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RESEARCH ARTICLE

Optimising cropping systems through BINA crop varieties in southwest Bangladesh

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Abstract

In southwest Bangladesh, short-duration, high-yielding and stress tolerant crop varieties developed by the Bangladesh Institute of Nuclear Agriculture (BINA) offer a practical pathway to intensify cropping systems under land scarcity and climate variability. Introduction of such crop varieties can enhance land use and overall farm profitability. Considering the fact, the current study was conducted in Jhenaidah and Magura districts of the Jessore region to assess the agronomic and economic performance of better cropping patterns utilizing BINA developed crop varieties. Two better or improved patterns, Transplanted *aman*–mustard–*boro* and Transplanted *aman*–mustard–mungbean–*aus* were evaluated against the established Transplanted *aman*–fallow–*boro* and Transplanted *aman*–mustard–mungbean sequences. Results showed that improved Transplanted *aman*–mustard–*boro* pattern increased rice equivalent yield by 15.6 % and production efficiency (PE) by 9.5 % over the existing Transplanted *aman*–fallow–*boro* system. Similarly, inclusion of mungbean and *aus* rice in a four-crop sequence enhanced land use efficiency to 93.97 %, compared with 73.15 % in the traditional 3-crop pattern. Though improved cropping patterns showed significantly higher gross return and gross margin over the existing patterns, the benefit cost ratio did not differ significantly among the patterns, likely due to higher input and management costs offset yield gains. Overall, integration of BINA developed short-duration and high-yielding crops like mustard, mungbean and *aus* rice enhanced overall system productivity and resource utilization. These findings suggest that improved patterns with BINA crop varieties can increase cropping intensity, yield and land utilization in southwest Bangladesh without compromising profitability.

Keywords: benefit cost ratio; BINA crop varieties; land use efficiency; production efficiency; rice equivalent yield

Introduction

Bangladesh, the world's largest delta, is encircled by the Ganges, Brahmaputra and Meghna rivers. The current population of the country is over 170 million, with a total area of around 150000 km^2 (1). Covered by major rivers, it has the benefit of many fertile soils, as every year a huge sum of alluvium is deposited surrounding the river areas. Thus, soils gain fertility and productivity on an yearly basis. With the adverse effect of global warming and climate change, drought, salinity, flooding and the presence of unsuitable land, crop production is becoming challenging day by day (2, 3). Though the national average cropping intensity (CI) of Bangladesh is around 200 % but the mean CI of Jessore region which includes Jhenaidah and Magura district are above 250 % and agricultural cultivation is limited to 75 % of the total cultivable area which is due to the prevalence of high (36.20 %) and medium high land (44.99 %) (4, 5). However, it is a great challenge for the farmers community to retain this cultivation area due to the unpredictable weather patterns, population growth, industrialisation, housing projects and other non-agricultural activities (6). Therefore, to sustain crop production and yields it is imperative to adopt updated agriculture technologies, particularly inclusion of new cropping patterns in the cropping systems (7).

A cropping pattern (CP) denotes the annual sequence and spatial-temporal configuration of crops grown on a particular parcel of land. A cropping system comprises the comprehensive crop production operations of a farm, incorporating all agricultural practices employed on its resources, alongside other home enterprises and is shaped by the physical, biological, technological and socioeconomic environment (8). Crop planning delineates the organisation and scheduling of crops cultivated on a certain land parcel. Any modification in the distribution of land assigned to various crops represents a change in the CP. It signifies the allocation of arable land across diverse crops at varied intervals (9). Soil or land and water are critical resources for agricultural development, which are increasingly becoming limited due to rapid population growth and urbanisation. Consequently, it is essential to identify the most efficient ways to utilise the available resources to maximise overall benefits within existing constraints (10). In recent years, crop optimisation has gained considerable attention, leading to the development of various mathematical models to support this goal (11).

Despite the negligible potential for horizontal development of arable land, CI might be elevated to 400 % (12). This objective can be accomplished by implementing contemporary technology, such as high-yielding, short-duration and stress-resistant cultivars of mustard, potato, legumes, jute and white rice. The recent advancement of early-maturing crop varieties by research institutions has created the potential to cultivate up to 4 crops on the same area within one year (13). The predominant cropping pattern in the Jessore region, encompassing Jhenaidah and Magura districts, is *Boro*-fallow-T. *aman* (22 %), succeeded by Mustard-*Boro*-T. *aman* (7.20 %) and Boro-T. *aus*-T. *aman* (6.50 %). In this region, the majority of the land is dedicated to 3 crops (55.25 %), followed by 2 crops (33.05 %). However, the acreage designated for 4 crops constitutes merely 2.35 % (5). Consequently, there exists an opportunity to implement a four-crop-based cropping plan in the Jhenaidah and Magura districts in the Jessore region.

