# Increasing Food Diversity and Nutritional Yield: Evaluating Diverse Cropping Systems

## A Field Study in Rajshahi District in Bangladesh

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## ABOUT THIS NOTE

Over the past 20 years, Bangladesh has made significant progress in food production, particularly in rice (ADB, 2023). However, many people still lack access to a nutritious and diverse diet. Diets remain largely imbalanced, with the staple cereal rice contributing approximately 70% of total energy intake (BBS, 2010). The increased production of high-yielding cereals such as rice, maize, and wheat has led to the replacement of more nutrient-rich cereals like millet, oats, and sorghum. To address this issue, new approaches are urgently needed to produce nutrient-rich, healthy foods while using land efficiently. In response to this challenge, a farmers' participatory research trial was conducted in collaboration with the Bangladesh Agricultural Research Institute and the Bangladesh Wheat and Maize Research Institute. The trial took place in the Rajshahi region, and a research brief has been prepared to summarize the findings on the nutrition yield of diverse and intensified cropping systems from experiments conducted in Rajshahi, Bangladesh, during 2022–2023.

## KEY STUDY FINDINGS

1.  The study found that the Rice–Maize+Red Amaranth–Sorghum (fodder) system achieved the highest nutritional yield, with 260% more carbohydrates, 202% more protein, 44% more fat, 203% more zinc, and 226% more iron compared to the Rice–Mustard–Fallow system, along with notable increases in Vitamins A and C.

2.  The Rice–Maize+Red Amaranth–Sorghum (fodder) system achieved the highest nutritional yield due to the high grain yield of maize and the inclusion of red amaranth as an intercrop, which boosted vitamin and mineral content.

3.  These results suggest that diversifying and intensifying rice-based cropping systems, including biofortified rice enriched with Zn and Fe, can sustainably improve dietary diversity, balanced nutrition, and reduce malnutrition risks for children and pregnant women. This is crucial for millions of marginal farmers in Bangladesh and South Asia.

# BACKGROUND

Bangladesh has made progress in food production, particularly in rice; however, many people still lack access to a nutritious and diverse diet (Iqbal et al., 2024). More than one-third of children suffer from stunted growth due to malnutrition. Diets remain largely imbalanced, with rice contributing about 70% of total energy intake (HIES, 2010). Additionally, 40% of the population derives less than 10% of total calories from protein, and 53% consumes less than 15% of total calories from fat, contributing to stunting, wasting, and being underweight in the country (BNNC, 2021). The dietary diversity score of 50% of households is below six, putting them at risk of micronutrient deficiencies, particularly in vitamin A, calcium, iron, zinc, and folic acid (BNNC, 2021). Recently developed biofortified rice varieties, such as BINA Dhan 20 and Bango Bandhu Dhan 100, can enhance nutritional security, particularly for Zn and Fe. BINA Dhan 20 can provide nutritional yields sufficient for 27 adults ha$^{-1}$ per year for Zn and 26 adults ha$^{-1}$ per year for Fe, compared to non-biofortified rice, which supports only 18 adults ha$^{-1}$ for Zn and 10 adults ha$^{-1}$ for Fe annually.

Bangladesh's agricultural policies and research systems primarily focus on the production and value chains of single crops, with less emphasis on developing evidence-based multisectoral farms and markets, often overlooking nutrition (GNR, 2021). Sustainable intensification and diversification of farming systems are needed without exceeding e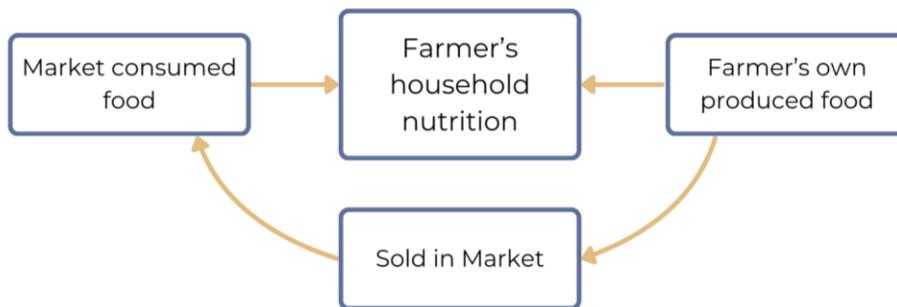nvironmental limits. The linkages between farm production and nutrition remain poorly established, highlighting the need for integrated approaches that consider household food production, nutritious diets, and market system development. Urgent food systems reforms are required to generate profits and incentivize farmers to produce nutritious foods while reducing consumer prices for healthy products by addressing inefficiencies in value chains (Fahim et al., 2021).

