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Enhancing nutritional yields through efficient crop diversification: A comparative study of rice-rice system in Bangladesh

Evidence from on-station research platform trial, Bangladesh

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Rationale/Background

- Over the past two decades, Bangladesh has made significant strides in food production, particularly in rice, which remains the country's primary crop (ADB, 2023).
- Many people still lack in access to a nutritious and diverse diets. Diets are largely imbalanced, with the staple cereal rice contributing around 70% of total energy intake (BBS, 2010).
- The lack of improvement in food security and the uneven progress in the economic access to healthy diets cast a shadow over the possibility of achieving sustainable food security. low-income countries having the largest percentage (71.5 percent) of the population that is unable to afford a healthy diets (FAO, 2024).
- There is the need to accelerate the transformation of our agrifood systems to strengthen their resilience through diversifying cropping systems and ensure that healthy diets are affordable for and available to all.
- This agronomic research trial has multiple objectives, including efficient use of land to produce more yields, increased nutritional yield for human consumption, climate resilience and increased income for farmers.
- We demonstrate an approach to examine trade-offs and synergies among these objectives for a complete cropping cycle (nine cropping pattern) for one year in northern part of Bangladesh. We estimate the profitability counting the total production cost and market value, nutritional yields for carbohydrate, protein, fat, including micronutrient iron, zinc and vitamin A and vitamin C.

Objective

The Regional One CGIAR Initiatives Transforming Agrifood Systems in South Asia (TAFSSA) focuses on farm- and landscape- level research to promote resource conservation and ecological services. Therefore, strategies for enhancing profits and nutritional yields through interdisciplinary approaches facilitating the implementation of research recommendations through extension networks and supportive policy reforms. This research study includes the assessing the nutritional yields of diversified alternative cropping patterns and compare them with farmers' common practices to identify the most beneficial options in the northern part of Bangladesh.

Above: Diversified agronomic research platform trial at BWMRI, Dinajpur. Photo Credit: Washiq Faisal

Data and methods

An experiment was set up in RCBD, with 9 scenarios and 3 replications. The scenarios were nine alternative cropping systems varying in intensification and integration of non-rice crops (cereals, legumes, oilseed, fiber, fodder and leafy vegetables) during winter and spring seasons to evaluate the nutritional yield and profitability. GPS coordinate: 25.742715, 88.672334.

All agronomic, crop phenology, costs of all inputs and outputs incl. labor and amount of irrigation water applied. Nutritional yield (NY) was calculated with established nutritional factors of edible yield of respective crops, as a measure of nutritional value of the production. Major nutrients (protein, fat, carbohydrates), Iron and Zinc as well as Vitamin A and C reported.

Treatment selection

The cropping patterns for the study were chosen through a participatory focus group discussion involving 50 farm households in three different location in this region. Farmers ranked various cropping options, including their most common practices. These patterns were then compared against the common cropping pattern used in the region. This method ensured that the chosen cropping systems reflected farmer preferences, increasing the likelihood of adoption if the trials proved successful.

Diversified cropping systems at on-station research platform trial , Dinajpur

Treatment	Diversification options	Kharif-2	Rabi	Kharif-1
T1	Business as usual - 1	Aman rice	Fallow	Boro rice (BF)
T2	Business as usual - 2	Aman rice	Maize	Fallow
T3	Profitability & improved nutrition	Aman rice (BF)	Potato	Sweet corn
T4	Increased production & improved nutrition	Aman rice (BF)	Leafy vegetables	Boro rice (BF)
T5	Increased production & improved nutrition	Aman rice (BF)	Maize + leafy vegetables	Sorghum (fodder)
T6	Diversified production	Aman rice (BF)	Mustard	Groundnut
T7	Diversified production & improved nutrition	Aman rice (BF)	Carrot	Maize (early)
T8	Profitability & soil health	Aman rice (BF)	Wheat	Jute
T9	Diversified production & soil health	Soybean	Mustard	Maize