Rice being the staple food of Bangladesh, covers over 75 % of the land area (14). So, to include any rice based improved or profitable CP in a cropping system, rice variety/cultivar bearing high yield, short duration and tolerant to stress are the key determinants considered by the farmers. Moreover, farmers of the Jessore region are highly advanced and updated to modern agriculture technologies with the blessing of Information and Communication Technology (ICT) tools (15). On the contrary, the border districts (Jessore, Chuadanga, Meherpur, Kushtia, Jhenaidah) farmers can sometimes collect the Indian cereal, pulse, oilseeds and fiber crop seeds, which have good yield and quality as per their preference. The National Agriculture Research Institutes, like Bangladesh Institute of Nuclear Agriculture (BINA) and Bangladesh Agricultural Research Institute (BARI) have developed many improved cereals, pulse, oilseeds, spices, fruits and fiber crop varieties which can considerably secure country's food if properly incorporated into the CPs (16). Previous examination of the yield and profitability of pulse and oilseed-based cropping patterns, comprising 3 and 4 crops, utilising BINA-developed varieties within the *Aman-Boro*-fallow systems in Magura and Pabna districts, indicated that both 3 and 4 crop patterns produced higher gross margins with a beneficial cost-benefit ratio, thereby maximising land utilisation per unit of time (16–17). Although previous studies have demonstrated the benefits of intensified cropping systems using improved varieties, comparative assessments of BINA-developed short-duration varieties within multi-crop patterns under farmer-managed conditions in the Jessore region remain limited. In particular, evidence is scarce on whether productivity gains can be achieved without compromising economic viability.

Given this context, the present study aimed to evaluate the agronomic performance, resource use efficiency and profitability of improved 3 and 4 crop patterns incorporating BINA developed crop varieties in Jhenaidah and Magura districts. We hypothesised that inclusion of BINA short-duration varieties would enhance CI, yield and efficiency without reducing overall profitability compared with existing farmer practices.

Materials and Methods

Experimental site, design and crop management

The experiment was executed at 2 different locations viz. Tiordaha village of Jhenaidah sadar upazila Jhenaidah district (23° 31′ 14.07″ N latitude, 89° 18′ 12.32″ E longitude) and Shibrampur village of Magura sadar upazila Magura district (23° 29′ 56.90″ N latitude, 89° 23′ 33.01″ E longitude). Specific geographical maps of the experimental locations are shown in Fig. 1 (18). These locations were under the agroecological zone (AEZ) 11. The total area of AEZ 11 is 1320549 ha. Under this Magura district holds 85700 ha and the Jhenaidah district holds 197000 ha of land (19–20). It belonged to a tropical monsoon climate with unimodal rainfall. Mean weather data (2024–25) of Magura sadar and Jhenaidah sadar district is presented in Fig. 2, Supplementary Table 1 and 2 (21). This AEZ, known as the high Ganges river floodplain, spans Chapai Nawabganj, Rajshahi, Kushtia, Meherpur, Jhenaidah, Magura, Chuadanga, Jessore and nearby districts, occupying the western part of the Ganges (Padma) river floodplain. The zone is characterised by tropical monsoon climate, calcareous alluvial soils and suitability for intensive rice-based cropping. Although post-harvest soil properties were not measured in this study, soil fertility sustainability was considered conceptually in the design of the cropping patterns. Inclusion of short-duration legumes (mungbean) and oilseed crops (mustard) was expected to contribute to improved nutrient cycling, biological nitrogen inputs and more efficient use of residual soil moisture and nutrients. Such diversified rice-based systems are widely recognized to reduce nutrient mining, enhance soil organic matter dynamics and support long-term soil productivity compared with continuous rice–rice or rice–fallow systems. Key soil properties are summarised in Table 1 (22).

A randomised complete block (RCB) design was implemented at each site with 2 cropping patterns: one existing farmer practice and one improved pattern. Each treatment was replicated 3 times. The specifics of the crop management (spacing, sowing/transplanting, irrigation and weeding) are presented in Table 2 and Table 3. The land area designated for each pattern (replicate) was 0.25 acres (25 decimals). For *aus*, *aman and boro* rice, preparation of land, recommended N–P–K–S–Zn fertiliser doses were applied with nitrogen split according to growth stage and others as basal dose. (23–25). Mustard and mungbean received basal and top-dressed fertilisers as per crop-specific

Table 1. Soil types and key nutrient properties of the study site in AEZ-11 (High Ganges river floodplain)