To address these challenges, intensive and diversified rice-based cropping systems, including biofortified crop varieties, can improve dietary habits and reduce malnutrition. In this study, the nutritional yield of macro and micronutrients was calculated. The concept of Dietary Recommended Intake (DRI) is key to understanding nutritional yield. DRI refers to the daily intake level of a specific nutrient likely to meet the requirements of healthy individuals in a particular life stage or gender group (DeFries et al., 2016). Nutritional yield refers to the number of adults who can meet 100% of their recommended dietary intake for a nutrient over a year from the production of one hectare of land (DeFries et al., 2016).

In the study area, farmers primarily consume the food they produce and sell any surplus in the local market. They also purchase additional food needed for household consumption (Figure 1). A balanced diet, with adequate macro and micronutrients, is crucial for human health, particularly for pregnant women, children, and adolescents (Table 1).

**Table 1:** Functions of carbohydrate, protein, fat, zinc, iron, vitamin c, and vitamin A (MOA, 2015)

| Nutrient | Functions |
|---|---|
| Carbohydrate | The primary source of energy in the body to function the metabolic process |
| Protein | Enables growth, development, maintenance, and repair of the body. |
| Fat | Produce energy, a source of essential fatty acids, that the body cannot produce on its own, and helps the body absorb fat-soluble vitamins such as A, D, E, and K. |
| Zinc | Growth and maintenance of immune function for both the prevention of and recovery from infectious diseases. |
| Iron | Important for hemoglobin production in blood, and it helps to carry oxygen and transport it throughout the body. Children, adolescents, and pregnant women suffer more from anemia due to a lack of iron-rich food. |
| Vitamin C | Essential for skin health, immune function, iron absorption, and overall tissue repair and protection. |
| Vitamin A | Essential for vision, immune function, skin health, cell growth, reproduction, etc. |



**Figure 1:** Food channels among farmers household in village, Rajshahi, Bangladesh

## OBJECTIVES

The research aims to identify effective strategies to improve farmers' dietary habits, increase nutritional yields, conserve resources, and enhance ecological services. A participatory research approach was employed in collaboration with stakeholders in the study area, focusing on producing diverse foods and improving the nutritional yield of both macro and micronutrients, particularly for disadvantaged rural communities. The primary objectives are:

- Estimate the nutritional yield of cropping system options and compare them with the farmers' common cropping systems.
- Conserve agricultural resources by developing resource-efficient and sustainable cropping systems.

## DATA AND METHODS

### SITE DESCRIPTION

Researcher-managed and farmer participatory field trials were conducted in rainfed and partially irrigated environments over three seasons: the 2022–23 winter (rabi), pre-monsoon 2023 (kharif 1), and monsoon 2023 (kharif 2) in the north-western part of Bangladesh, specifically in the high Barind Tract, Rajshahi (Figure 1).

### TREATMENT SELECTION

The cropping patterns for this study were selected through a participatory approach involving 50 farm households. Each household evaluated various cropping options by assigning scores based on their preferences. The top-ranked patterns (1st, 2nd, and 3rd) were chosen for further evaluation.

These top-scoring cropping patterns were then compared to the conventional Rice-Mustard-Fallow system, commonly practiced in the region, to assess their performance in terms of nutritional yield and overall benefits. The scoring method ensured that the selected cropping patterns aligned with farmers' preferences and practical considerations, making the findings more relevant to local agricultural contexts (Table 1 and Cheesman et al., 2022 for details).

### EXPERIMENTAL DESIGN

The on-farm research trials follow a randomized complete block design (RCBD), with 20 farmer households as replications within each village. In four villages, three diversified cropping patterns and a farmers' practice are being compared. The plot size ranges from 150 to 300 m² per treatment.

### CROP MANAGEMENT

The planting of the kharif 1 crops (sweet corn, sorghum, and cowpea) ranged from 1 to 26 February 2023. Kharif 2 rice was transplanted from 10 to 20 August 2023 using 25-30-day-old seedlings, and the rabi crops (maize and mustard) were planted from 10 to 20 November 2023. In all three seasons, crops were fertilized according to the Bangladesh Fertilizer Recommendation Guidebook (FRG, 2018). Weed control, pest management, irrigation, and other practices were carried out following standard agronomic procedures.