Leafy vegetables: spinach, red amaranth, coriander, napa shak; BF = biofortified

Design:	RCBD with three replications	Date of initiation:	05 December 2022

$$REY_j\,(t/ha) = Y_j\,(t/ha) \times \frac{mktpr_j\,(US\$/t)}{mktpr_{rice}\,(US\$/t)} \quad \text{(eq. 1)}$$

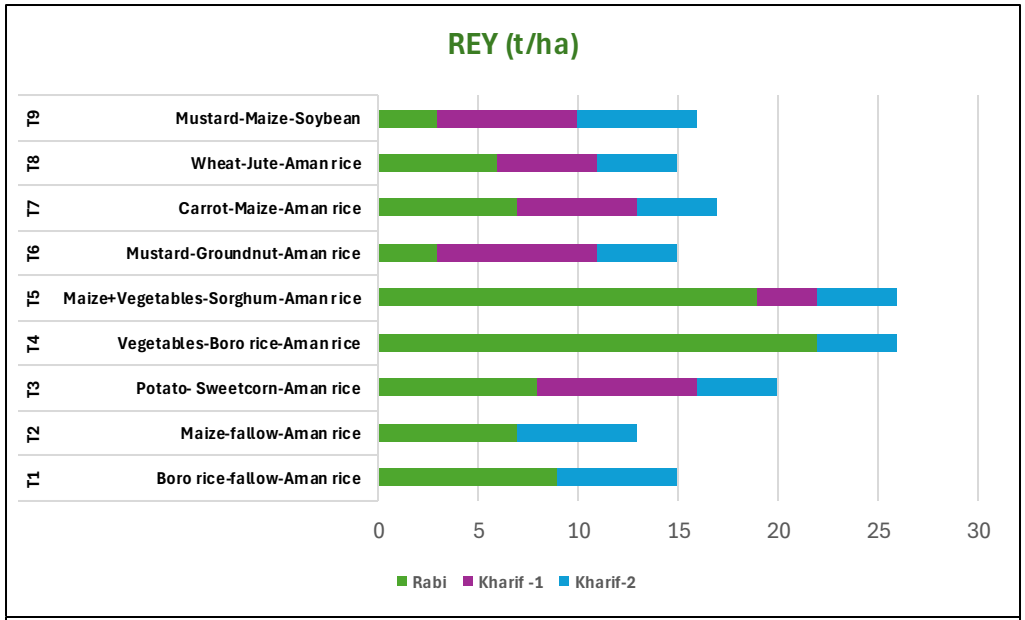
$$NY_{ij}\,(adults/ha/yr) = \frac{Y_j\,(t/ha) \times 10^6 \times Nc_{ij}\,(\%)}{DRI_i\,(g/adult) \times 365} \quad \text{(eq. 2)}$$

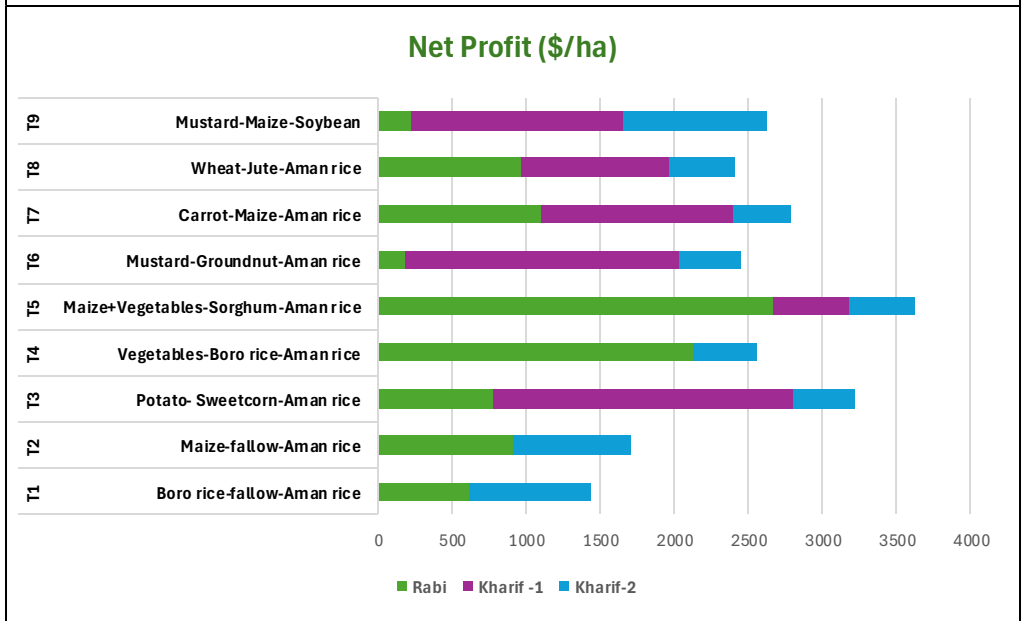
$$Net\ income_j\,(US\$/ha) = Y_j(t/ha) \times mpr_j(US\$/t) - \sum prod\ cost_j(US\$/ha) \quad \text{(eq. 3)}$$