Major land type	Soil pH	Soil OM	Nutrient status							
			N	P	K	S	Ca	Mg	Zn	B
Highland (43 %)	4.6-8.8	L-M	VL-L	VL-L	L-M	VL-L	Opt-H	Opt-H	VL-L	L-M
Medium highland (32 %)	4.8-8.9	L-M	VL-L	VL-L	L-M	VL-L	Opt-H	Opt-H	VL-L	L-M
Medium lowland (12 %)	5.8-8.7	L-M	VL-L	VL-L	L-M	VL-L	Opt-H	Opt-H	VL-L	L-M

Opt-H, Optimum high; L-M, Low to medium, VL-L, Very low to low, L-M, Low to medium. Source: BARC (22).

Table 2. Crop management of existing and three crops-based pattern at Jhenaidah

Parameters	Existing cropping pattern			Improved cropping pattern		
Crop	Rice (T. *aman*)	Fallow	Rice (*boro*)	Rice (T. *aman*)	Mustard	Rice (*boro*)
Variety/cultivar	*Khato babu*	-	*Rod minikit*	Binadhan-17	Binasarisha-9	Binadhan-24
Spacing (cm^2)	20 x 20	-	20 x 20	20 x 20	Broadcast	20 x 20
Date of sowing/ transplanting	25 July 2024	-	15 January 2025	25 July 2024	06 November 2024	15 February 2025
Irrigation (no.)	1	-	3	1	1	2
Weeding (no.)	2	-	2	2	0	2
Field duration (days)	110	-	120	97	91	112
Turnaround time (days)	71	-	64	49	6	10
Date of harvesting	12 November2024	-	15 May 2025	30 October2024	05 February 2025	7 June 2025

Table 3. Crop management of existing and four crops-based pattern at Magura

Parameters	Existing cropping pattern			Improved cropping pattern			
Crop	Rice (T. *aman*)	Mustard	Mungbean	Rice (T. *aman*)	Mustard	Mungbean	Rice (*aus*)
Variety/ cultivar	*Khato babu*	BARI sarisha14	BARI moog6	BINA dhan26	Binasarisha-11	Binamoog-8	Binadhan-19
Spacing (cm^2)	20 x 20	Broadcast	20 x 20	20 x 20	Broadcast	20 x 20	20 x 20
Date of sowing/ transplanting	20 July 2024	14 November 2024	27 February 2025	21 July 2024	28 October2024	27 January 2025	05 April 2025
Irrigation (no.)	1	1	2	1	1	2	1
Weeding (no.)	2	0	2	2	0	2	1
Field duration (days)	113	88	66	95	84	62	102
Turnaround time (days)	77	04	17	06	03	07	06
Date of harvesting	10 November2024	10 February 2025	03 May 2025	24 October2024	20 January2025	30 March 2025	16 July 2025