## DETERMINATION OF NUTRITION YIELD

To determine the nutritional yield, it is first necessary to understand the Daily Dietary Recommendation (DRI). The DRI of a particular nutrient refers to the nutrient requirement of a healthy individual in a specific life stage or gender group (Table 2).The nutritional yield of a specific nutrient refers to the number of adults who can meet 100% of the DRI for that nutrient over an entire year from the production of one hectare of land (Equation 1) (DeFries et al., 2015).

## STATISTICAL ANALYSIS

The data were analyzed using a Randomized Complete Block Design with 20 farmer fields in each location, considering replication as a random effect. The village, treatment, and their interaction were considered fixed effects (Gomez, 1984). The analysis was performed using JMP14 (SAS Institute Inc., San Francisco). The inputs and outputs of the component crops and system means were compared using Tukey's Honest Significant Difference test at $P \leq 0.05$.
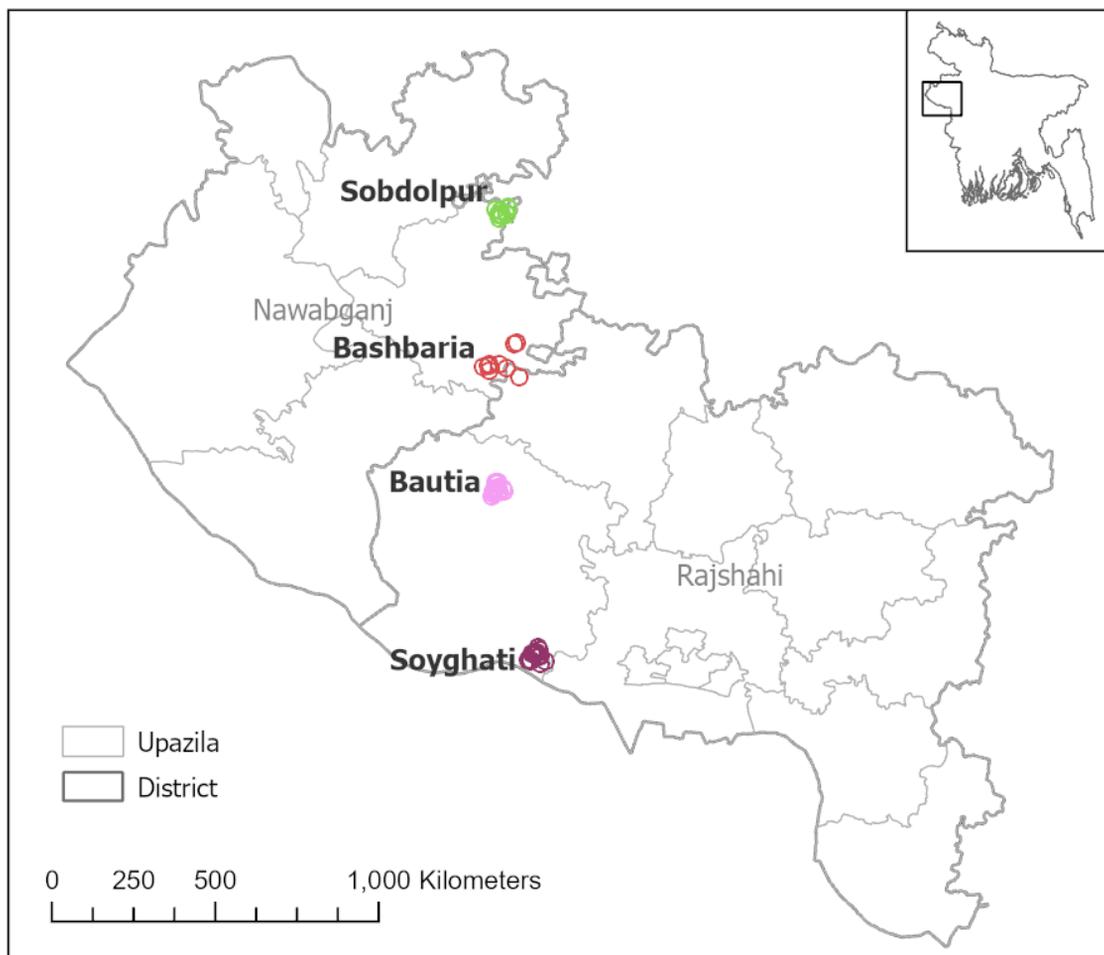
$$NY_{ij} \text{ (adult/ha per year)} = \frac{Y_j \text{ (t/ha)} \times 10^6 \times Nc_{ij} \text{ (\%)}}{DRI_i \text{ (g/adult/}day） \times 365} \dots \dots \dots (Equ\ 1)$$

