

Enhancing nutritional yields through efficient crop diversification: Comparison to the common of rice-rice system in Bangladesh

Comparing diversified cropping
patterns in Dinajpur, Bangladesh

Research note 52

December 2024

ABOUT THIS NOTE

Focusing on economic access to nutritious foods, updated and improved estimates show that more than one-third of people in the world – about 2.8 billion – could not afford a healthy diet in 2022. Low-income countries having the largest percentage of the population that is unable to afford a healthy diet (71.5 percent). (FAO, 2024)

This research note focuses to accelerate the transformation of our agrifood systems through introducing different diversified cropping options especially for the northern part of Bangladesh to strengthen their resilience to the major drivers and address inequalities to ensure that healthy diets are affordable and available to all. The research trial was established at the Bangladesh Wheat and Maize Research Institute (BWMRI) in Dinajpur, Bangladesh in August 2022.

KEY STUDY FINDINGS

1. After the one-year complete cropping season (three seasons within one year) we observed that all diversified of cropping patterns contributes to the availability of vitamins (A & C) and micronutrients (Zn & Fe).
2. The treatment (T5) Maize intercropped with leafy vegetables, sorghum and aman rice cropping pattern is the best performing cropping patterns in terms of net profit and nutritional yields.
3. Vegetable-based systems are superior in almost all aspects over traditional rice – rice system.
4. Biofortification of staple crops like rice can contribute to nutritional security throughout the year. Varieties currently available for Aman and Boro season. 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 and nutritional outcome.

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). Bangladesh's agricultural policies have traditionally focused on single-crop production, with limited attention to integrated to other crops. In Bangladesh, rice is the major staple food crop grown on 80% of the cultivated land area sometimes in rotation with other crops (Gumma et al., 2012). 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). In recent times, the sustainability of rice-rice cropping systems has been threatened by a yield plateau, high input cost, declining water and labor availability, and increasing food demand. Hence, the rice-based cropping systems seek more attention in relation to ensure future food security and nutritional outcomes. 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 diet (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.



Above: Carrot field at research platform trial, Dinajpur. (Rabi crop-2023). Photo: CIMMYT

OBJECTIVES

The Regional CGIAR Initiative 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.

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.



Above: Diversified agronomic research platform trial at BWMRI, Dinajpur; Photo: 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. About the experiment setup and data collected (for more information see the research protocol: Cheesman et al., 2022).

Table 1: 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

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

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

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

$$\text{Net income}_j (US\$/ha) = Y_j (t/ha) \times mpr_j (US\$/t) - \sum \text{prod cost}_j (US\$/ha) \quad (\text{eq. 3})$$

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.

Table 2: Summarizes the agronomic results from the trial after the one-year complete cropping cycle.

Treatment	REY (t/ha)	Production cost (US\$/ha)	Net profit (US\$/ha)	Labor cost (US\$/ha)	Irrigation cost (US\$/ha)	Water use efficiency (kg/m ³)
T1	14.88 cde	2849.84 c	1436.40 d	1782.54 c	508.13 a	1.28 e
T2	13.44 e	2141.72 f	1710.46 d	1057.15 h	253.64 bc	1.98 de
T3	20.41 b	2789.03 d	3224.72 ab	1510.15 d	259.53 bc	3.06 bc
T4	26.18 a	4792.23 a	2554.90 c	1861.61 b	515.14 a	2.25 cde
T5	25.67 a	3965.31 b	3628.23 a	2036.36 a	273.54 b	3.52 b
T6	14.85 cde	1866.73 h	2455.82 c	1016.51 l	225.56 c	2.34 cd
T7	17.09 c	2217.40 e	2793.55 bc	1166.90 f	228.42 c	2.70 bcd
T8	14.78 de	1883.51 h	2416.36 c	1144.57 g	236.83 bc	2.23 cde
T9	16.27 cd	2065.18 g	2628.19 bc	1189.81 e	54.31 d	12.68 a
P-Values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 3: Summarizes the nutritional results from the trial after the one-year complete cropping cycle.