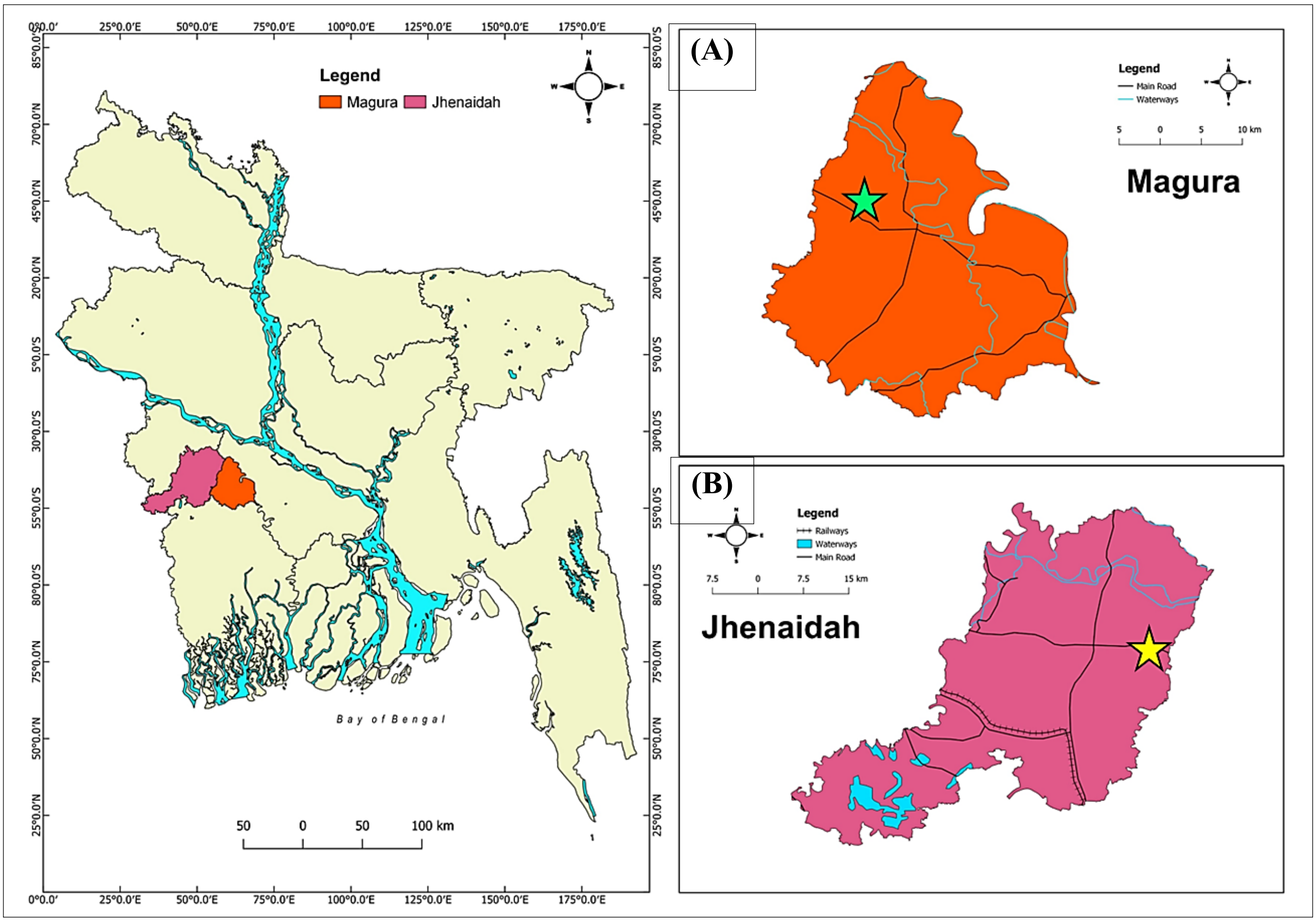

Fig. 1. Detail location of the experimental site shown in the map of Bangladesh. (A): Shibrampur village of Magura sadar upazila Magura district (green star marked), (B): Tiordaha village of Jhenaidah sadar upazila Jhenaidah district (yellow star marked). Source: QGIS software (18). Specific location of the experimental site is shown in the supplementary Fig. 1A and 1B.

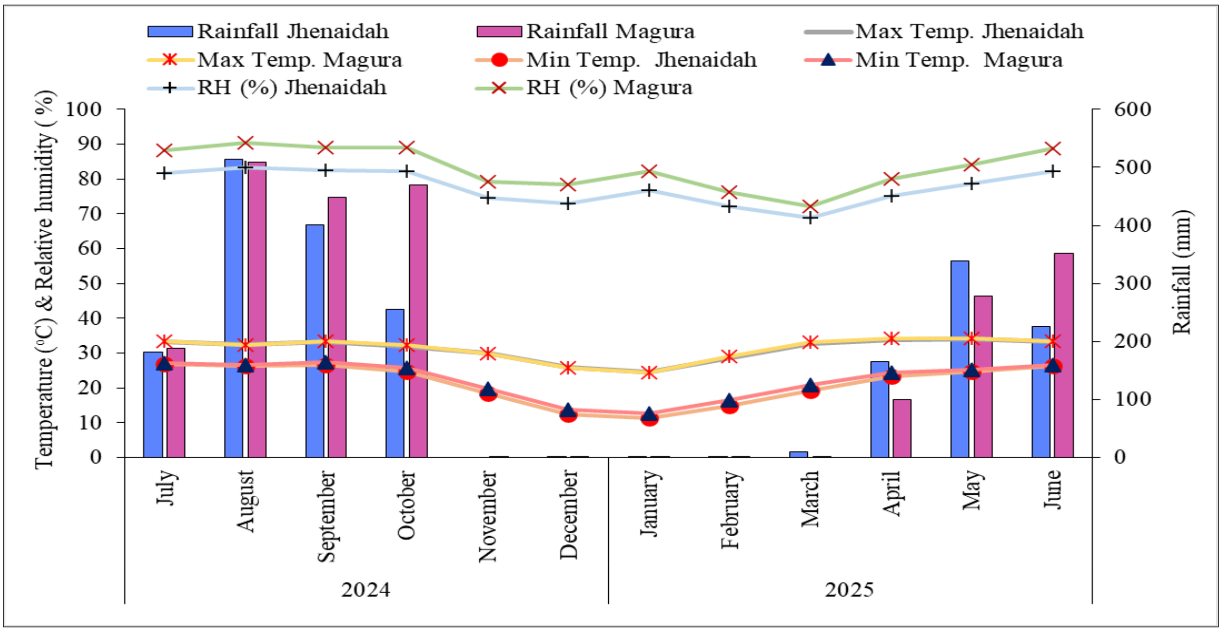

Fig. 2. Mean weather data of the experimental sites during July 2024 to June 2025.

