21 spots of each plot. Then bulk samples were stored for three weeks in a dark place at room temperature (Jagat *et al.*, 2007) and then transferred to plastic trays. The soil cores from each plot and each depth was combined, crumbled and laid on the tray (5 × 19 × 24 cm^3). The soil was kept moist by watering if and when necessary. To identify the number and species of weed, trays were placed under open environment at 20 June in both the years. Germinated weed seedlings were pulled out, identified and counted at 20, 40 and 60 days after placement of tray (DAP). Total number of weed (group wise) was calculated from 20-60 DAP respectively. The identified weeds were categorized into different groups' like grass, sedge, broadleaf etc.

Data analysis All data were analyzed by statistical software, Statistix9. Means of cultivation methods were compared to LSD with 0.05 probability level.

RESULTS

Total weed seed size and compositions at different soil depth and treatment: A total of five weed species were identified during 2011 and six species were during 2012 (Table 1). Out of them, the ranked of weed species were grass > broad leaf > sedge based on their number per unit area in both years. *M. vaginalis, F. miliacea* and *C. iria* were fewer in number. A total seed of *E. crus-galli* was higher during 2011 than 2012. Total number of *E. crus-galli* was significantly higher under DS than TP either in CT or NT system at 0-5 cm soil depth in both years and reduced drastically under NT towards deeper horizon of soil than under CT (Fig. 3a). Total number of *L. octovalvis* was similar in CTTP, NTTP and CTDS at 0-5 cm soil depth during 2011 but was higher in CTDS followed by NTTP during 2012. It was significantly higher in CTTP but NTTP, NTDS and CTDS were similar in number at 5- 10 cm depth during 2011and CT had significantly higher number of L. *octovalvis* than NT either in TP or DS during 2012. Same trend was observed at 10-15 cm soil depth (Fig. 3b). In case of C. *difformis*, total number was higher in CT than NT at all soil depth in both years (Fig. 3c).

Table 1. Weed species found in weed seed bank study, Changsha, Hunan, China, 2011-2012.

Latin name	Bayer code	Common name
2011		
Cyperusdifformis L	CYPD1	Sedge, small flower umbrella
Echinochloacrus-galli(L) Beauv	ECHCG	Barnyard grass
Fimbristylismiliacea (L) Vahl	FIMMI	Globe, fringe rush
Ludwigiaoctovalvis (jacq.) Raven	LUDOC	Primrose-willow, long fruited
Monochoria vaginalis (Burm.f) Kunth	MOOVA	Monochoria
2012		
Cyperusdifformis L	CYPD1	Sedge, small flower umbrella
*Cyperusiria*L	CYPIR	Flat sedge, rice
Echinochloacrus-galli(L) Beauv	ECHCG	Barnyard grass
Fimbristylismiliacea (L) Vahl	FIMMI	Globe, fringe rush
Ludwigiaoctovalvis (jacq.) Raven	LUDOC	Primrose-willow, long fruited
Monochoria vaginalis (Burm.f) Kunth	MOOVA	Monochoria

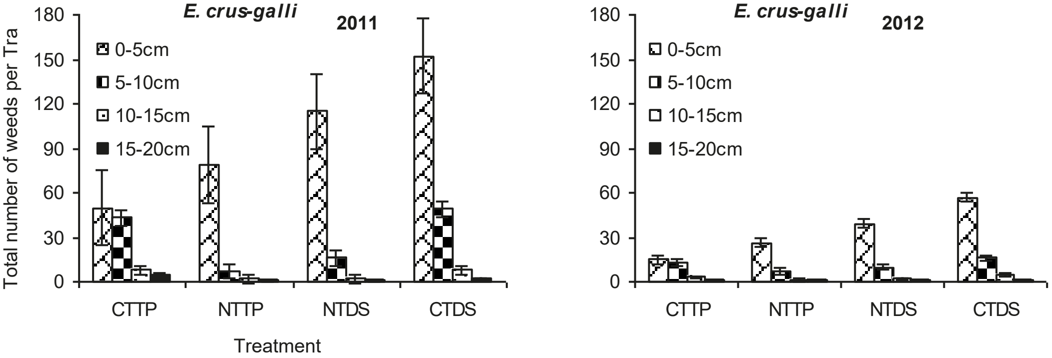


Fig. 3a. Effect of treatments and soil depth on total number of predominant weeds up to 60 DAP. Bar represents SE