Treatment	Carbohydrate	Protein	Fat	Zinc	Iron	Vitamin A	Vitamin C
T1	73.04 ab	61.56 cd	1.71 e	58.65 bc	23.94 e	0.00 d	0.00 d
T2	80.27 a	63.63 bc	13.53 cd	81.90 a	105.73 b	4.96 c	0.00 d
T3	56.04 cd	44.65 e	5.15 e	83.40 a	69.02 c	3.23 c	179.43 b
T4	67.20 abc	78.16 a	2.87 e	66.38 b	98.09 b	93.36 b	285.64 a
T5	71.59 ab	73.34 ab	14.79 c	81.62 a	141.10 a	78.15 b	270.18 a
T6	22.317 e	51.08 de	39.34 a	51.62 c	43.13 d	0.04 c	0.00 d
T7	58.63 bcd	49.49 e	10.34 d	65.91 b	75.14 c	283.63 a	10.44 c
T8	33.74 e	33.05 f	1.92 e	32.05 d	34.40 de	0.00 d	0.00 d
T9	48.84 d	50.97 de	21.39 b	64.27 bc	87.54 bc	3.28 c	0.00 d
P-Values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001



Above: Mustard field at research platform trial, Dinajpur. (Rabi crop-2023). Photo: Washiq Faisal

STATISTICAL ANALYSIS

Statistical analysis were performed using the package in R 4.41 (R Core team 2024). The data were analyzed using a Randomized Complete Block Design with nine treatments and three replications to evaluate the effect of various treatments. All output data were compared using Tukey's HSD significant difference test function from agricolae R package at $P < 0.001$.

Figure 1: Nutritional yield and net profit influenced by diversified cropping systems.