*Where, NY = nutrition yield; Nc = Nutrient content; DRI = daily dietary reference intake; Y= crop yield; The subscripts "i" and 'j' refer to the nutrient of interest and crop, respectively.*
*Note that (1) the source of nutrient content values is the Food Composition Table for Bangladesh, published in 2013.*



**Above:** Sweet corn on the left and Sorghum on the right side, trial plot *kharif 1* 2023 in Soyghati, Rajshahi, Bangladesh; photo: Juel Rana

**Figure 2:** Small circles indicate the farmers' participatory trial fields at Bautia and Soyghati villages in Rajshahi district

**Table 2:** : Description of treatments

| Treatment code | Kharif-2 | Rabi | Kharif-1 |
|---|---|---|---|
| R-L-Sc | Rice | Lentil | Sweet corn |
| R-M+Ra-S | Rice | Maize+red amaranth | Sole sorghum (fodder) |
| R-Mu-S+C | Rice | Mustard | Sorghum+Cowpea (fodder) |
| R-Mu-F | Rice | Mustard | Fallow |

**Note**: R-L-Sc: Rice-Lentil-Sweet corn; R-M+Ra-S: Rice-Maize intercrop with read amaranth-Sole Sorghum (fodder), R-Mu-S+C: Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with Cow Pea (Fodder), R-Mu-F: Rice-Mustard (BARI Mustard 18)-Fallow

**Table 3:** DRI  of  carbohydrate, protein, fat, zinc, iron, vitamin C, and vitamin A (DeFries et al., 2015; Mahjabin et. al., 2021)

| DRI (g/adults/day) | | | | | | |
|---|---|---|---|---|---|---|
| Carbohydrate | Protein | Fat | Zinc | Iron | Vitamin C | Vitamin A |
| 431.5 | 56 | 96 | 0.012 | 0.012 | 0.08 | 0.007 |

**Table 4**:  Nutrient content of component crops of cropping system options (Shaheen et al.,  2013)

| Crop | Nutriment content (g 100$^{-1}$ g) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Carbohydrate | Protein | Fat | Zinc | Iron | Vit-C | Vit-A |
| Rice (BF) | 76.8 | 6.5 | | 0.00265 | 0.002 | | - |
| Rice(NBF) | 76.8 | 6.5 | 0.4 | 0.001.32 | 0.0007 | | - |
| Wheat | 62 | 11.2 | 2.9 | 0.002.79 | 0.0049 | | - |
| Maize | 64.7 | 9.9 | 3.4 | 0.003.27 | 0.0029 | | 0.000011 |
| Sweet corn | 28.7 | 3.5 | 1.4 | 0.0008 | 0.0007 | 0.0059 | 0.000004 |
| Lentil | 43.2 | 27.7 | 0.8 | 0.003.89 | 0.0051 | - | 0.000003 |
| Chickpea | 44.8 | 20.4 | 6 | 0.002.68 | 0.0088 | 0.004 | 0.000003 |
| RA | 0.5 | 4.5 | 0.3 | 0.0009.6 | 0.006 | 0.042 | 0.000793 |

**Table 5**:  Yield  of component crops of cropping system options from field trials 2022-23, Rajshahi

| Village | Cropping system | Crop yield (t ha$^{-1}$) | | |
|---|---|---|---|---|
| | | Kharif 2 | Rabi* | Kharif 1 |
| Bautia | R-L-Sc | 2.86 | 1.83 | 3.47 |
| | R-M+Ra-S | 2.75 | 12.16 (3.35) | |
| | R-Mu-S+C | 2.63 | 1.75 | |
| | R-Mu-F | 2.58 | 1.17 | |
| Soyghati | R-L-Sc | 4.75 | 1.70 | 3.91 |
| | R-M+Ra-S | 4.59 (4.35) | 9.16 (4.35) | |
| | R-Mu-S+C | 4.54 | 1.87 | |
| | R-Mu-F | 4.34 | 1.32 | |