recommendations (26, 27). Irrigation frequency ranged from 1 to 3 applications, depending on crops and seasons. Pest and disease management followed integrated pest management practices using need-based chemical control (28). In addition, for BARI and BINA developed crop varieties, cultivation techniques for individual variety were followed as per the description of the production package handbook or leaflet (29, 30).

Data collection on different parameters

Following the harvest of each crop, statistics were gathered on yield and yield components, gross return, total variable cost, gross margin and the benefit-cost ratio (BCR). Although cropping patterns differed in crop number, analysis of variance (ANOVA) was appropriate because rice equivalent yield (REY), production efficiency (PE) and economic indices were expressed as annual, area-based system-level variables. Thus, each cropping pattern functioned as a single experimental unit with equal replication, satisfying ANOVA assumptions of independence and comparability. The outcomes for each parameter were subsequently summarized individually and the mean performance across crops was computed. The specifics of the individual parameters and their calculating methodologies are outlined below.

The REY was calculated using equation, the yield of each crop was translated into rice equivalent yield according to the current market price of the relevant crop (31). This uniformity facilitated direct comparison among various cropping patterns. The REY was computed with the subsequent equation (32).

$$\text{REY (t ha}^{-1}) = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{Market price of rice}} \quad \text{(Eqn. 1)}$$

Land use efficiency (LUE) was assessed following the approach, where the cumulative duration of all crops grown in a sequence is divided by 365 days (33). This provides a measure of how effectively land is utilised throughout the year. LUE was calculated using the following equation:

$$\text{LUE (\%)} = \frac{d_1 + d_2 + d_3 + d_4}{\text{Market price of rice}} \times 100 \quad \text{(Eqn. 2)}$$

Here, d_1, d_2, d_3 and d_4 denote the durations of the 1st, 2nd, 3rd and 4th crop in the sequence, respectively.

PE was calculated as the ratio of the total production obtained from a cropping sequence to the cumulative growth duration of all crops within that sequence (33). The result was expressed in kilogram per hectare per day. The formula used for calculating PE is provided below:

$$\text{PE (kg ha}^{-1}\text{day}^{-1}) = \frac{y_1 + y_2 + y_3 + y_4}{d_1 + d_2 + d_3 + d_4} \quad \text{(Eqn. 3)}$$

Here, y_1, y_2, y_3 and y_4 represent the yields (kg) of the 1st, 2nd, 3rd and 4th crops in the sequence, respectively, while d_1, d_2, d_3 and d_4 denote their corresponding growth durations (days).

For economic analysis, family labor costs were imputed uniformly across all cropping patterns and locations to ensure consistency and avoid bias in cost comparison. Gross return and BCR were calculated using current market prices at the time of harvest rather than seasonal averages, as these prices reflect the actual economic conditions faced by farmers when crops are sold. This approach allows a realistic assessment of profitability and supports meaningful comparison among cropping patterns within the same production year. Therefore, economic analysis was computed by data on input use (seed, fertiliser, labor, pesticides, etc.) and output production (grain, straw, by-products, etc.) were collected and valued at prevailing market prices. These data was used to estimate net income, BCR and REY of the crops. Net income was calculated as the difference between gross return (GR) and total management cost (TVC) including family and operator labor (34). The BCR was computed using the following formula (35).

$$\text{BCR} = \frac{\text{Gross return}}{\text{Total variable cost of production}} \times 100 \quad \text{(Eqn. 4)}$$

Statistical analysis

The data obtained were examined independently with the use of ANOVA in Statistix 10.0 (Analytical Software, Tallahassee, USA) and the treatment means were compared using the Least Significant Difference (LSD) test at 5 % probability ($p < 0.05$) level (36–39).