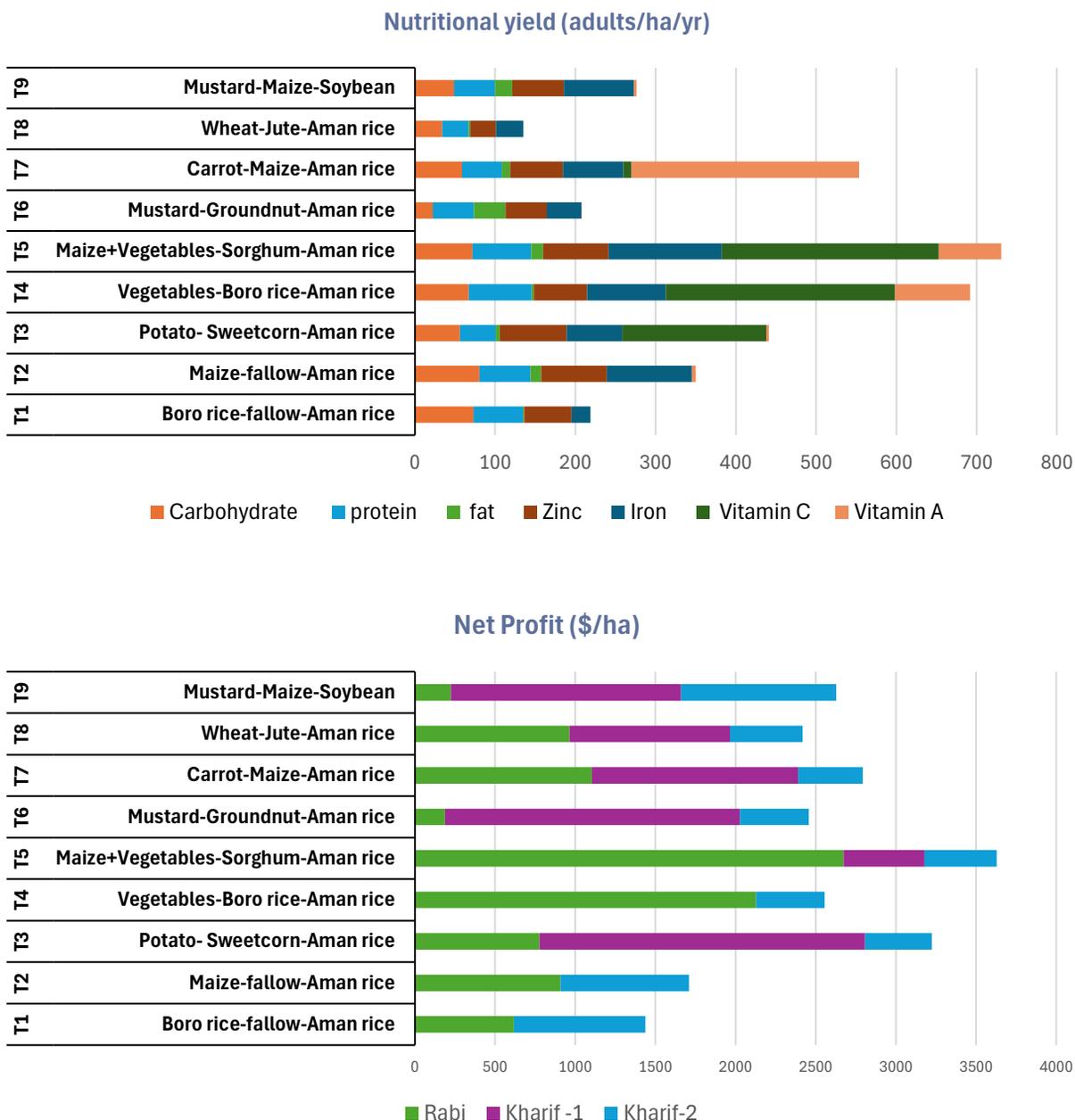
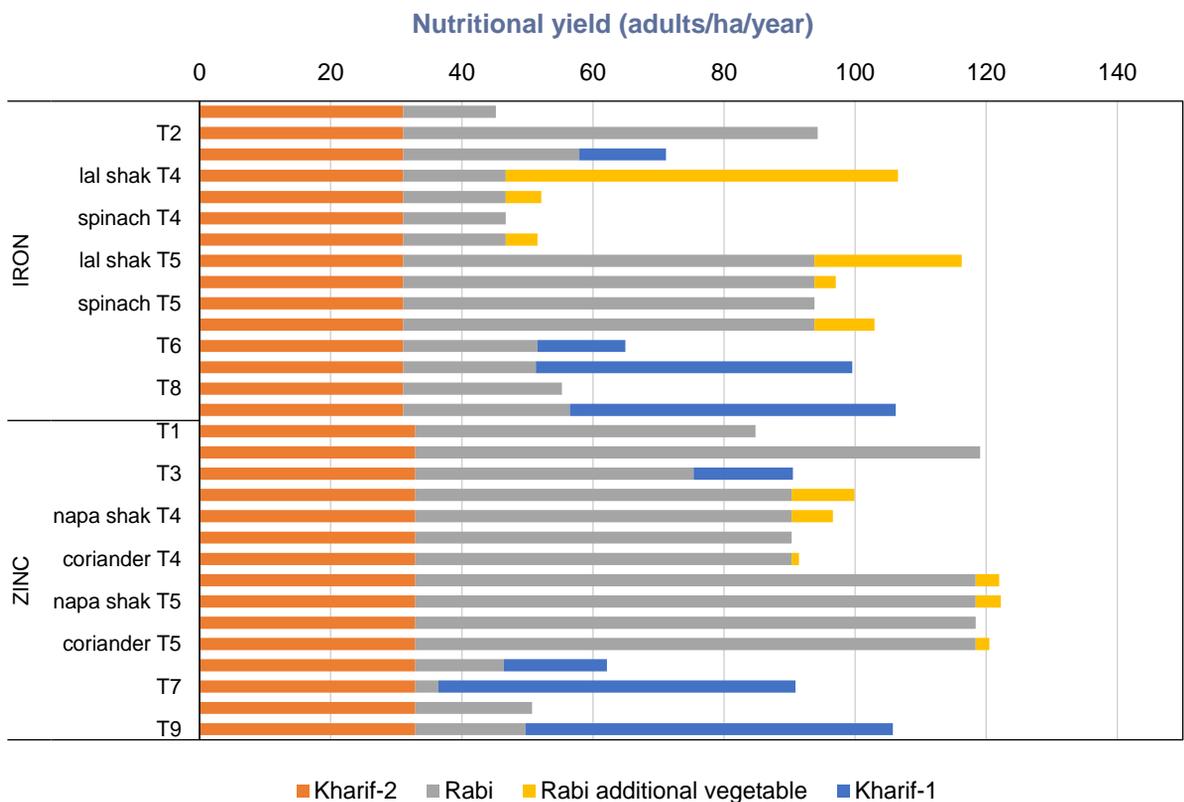