**Note**: R-L-Sc: Rice-Lentil-Sweet Corn; R-M+Ra-S: Rice-Maize intercrop with read maranth-Sole Sorghum (fodder), R-Mu-S+C:  Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with Cow Pea (Fodder), R-Mu-F: Rice-Mustard (BARI Mustard 18)-Fallow**. \***The value in parenthesis is the fresh yield of red amaranth intercropping with maize in the rabi season.
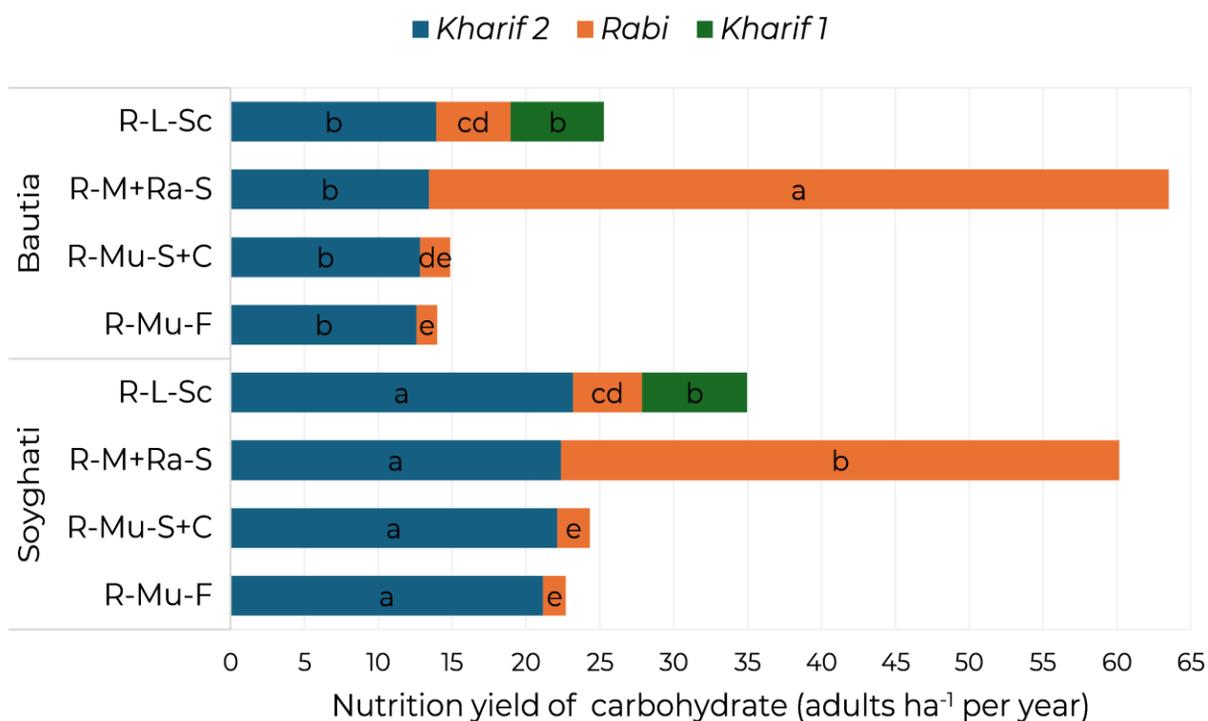
# STUDY FINDINGS
## NUTRITION YIELD OF CARBOHYDRATES

Carbohydrates are the primary source of energy and mainly come from cereals. Among cereals, rice is the staple food for people in South Asia. Therefore, biofortified rice enriched with Zn and Fe was included in each cropping pattern.

The field study revealed that the nutrition yield (NY) of carbohydrates varied significantly across different cropping system options (T), villages (L), and their interactions (L×T) (Table 6). The highest NY of carbohydrates (63.5 adults ha$^{-1}$ per year) was found in the R-M + Ra-S cropping system in Bautia.