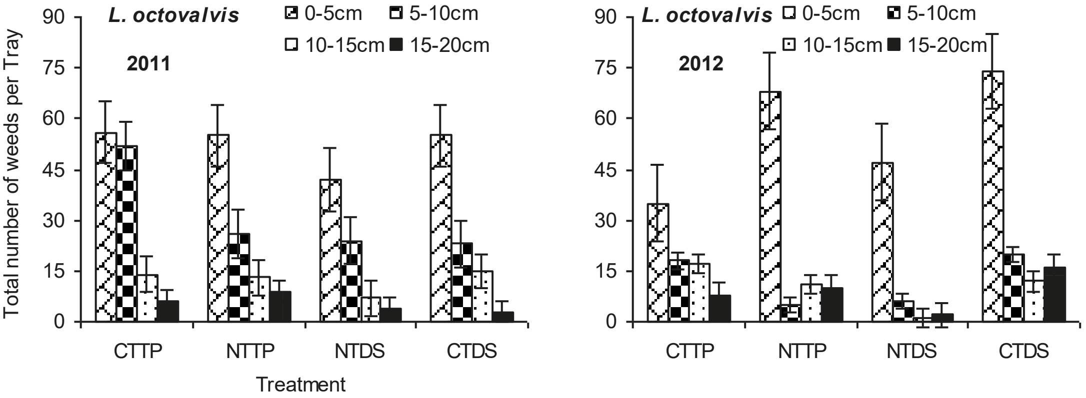


Fig. 3b. Effect of treatments and soil depth on total number of predominant weeds up to 60 DAP. Bar represents SE

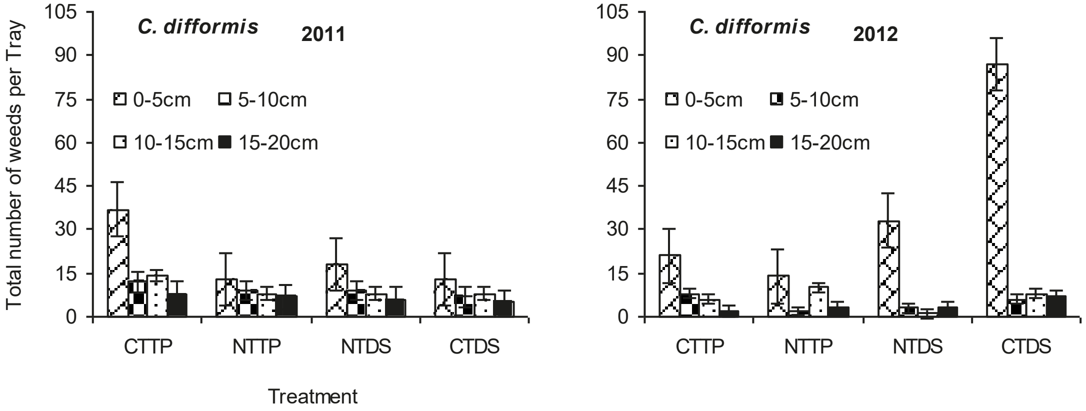


Fig. 3c. Effect of treatments and soil depth on total number of predominant weeds up to 60 DAP. Bar represents SE

Effect of soil depth and treatment on weed seed bank size and composition at different DAP

A few weeds were found at 60 DAP as well as at 15-20 cm soil depth at all treatments in both years. So, weeds on 20 and 40 DAP were reported and weeds at 15-20 cm soil depth were excluded from the presentation but were considered when calculated total number of weeds which discussed earlier.

At first counting (20 DAP) The rank of *E. crus-galli* was CTDS > NTTDS > NTTP > CTTP among the treatments at 0-5 cm soil depth in both years. *E. crus-galli* was comparatively higher during 2011 than 2012. DS plots had significantly higher number of seeds than TP plots irrespective of tillage system. In direct seeding (DS), CTDS had higher number of seeds than NTDS but they were statistically similar and in TP, higher number of seeds was found in NTTP than CTTP in both years. Tillage system had positive impact on *E. crus-galli* and towards deeper horizon of soil *E. crus-galli* reduced drastically under NT than under CT (Table 2a). Number of L. *octovalvia* was higher in 2012 than 2011 at 0-5 cm soil depth. There was no significant difference among the treatments at all soil depth during 2011. In TP, L. octovalvis was slightly higher under NT at 0-5 cm soil depth than under CT but in DS, was higher under CT than under NT in both years. Towards deeper horizon of soil, L. octovalvis decreased gradually under CT but decreased sharply under NT during 2012 (Table 2b). Number of *C. difformis* was higher in 2012 than 2011 at 0-5 cm soil depth. There was no significant difference among the treatments at all soil depth in both years except 15-20 cm during 2012. Both in TP and DS, *C. difformis* was higher under CT at 0-5 cm soil depth than under NT in both years. Towards the deeper soil depth, *C. difformis* decreased gradually under CT than NT (Table 2c).