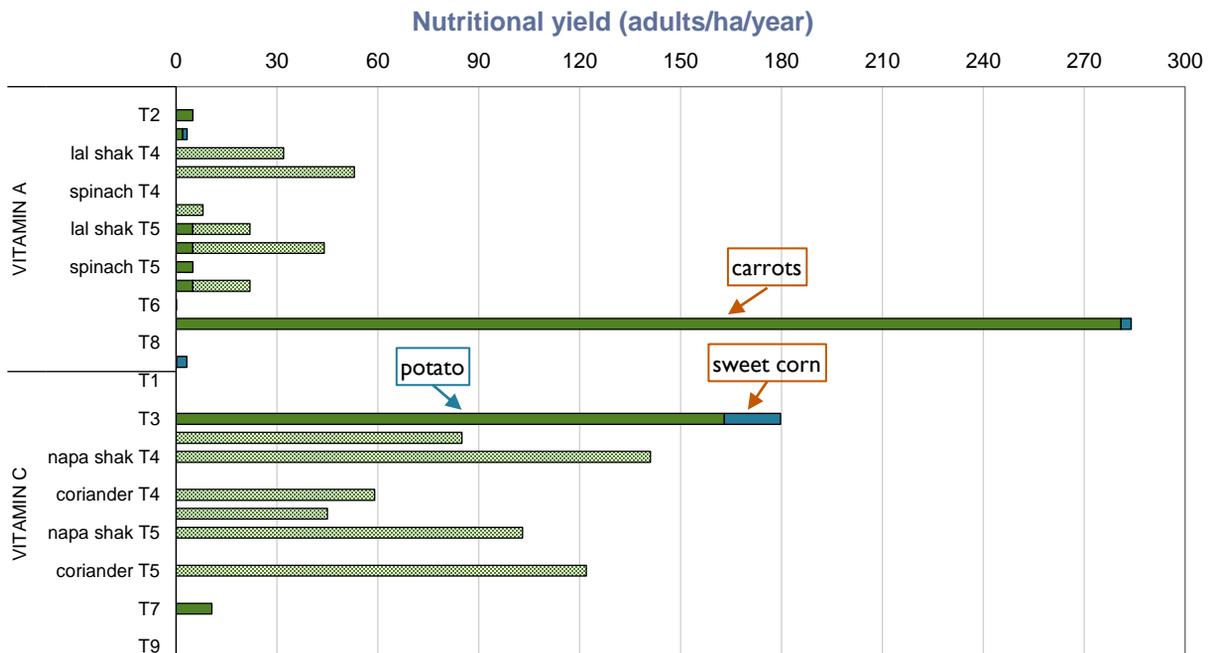
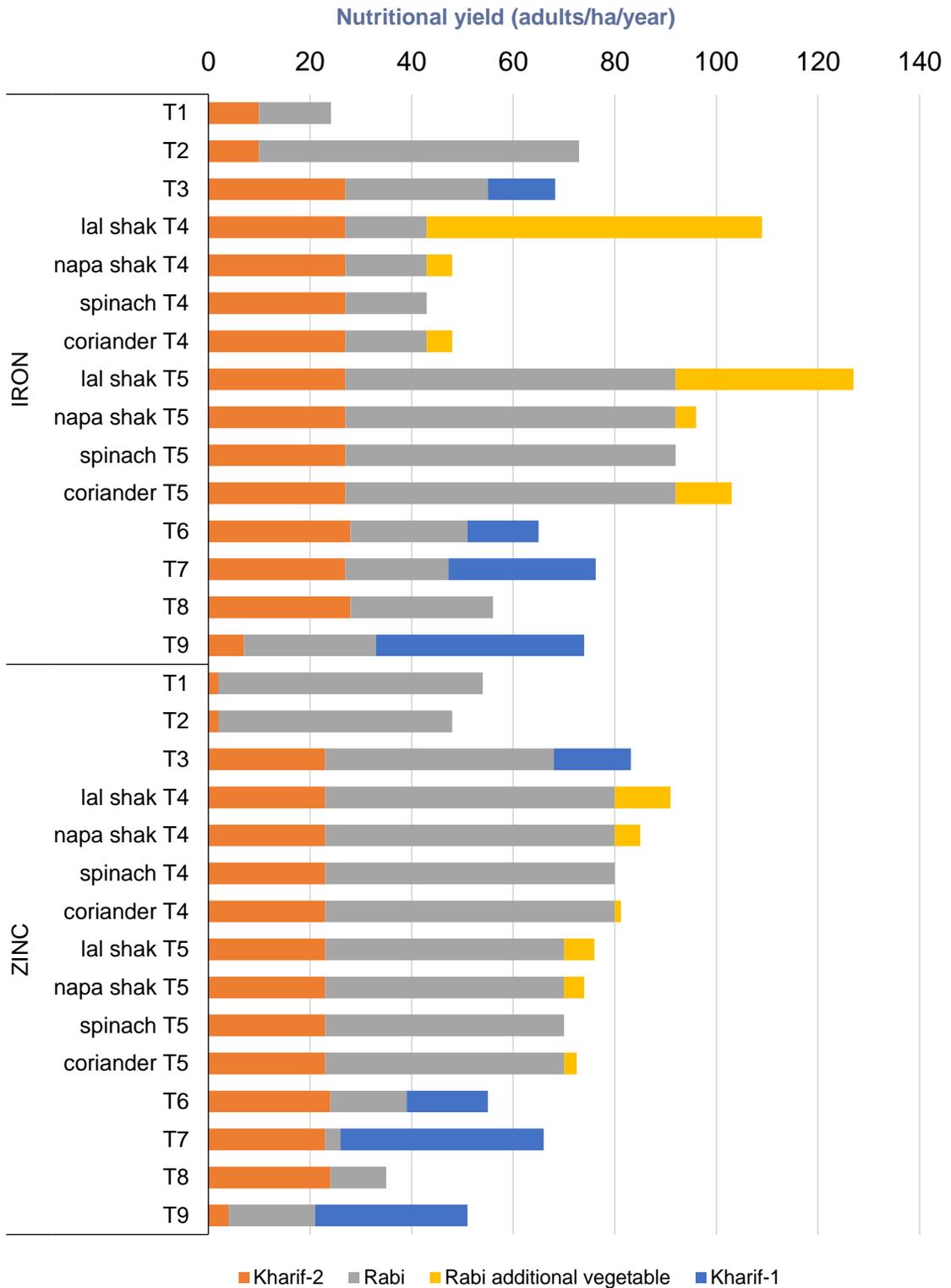