Results

Yield and duration

The cropping sequence implemented at Tiordah, Jhenaidah, was "Binadhan-17 (T. *aman* rice) - Binasarisha-9 (mustard) - Binadhan-24 (*boro* rice)," replacing the previous sequence of "T. *aman* rice - fallow - *boro* rice" in Tiordaha village, Jhenaidah (Table 2). The improved cropping pattern resulted in a total field duration for all crops of 300 days, with an overall turnaround time of 65 days. The current pattern indicates total field duration and turnaround times of 230 days and 135 days, respectively (Table 2). During the *aman* season, the grain yield of Binadhan-17 (6.58 t ha^{-1}) and *Khato babu* cultivar (6.25 t ha^{-1}) was comparable; however, *Khato babu* produced a greater straw yield (8.56 t ha^{-1}) compared to Binadhan-17 (6.12 t ha^{-1}) (Fig. 3). The field duration of Binadhan-17 was 13 days shorter than that of *Khato babu* (Table 2). The yield of mustard Binasarisha-9 was satisfactory, producing a seed yield of 2.17 t ha^{-1} and a straw yield of 2.92 t ha^{-1}. In the *boro* season, the *Rod minikit* cultivar demonstrated superior grain and straw yields of 8.58 t ha^{-1} and 9.14 t ha^{-1} respectively, compared to the Binadhan-24 rice variety. (Fig. 3). Improved T. *aman*–mustard–*boro* pattern reduced total turnaround time by 70 days compared with the existing system, allowing inclusion of mustard without extending the annual cropping calendar. Grain yield of Binadhan-17 was comparable to the local cultivar, while its shorter duration contributed to higher system efficiency.

In the Shibrampur village of Magura, a 4 crops pattern (T. *aman*-mustard-mungbean-*aus*) including the varieties, "BINA dhan26 Binasarisha-11 —Binamoog-8 — Binadhan-19" were studied over the 3 crops pattern (T. *aman*-mustard-mungbean) with variety/cultivars, "*Khato babu* — BARI sarisha14 — BARI moog6" (Table 3). The sum of field duration and turnaround time for the 4 crops improved pattern was 343 days and 22 days; whereas, in case of the existing practice in 3 crops pattern it was 267 days and 98 days respectively (Table 3). No big changes in yield of *aman* rice were noticed in either pattern. Interestingly the later crops in the sequence, mustard and mungbean varieties showed different seed and straw yield. BARI sarisha14 (1.38 t ha^{-1}) and BARI moog6 (1.20 t ha^{-1}) produced lower seed/grain yield than Binasarisha-11 (1.69 t ha^{-1}) and Binamoog-8 (1.37 t ha^{-1}). Contrary, Binasarisha-11 (2.14 t ha^{-1}) and Binamoog-8 (1.88 t ha^{-1}) produced less straw yield than BARI sarisha14 (2.45 t ha^{-1}) and BARI moo6 (2.11 t ha^{-1}). The last crop variety of *aus* season in improved pattern, Binadhan-19 gave a grain and straw yield of 4.98 t $ha^{-1}$and 6.07 t ha^{-1} (Fig. 4) with 102 days of duration (Table 3). Here improved varieties of mustard and mungbean produced 22–25 % higher grain yields than existing cultivars, enabling successful inclusion of *aus* rice as a 4^{th} crop.

Resource use efficiencies

The improved T. *aman*–mustard–*boro* pattern recorded 15.6 % higher REY and 9.5 % higher PE than the existing pattern in Jhenaidah. In Magura, the four-crop system achieved the highest LUE (93.97 %), reflecting near year-round land occupation. The higher REY observed in the improved cropping patterns was mainly due to the inclusion of short-duration, high-yielding BINA crop varieties and additional crops with higher market value, particularly mustard, mungbean and *boro* rice, which collectively increased total system output per unit area (Table 4 and Supplementary Table 3). Improved varietal performance, combined with reduced turnaround time, allowed better temporal use of land and resources, resulting in higher LUE and PE.

Economic returns

Improved cropping patterns generated significantly higher gross return and gross margin at both locations. However, BCR did not differ significantly among patterns (Table 4). Higher input costs associated with additional crops and improved management largely offset yield gains, resulting in comparable profitability across systems (Supplementary Table 3).

Discussion

In the Tiordah village of Jhenaidah and Shibrampur village of Magura district, an oil seed crop was introduced in middle of the two rice cultivation season in the improved patterns. As oil crops especially mustard can aid in the increased profitability (40). Previous works reported that a short-duration, high-yielding mustard variety like BARI Sarisha14 can be successfully grown during the fallow period (41). Including such a mustard crop in the T. *aman*–fallow–*boro* rice cycle can increase total production compared to the existing pattern. Yield of mustard varieties in both the patterns were consistent with early findings (42). We also included a legume crop in the 4 crops pattern as intensive cultivation can deteriorate the soil. So, in the kharif season short duration mungbean can prevent soil degradation and improve soil health (43). In addition, short duration *aus* rice cultivation through direct seeded or dibbling method is another potential way of resource conservation as it requires less inputs like- fertiliser, irrigation (44). To increase the cropping intensity and profitability in a pattern; crop variety, type, yield and duration are important determinants (45). Though in the improved patterns we included modern varieties of BINA but in case of rice the Indian rice cultivars (*Khato babu*, *Rod minikit*) showed promising performance over the BINA released rice varieties. Hence, there's scope for inclusion of further improved varieties in the patterns.