Table 2a. Effect of treatments and soil depth on predominant weed seed size at 20 DAP

Treatment	*E. crus-galli*					
	0-5 cm		5-10 cm		10-15 cm	
	2011	2012	2011	2012	2011	2012
CTTP	38 c	10 b	31 a	8	7	2 a
NTTP	62 bc	19 ab	6 b	6	1	0 b
NTDS	95 ab	29 ab	14 b	8	2	0 b
CTDS	117 a	42 a	34 a	11	7	4 a
Analysis of variance						
Establishment method (A)	*	NS	NS	NS	NS	NS
Tillage (B)	NS	NS	*	NS	*	*
A X B	*	*	*	NS	NS	*
SE at 0.05	20.91	12.6	3.73	2.09	2.91	0.78

* = significant at $P = 0.05$, NS = not significant at $P = 0.05$.

Table 2b. Effect of treatments and soil depth on predominant weed seed size at 20 DAP

Treatment	*L. octovalvis*					
	0-5 cm		5-10 cm		10-15 cm	
	2011	2012	2011	2012	2011	2012
CTTP	13	28	17	11	7	8 a
NTTP	16	39	9	2	5	5 ab
NTDS	13	20	11	4	5	0.33 c
CTDS	19	38	13	6	14	3 bc
Analysis of variance						
Establishment method (A)	NS	NS	NS	NS	NS	*
Tillage (B)	NS	NS	NS	NS	NS	NS
A X B	NS	NS	NS	NS	NS	*
SE at 0.05	8.82	9.71	3.36	3.78	4.56	1.81

* = significant at $P = 0.05$, NS = not significant at $P = 0.05$.

Table 2c. Effect of treatments and soil depth on predominant weed seed size at 20 DAP.

Treatment	*C. difformis*					
	0-5 cm		5-10 cm		10-15 cm	
	2011	2012	2011	2012	2011	2012
CTTP	15	18	7	6	10	3
NTTP	7	9	7	1	6	6
NTDS	5	18	7	3	7	1
CTDS	8	66	5	4	8	5
Analysis of variance						
Establishment method (A)	NS	NS	NS	NS	NS	NS
Tillage (B)	NS	NS	NS	NS	NS	NS
A X B	NS	NS	NS	NS	NS	NS
SE at 0.05	5.37	31.56	4.01	2.31	2.74	3.70

* = significant at $P = 0.05$, NS = not significant at $P = 0.05$.

At 2nd counting (40 DAP) Similar trend like 20 DAP was observed in case of *E. crus-galli (*Table 3a). But in case of *L. octovalvia*, it was higher in 2011 than 2012 at 0-5 cm soil depth. There was significant difference among the treatments at all soil depth in both years. In TP, *L. octovalvis* was slightly higher under NT at 0-5 cm soil depth than CT but in DS, was significantly higher under CT than NT during 2011. With increasing of soil depth *L. octovalvis* decreased gradually under CT but decreased sharply under NT in both years (Table 3b). Number of *C. difformis* was higher in 2011 than 2012 at 0-5 cm soil depth. There was significant difference among the treatments at all soil depths during 2011. In CT, *C. difformis* was higher in TP than DS at 0-5 cm soil depth during 2011 but reversed during 2012. In NT, it was higher in DS in both years. Towards the deeper soil depth *C. difformis* decreased gradually both under CT and NT except 10-15 cm soil depth (Table 3c).

Table 3a. Effect of treatments and soil depth on predominant weed seed size at 40 DAP.

Treatment	*E. crus-galli*					
	0-5 cm		5-10 cm		10-15 cm	
	2011	2012	2011	2012	2011	2012
CTTP	10 b	4 c	9 a	5	1	1 a
NTTP	14 b	6 bc	1 b	1	1	0 b
NTDS	17 b	9 ab	1 b	2	0.33	0 b
CTDS	35 a	12 a	15 a	5	1	1 a
Analysis of variance						
Establishment method (A)	*	*	NS	NS	NS	NS
Tillage (B)	NS	NS	*	NS	NS	*
A X B	*	*	*	NS	NS	*
SE at 0.05	6.30	2.04	2.19	2.25	0.90	0.24

* = significant at $P = 0.05$, NS = not significant at $P = 0.05$.