where: REY = rice equivalent yield; Y = yield; mktpr = market price; NY = nutritional yield; Nc = Nutrient content; DRI = daily dietary reference intake; prod cost = production costs; subscripts "i" and "j" refer to the nutrient and crop, respectively.
N.B.: (1) The source of nutrient contents values is the Food Composition Table for Bangladesh (2013); (2) prod cost includes costs for seed, fertilizer, irrigation, pesticides / insecticides / herbicides used and labor for all operations; not included is land rent, which however for farmers can be substantial.

Productivity and profitability influenced by diversified cropping systems

Treatment	REY (t/ha)	Production cost (US$/ha)	Net profit (US$/ha)	Labor cost (US$/ha)	Irrigation cost (US$/ha)	Water applied (m3/ha)	Water use efficiency (kg/m3)
T1	14.88 cde	2849.84 c	1436.40 d	1782.54 c	508.13 a	11588.41 a	1.28 e
T2	13.44 e	2141.72 f	1710.46 d	1057.15 h	253.64 bc	6776.20 c	1.98 de
T3	20.41 b	2789.03 d	3224.72 ab	1510.15 d	259.53 bc	6670.71 c	3.06 bc
T4	26.18 a	4792.23 a	2554.90 c	1861.61 b	515.14 a	11609.00 a	2.25 cde
T5	25.67 a	3965.31 b	3628.23 a	2036.36 a	273.54 b	7289.93 b	3.52 b
T6	14.85 cde	1866.73 h	2455.82 c	1016.51 I	225.56 c	6327.66 d	2.34 cd
T7	17.09 c	2217.40 e	2793.55 bc	1166.90 f	228.42 c	6325.94 d	2.70 bcd
T8	14.78 de	1883.51 h	2416.36 c	1144.57 g	236.83 bc	6618.57 cd	2.23 cde
T9	16.27 cd	2065.18 g	2628.19 bc	1189.81 e	54.31 d	1283.02 e	12.68 a
P-Values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