Table 4. Comparison of cropping patterns with yields, efficiencies, returns, costs and BCR in two districts

Location	Pattern	REY (t ha^{-1})	LUE (%)	PE (kg ha^{-1} day^{-1})	GR (Tk ha^{-1})	TVC (Tk ha^{-1})	GM (Tk ha^{-1})	BCR
Jhenaidah	T. *aman*-fallow-*boro*	14.83 b	63.01 c	46.33 b	607550 b	342500 a	265050 b	1.77 a
	T. *aman*-mustard-*boro*	17.15 a	82.19 b	50.74 a	816800 a	398300 a	418500 a	2.05 a
Magura	T. *aman*-mustard-mungbean	9.55 c	73.15 b	31.24 d	544100 b	258800 b	285300 b	2.10 a
	T. *aman*-mustard-mungbean-*aus*	13.79 b	93.97 a	39.86 c	780450 a	360900 a	419550 a	2.16 a
$LSD_{0.05}$		1.89	9.80	3.87	125463	75486	130634	0.49
CV (%)		6.87	6.28	4.61	9.14	11.11	18.84	12.37
SEm		0.77	4.00	1.58	51274	30849	53387	0.20

Means with common letter in a column do not differ significantly at 5 % level of significance by LSD. REY, Rice equivalent yield; LUE, Land use efficiency; PE, Production efficiency; TVC, Total variable cost; GM, Gross margin; BCR, Benefit cost ratio; SEm, Standard error mean. Note: Average selling price (Tk/kg)- Rice 35, Mustard 100, Moog seed 110, Rice straw 5. 1 USD = 122 BDT.

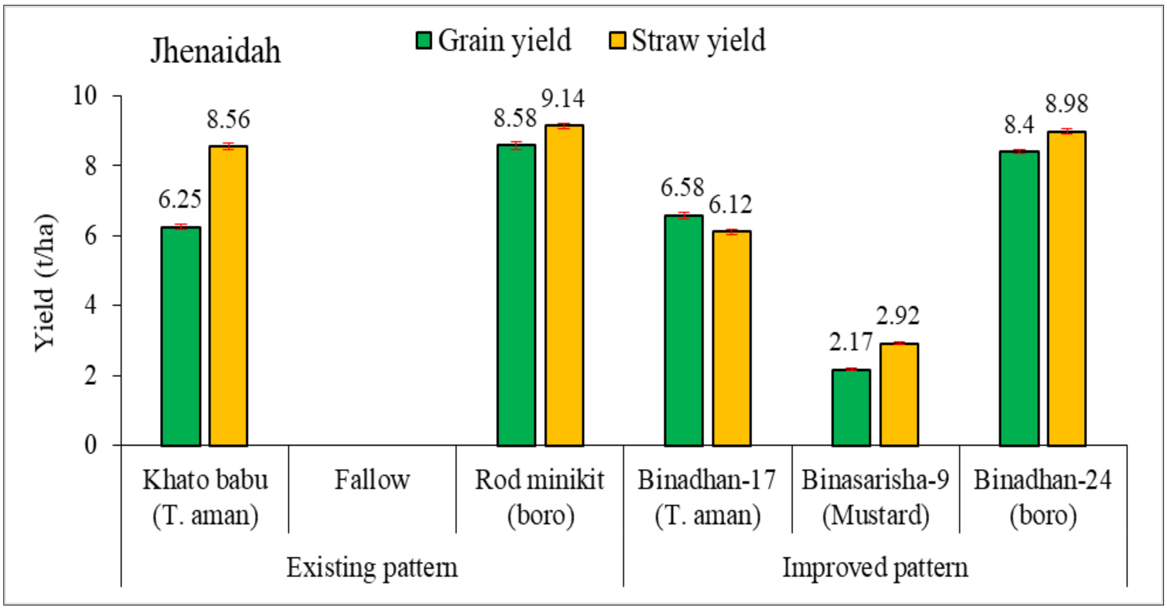

Fig. 3. Yield of existing and improved cropping patterns in Tiordaha, Jhenaidah.