Table 3b. Effect of treatments and soil depth on predominant weed seed size at 40 DAP

Treatment	*L. octovalvis*					
	0-5 cm		5-10 cm		10-15 cm	
	2011	2012	2011	2012	2011	2012
CTTP	24 ab	5 b	16 a	6 ab	3	8 a
NTTP	29 ab	20 ab	8 ab	1 b	4	4 ab
NTDS	22 b	20 ab	2 b	2 b	0	1 b
CTDS	36 a	25 a	10 ab	11 a	1	9 a
Analysis of variance						
Establishment method (A)	NS	NS	NS	NS	NS	NS
Tillage (B)	NS	NS	*	*	NS	*
A X B	*	*	*	*	NS	*
SE at 0.05	5.03	7.25	3.72	2.44	2.16	2.71

* = significant at $P = 0.05$, NS = not significant at $P = 0.05$.

Table 3c. Effect of treatments and soil depth on predominant weed seed size at 40 DAP

Treatment	*C. difformis*					
	0-5 cm		5-10 cm		10-15 cm	
	2011	2012	2011	2012	2011	2012
CTTP	16 a	2	5 a	1	3 a	2 a
NTTP	4 b	4	1 b	1	2 ab	3 a
NTDS	10 ab	10	2 ab	0.33	1 bc	0 b
CTDS	5 b	13	2 ab	1	0 c	2 a
Analysis of variance						
Establishment method (A)	NS	*	NS	NS	*	*
Tillage (B)	NS	NS	NS	NS	NS	NS
A X B	*	NS	*	NS	*	*
SE at 0.05	3.81	4.76	1.27	0.77	0.77	0.68

* = significant at $P = 0.05$, NS = not significant at $P = 0.05$.

DISCUSSION

Total grass weed seeds decreased over time but the pressure was more in the first 0-5-cm depth at 20 DAP. The seed bank size of *E. crus-galli* under DS was 53% higher than TP in both years. It decreased 67% under CT and 87% under NT from 0-5 to 5-10 cm soil depth during 2011. Similar trend was found in 2012. Weed seeds of sedges and broadleaf also showed a similar trend but the percent increase was not as high as in grass. About 61% weed seeds (% to total number of weed seeds) were concentrated at 0-5 cm soil depth, 25% at 5-10 cm, 10% at 10-15 cm and 4% at 15-20 cm soil depth during 2011 but were 67% at 0-5 cm soil depth, 16% at 5-10 cm, 10% at 10-15 cm and 7% at 15-20 cm soil depth during 2012. Seeds of *E. crus-galli, L. octovalvis* and *C. difformis* were 58%, 30% and 12% respectively at 0-5 cm soil depth during 2011 and were 27%, 42% and 31% during 2012. Seeds of *E. crus-galli, L. octovalvis* and

C. difformis were 41%, 45% and 14% respectively at 5-10 cm soil depth during 2011 and were 41%, 42% and 17% during 2012. More than 60% seeds were germinated at 20 DAP, 29% at 40 DAP and 10% at 60 DAP during 2011 but were 63%, 28% and 9% during 2012.

The vertical distribution of total weed seeds in the seed bank showed a declining trend in density as the depth increased from 5- 20 cm to all other treatments. *E. crus-galli* was higher in CTDS at 0-5 cm soil owing to continuous direct seeding for long time and drastically reduced under NT than CT towards deeper horizon of soil owing to tillage system. But in case of broad leaf weed, there was no distinct trend followed like grass weeds. Weed density was greater in conventionally tilled land than in no-tillage systems (Shrestha *et al.*, 2002). Weed seeds accumulate near the soil surface in NT and are more or less uniformly distributed with depth by mould board plough in combination with disking (Ball, 1992; Yenish *et al.*, 1992).

CONCLUSION

The weed seed accumulation of most species was highest in the 0-5 cm soil depth. The ranked of weed species were grass > broad leaf > sedge based on their number per unit area in both years. The rank of *E. crus-galli* was CTDS > NTTDS > NTTP > CTTP among the treatments at 0-5 cm soil depth in both years. The pressure of germination of weed seeds was more at 20 DAP at 0-5 cm soil depth. Total number (up to 60 DAP) of *E. crus-galli* was higher in CTDS at 0-5 cm soil depth in both years and was drastically reduced under NT than under CT towards deeper horizon of soil. But there was no distinct trend like followed grass weeds in case of broad leaf weed seed size and composition.

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BRJ: Publication no. : 377; 500 copies, Published in July 2023
Published by the Director General, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh
Printed by Akkhor Printing Press, West Joydebpur, Gazipur-1700