Figure 2: Nutritional yields by cropping pattern for major nutrients (proteins, carbohydrates), minerals (Iron, Zinc) as well as Vitamin A and C.



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



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

RESULTS

After the first full cropping cycle-three seasons within one year, diversification of cropping patterns contributes to the availability of vitamins (A & C) and micronutrients (Zn & Fe). The second most common cropping pattern rice-maize-fallow (T2) can be intensified by adding a leafy vegetable intercrop during the maize growing phase as well as replacing the fallow period with a fodder crop (sorghum) (T5). Treatment (T5) Maize + vegetables – sorghum - aman rice systems outperform and produce all essential macro and micro nutrition (carbohydrate, protein, fat, zinc, iron) including vitamin A and C (Table 3). Treatment T4 and Treatment T3 showed the second significant nutritional output results for nutritional yields (Table 3).

In rabi for the treatment T7, carrot and some leafy vegetables contribute to vitamin A food security (Figure 2). Potato and leafy vegetables are good for vitamin C (Figure 2). Biofortification of staple crops like rice can contribute to nutritional security throughout the year. However, the varieties currently available for aman season are not performing well in terms of yield potential and consumer preferences.

Results from the complete one-year cropping cycle maximum net profit (3628.23 US\$/ha) was observed in treatment (T5) Maize + vegetables – sorghum - aman rice systems because of higher production and market price of vegetables (Table 2). 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.

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 (Table 2).

Farmers Net profit was calculated using local market prices, the prices of vegetables and other crops are highly variable even within cropping seasons; this needs to be calculated for more accurate profitability assessments.



Above: Carrot harvesting at the Research Platform Trial. (Rabi crop- 2023). Photo : Washiq Faisal

CONCLUSION AND RECOMMENDATION

The findings indicate notable variations in nutritional yield and net profit among different cropping patterns after one full cropping cycle. From the research it can be concluded that treatment (T5) Maize + vegetables – sorghum – aman rice cropping sequence resulted in higher nutritional yields and net returns. Kharif-2/monsoon season only scope for improving nutritional yields by cultivating biofortified rice. Crop diversification that contributes to nutritional yield improvements is possible mainly in rabi.

Adding a leafy vegetable as an intercrop to maize (T5) or as a sole crop between two rice crops (T4) is a source of macro and micronutrients and this practice is not an expensive investment in terms of additional production costs. Choosing right vegetable can contribute to the maximum nutritional yield and net profit. Selection of leafy vegetables depends on the local market and consumption pattern that influenced the profitability of the rabi maize crop.