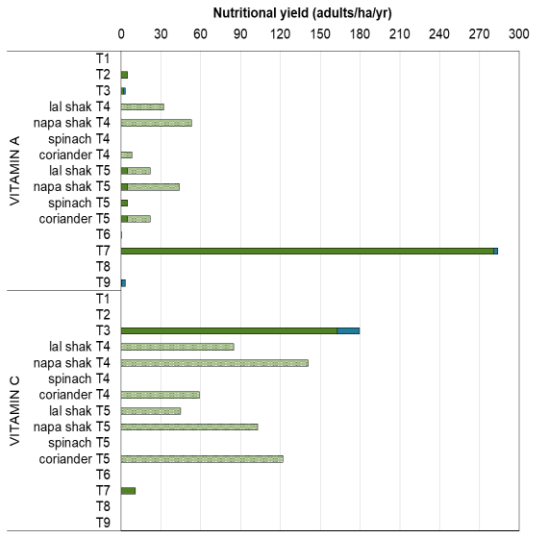


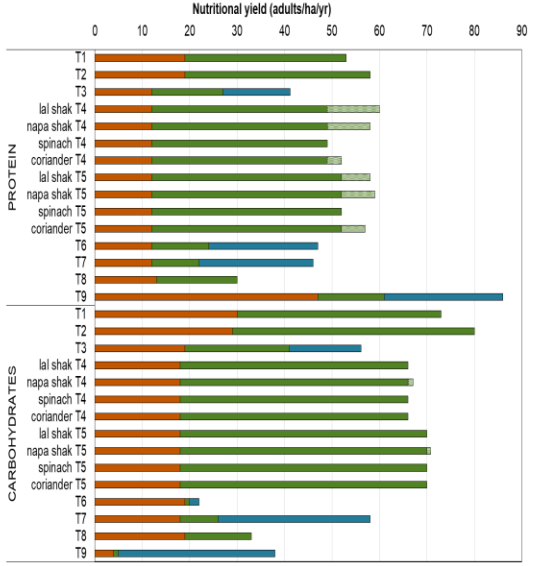


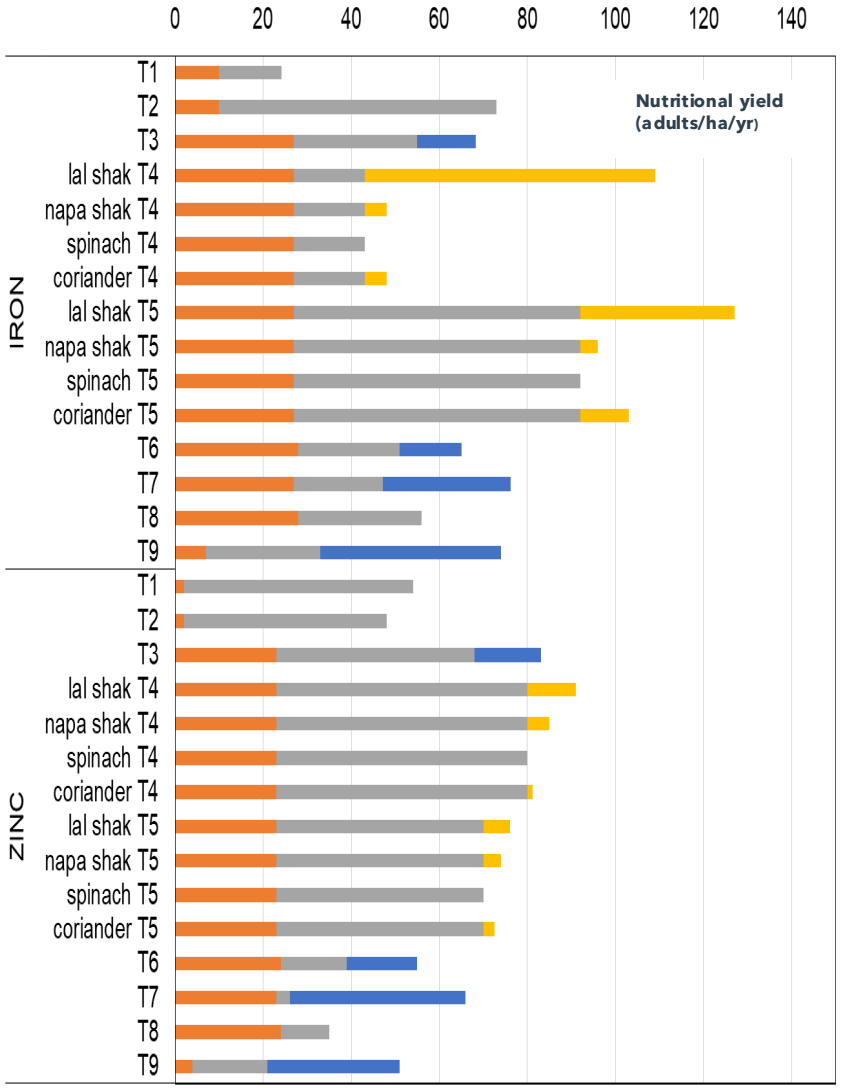
Preliminary findings (After the first full cropping cycle – three seasons within one year)**:**

- All diversified cropping systems (T3-T9) outperform the most common farmer practice (T1 and T2) in terms of rice equivalent yields (REY) and net profit.
- up to 30% more REY is recorded for example
  - by adding the leafy vegetable napa shak between two rice crops (T4 vs. T1)
  - or by intercropping the same vegetable with maize (T5 vs. T2)
- T4 & T5 shows best REY compared with other's treatments.
- Sweetcorn gives significant output results but limitations with local market facilities.