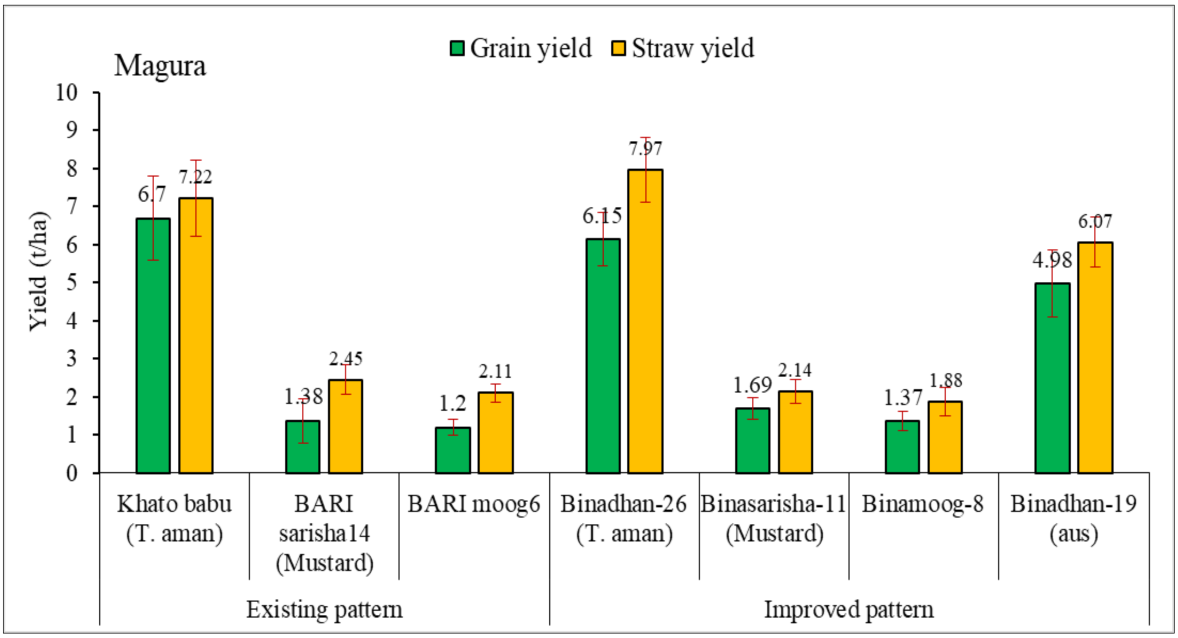

Fig. 4. Yield of existing and improved cropping patterns in Shibrampur, Magura.

The observed increase in REY and PE in improved patterns can be attributed to reduced turnaround time and effective use of short-duration high yielding crops, particularly mustard and mungbean (46). Inclusion of mungbean likely contributed to improved soil nitrogen availability through biological nitrogen fixation, benefiting subsequent rice crops (47, 48). The high land use efficiency of the four-crop system reflects more complete utilization of available growing periods, a key requirement for sustainable intensification (49). Despite higher productivity, similar benefit cost ratios across patterns indicate that farmers may not experience immediate profit advantages unless input costs are optimised (50). Furthermore, increased yields were largely offset by higher labor demand, input use and management complexity associated with multi-crop systems, especially in the four-crop pattern. This indicates that while intensified systems enhance productivity and resource use efficiency, their economic advantage depends on farmers' capacity to manage additional labor and inputs, which is critical for large-scale adoptability under farmer-managed conditions. The study was limited to a single season and 2 locations and longer-term effects on soil health and system stability were not assessed. These findings highlight the agronomic potential of BINA-developed crop varieties while underscoring the need for cost-efficient management strategies to enhance farmer profitability. In future, it will be necessary to include more short duration and high yielding crop variety/ cultivars to effectively trace the actual BCR.

Conclusion

Integration of BINA-developed short duration varieties into rice-based cropping systems increased cropping intensity, yield and resource-use efficiency in southwest Bangladesh without reducing profitability. The T. *aman*–mustard–*boro* pattern was most effective for enhancing PE, while the four-crop sequence maximized land use. Future research should validate these results across multiple seasons and agroecological zones. The findings support incorporating BINA-developed varieties into regional crop planning and extension programs to promote sustainable agricultural intensification.

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Authors' contributions

SC conceived, designed and executed the experiments, collected relevant data and prepared the initial draft of the manuscript. SRG, MKJA, MRS, SAS, STA, RS and MMR contributed by writing the Results and Discussion part. MSR and MAR assisted in literature review and data curation. MI, SA, NIT and MFI performed data analysis, prepared figures and tables and contributed to manuscript revision and proofreading. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT-5 and Quillbot in order to proofread, check grammar, paraphrase and improve the language of the manuscript.

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