Land use efficiency was maximum from Maize + vegetables – sorghum – aman rice which utilized the land for maximum period. However, especially for vegetable crops prices can strongly fluctuate within and across seasons and there is need to take that into account.

However, by doing so 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 (Table 2). Other than the net income decreases if the wrong leafy vegetable is chosen as competition negatively affects maize performance and without a good leafy vegetable establishment the loss can't be compensated.

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.



Above: Binadhan-20 transplanting. (Kharif-2-2023). Photo: Washiq Faisal

REFERENCES

ADB. (2023). *Bangladesh's agriculture, natural resources, and rural development sector assessment and strategy*. Mandaluyong City, Metro Manila, Philippines: Asian Development Bank. <https://doi.org/10.22617/TCS230050>

Bangladesh Bureau of Statistics. (2010). *Report of the Household Income and Expenditure Survey (HEIS)*. Statistics Division, Ministry of Planning, Bangladesh. <https://doi.org/BGD-BBS-HIES-2010-V01>

Cheesman, S., Faisal, M. W., Kurishi, A., Hossain, A., Aonti, A. J., Rahman, M. M., Hossain, M. S., Gathala, M. K., & Krupnik, T. J. (2022). *Agronomic research platform trial comparing diversified cropping patterns in Dinajpur, Bangladesh – Protocol for field implementation* (Work Package 2, Research Protocol 1). CGIAR research initiative on Transforming Agrifood Systems in South Asia (TAFSSA). International Maize and Wheat Improvement Center, Dhaka, Bangladesh. <https://repository.cimmyt.org/handle/10883/22447>

DeFries, R., Fanzo, J., Remans, R., Palm, C., Wood, S., & Anderman, T. (2015). Metrics for land-scarce agriculture: Nutrient content must be better integrated into planning. *Science*, 349(6245), 238–240. <https://doi.org/10.1126/science.aaa5766>

FAO, IFAD, UNICEF, WFP, & WHO. (2024). *The state of food security and nutrition in the world 2024: Financing to end hunger, food insecurity, and malnutrition in all its forms*. Rome, Italy: FAO. <https://doi.org/10.4060/cd1254en>

Gumma, M. K., Nelson, A., Maunahan, A., Thenkabail, P. S., & Islam, S. (2012). Rice cropping patterns in Bangladesh. *Rice Today*, 11(1), Jan–Mar. Los Baños, Philippines: International Rice Research Institute (IRRI). <https://hdl.handle.net/10568/34670>



Above: Diversified crop fields at research platform trial, BWMRI, Dinajpur. (Rabi crop-2023). Photo: Washiq Faisal

AUTHORS

Md. Washiq Faisal, Research Associate, CIMMYT

Timothy J. Krupnik, Regional Director, Sustainable Agrifood Systems Program, Asia, CIMMYT Country Representative for Bangladesh

Akbar Hossain, Principal Scientific Officer, BWMRI

Annika Jahan Aonti, Scientific Officer, BWMRI

Md. Mobinur Rahman, Scientific Officer, BWMRI

Mahesh Kumar Gathala, Senior Scientist and Cropping System Agronomist, CIMMYT

SUGGESTED CITATION

Faisal, M. W., Krupnik, T. J., Hossain, A., Aonti, A. J., Rahman, M. M., & Gathala, M. K. (2024). *Enhancing nutritional yields through efficient crop diversification: Comparison to the common of rice-rice system in Bangladesh*. Research Note 52, CGIAR research initiative on Transforming Agrifood Systems in South Asia (TAFSSA).

FUNDING ACKNOWLEDGEMENT

We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund: <https://www.cgiar.org/funders/>

To learn more, please contact:

m.faisal@cgiar.org

To learn more about TAFSSA, please contact:

t.krupnik@cgiar.org; p.menon@cgiar.org

ABOUT TAFSSA

TAFSSA (*Transforming Agrifood Systems in South Asia*) is a CGIAR Regional Integrated Initiative to support actions that improve equitable access to sustainable healthy diets, improve farmers' livelihoods and resilience, and conserve land, air, and water resources in South Asia.

ABOUT CGIAR

CGIAR is a global research partnership for a food secure future. Visit <https://www.cgiar.org/research/cgiar-portfolio> to learn more about the initiatives in the CGIAR research portfolio

DISCLAIMER

The views and opinions expressed in this publication are those of the author(s) and are not necessarily representative of or endorsed by CGIAR, centers, our partner institutions, or donors.