Nutritional yields by cropping pattern for major nutrients (proteins, carbohydrates), minerals (Iron, Zinc) as well as Vitamin A and C.







Preliminary findings

(After the first full cropping cycle – three seasons within one year)**:**

- Diversifications of cropping patterns contributes to the availability of vitamins (A & C) and micronutrients (Zn & Fe)
- Biofortification of staple crops like rice can contribute to nutritional security throughout the year. Varieties currently available for *Aman* and Boro season.

N.B.: Nutritional yields of maize contribute considerably to micronutrient availability, however as maize is mainly grown for feed this doesn't translate into improved human nutrition security and thus the data is not displayed.

Season	Variety	Nutrient content (mg/100g)		Nutritional yield (adults/ha/yr)	
		Zn	Fe	Zn	Fe
boro	not biofortified	1.32	0.7	18	10
	* BRRI dhan 100	2.57	0.7	35	10
aman	not biofortified	1.32	0.7	14	7
	BINA dhan 20	2.62	2.5	27	26

N.B.: Nutritional yield calculated assuming a yield of 4.5 t/ha for *aman and* 6 t/ha for *boro*.

Definition: The nutritional yield of a specific nutrient refers to the number of adults who can fulfil 100% of their recommended dietary refence intake of that nutrient for an entire year from the produce of one hectare land. (DeFries et al., 2015)

Results

- The rice equivalent yield (REY) was recorded significantly higher in both (T4 & T5) Vegetables-boro rice-aman rice (26.18 t/ha/yr) and Maize + vegetables – sorghum - aman rice (25.67 t/ha/yr) compared to the other treatments due to high market price of vegetables.
- Maximum net profit (3628.23 US$/ha) was observed in Maize + vegetables – sorghum - aman rice (T5) because of higher production and market price of vegetables.
- Potato- sweetcorn-aman rice (T3) showed the second highest net profit (3224.72 US$/ha) due to the high market price of sweetcorn.
- The lowest net profit was recorded from the traditional treatment (T1) rice – rice system which was 2.5 times lower than treatment (T5) Maize + vegetables – sorghum - aman rice system.
- All diversified of cropping patterns (T3 to T9) contributes to the availability of vitamins (A & C) and micronutrients (Zn & Fe).
- During Kharif-1 growing sweetcorn (T3) or groundnut (T6) instead of maize (T7 or T9) increases extra REY.
- In case of labor, Aman rice-potato-sweetcorn (T3) showed to be more profitable than the “business as usual” cropping patterns treatment (T1 and T2) without the need of more labour.
- The net profit (calculated as market value of produce minus total production costs) increases from ~1437 US$/ha (T1) to ~2468 US$/ha by adding the leafy vegetable napa shak between two rice crops (T4) and increases from ~1710 US$/ha (T2) to ~2442 US$/ha by intercropping the same vegetable with maize and adding a fodder crop (T5) instead of fallow during the Kharif-1 season.

Implication

- Adding a leafy vegetable as an intercrop to maize or as a sole crop between two rice crops is not an expensive investment in terms of additional production costs.
- Selection of leafy vegetables depends on the local market and consumption pattern that influenced the profitability of the rabi maize crop.
- Overall, it can be concluded that vegetable-based systems are superior in almost all aspects over traditional rice – rice system. So, it is advisable to farmers to substitute cereal-based system with diversified crops and intercropping alternative high-value crops into the conventional cropping system that can provide additional sources of revenue, nutritional outcome, promoting a diverse ecosystem for the long-term viability of the farm, sustainable production and for better resource use efficiency.
- The findings indicate notable variations in productivity, nutritional yields, and profitability among different cropping patterns after one full cropping cycle. However, conclusions remain premature, necessitating further data from multiple cropping years. Additionally, an analysis of the environmental footprint of each cropping system is essential for recommending optimal practices in sustainable agriculture.

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Thank you!