This high nutrition yield is attributed to the significantly higher grain production of maize in the rabi season at both locations. The comparison of the nutrition yield of carbohydrates across cropping systems is as follows: R-M + Ra-S > R-L-Sc > R-Mu-S + C > R-Mu-F. The same trend was observed among the component crops of the systems during the rabi season. In Kharif 2, all plots were planted with rice (BINA dhan 20) with no significant difference between treatments; however, there was a significant difference between the locations due to weather constraints in Bautia (Figure 2 and Table 6).
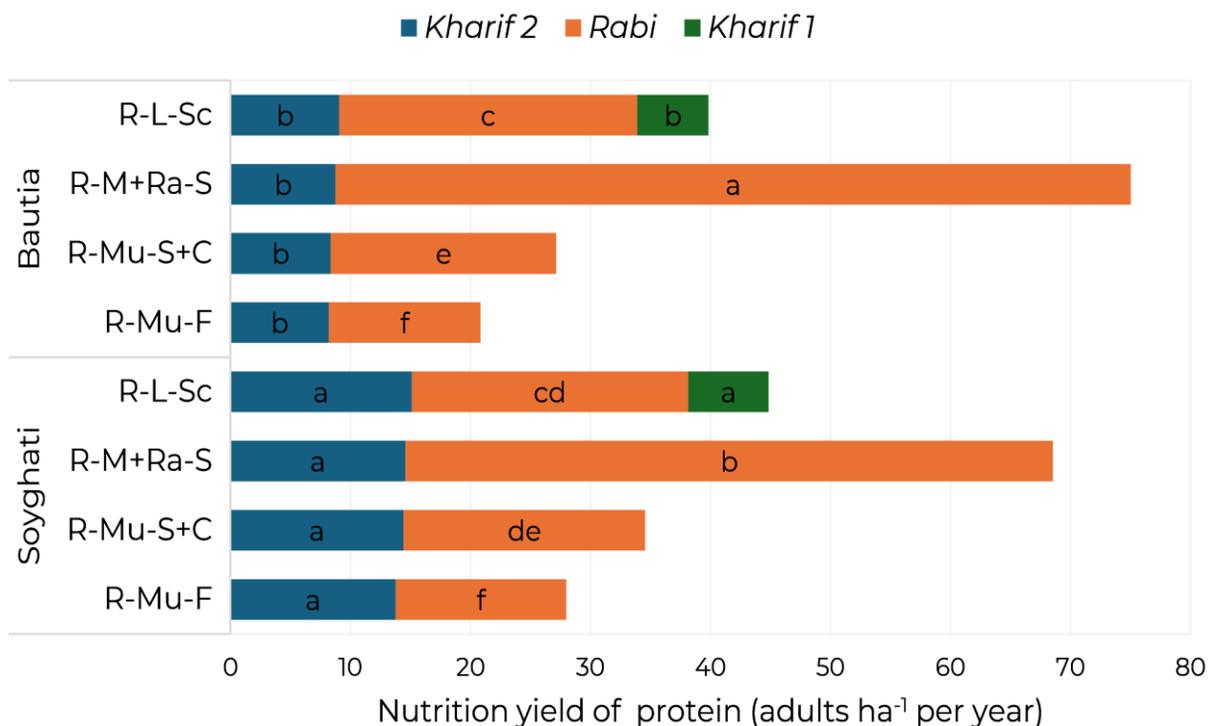


**Figure 3:** Nutrition yield of carbohydrate (adults ha$^{-1}$ per year ) by component crops and cropping systems in Bautia and Soyghati villages, Rajshahi, 2022-23

**Note:** R-L-Sc: Rice-Lentil-Sweet Corn; R-M+RA-S: Rice-Maize intercrop with read amaranth-Sole Sorghum (fodder), R-Mu-S+C: Aman Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with Cowpea (Fodder), R-M-F: Rice-Mustard (BARI Mustard 18)-Fallow. Means followed by the same lower-case letters in same color bars are not significantly different (at $p<0.05$) according to Tukey's HSD test.

## NUTRITION YIELD OF PROTEIN

Protein is an essential macronutrient for human health, as it supports the growth, development, maintenance, and repair of the body. Currently, dietary proteins are primarily obtained from animal sources (such as meat, fish, poultry, eggs, and dairy) and plant-based foods (including grains, legumes, nuts, and beans). At a basic level, proteins consist of amino acids, nine of which cannot be synthesized by the human body and are therefore considered essential, requiring intake from dietary sources (MOA, 2015). Therefore, it is crucial to include diverse crops in cropping systems. The highest NY of protein, assessed by the R-M + Ra-S cropping system, is attributed to the significantly highest grain yield of maize in the rabi season at both locations. The comparison of the NY of protein across cropping systems is as follows: R-M + Ra-S > TR-L-Sc > R-Mu-S + C > R-Mu-F. The same trend was observed among the component crops of the systems in the rabi season. In Kharif 2, all plots were planted with rice (BINA dhan 20) with no significant difference among treatments; however, there was a significant difference between the locations due to weather constraints in Bautia (Figure 4 and Table 6).
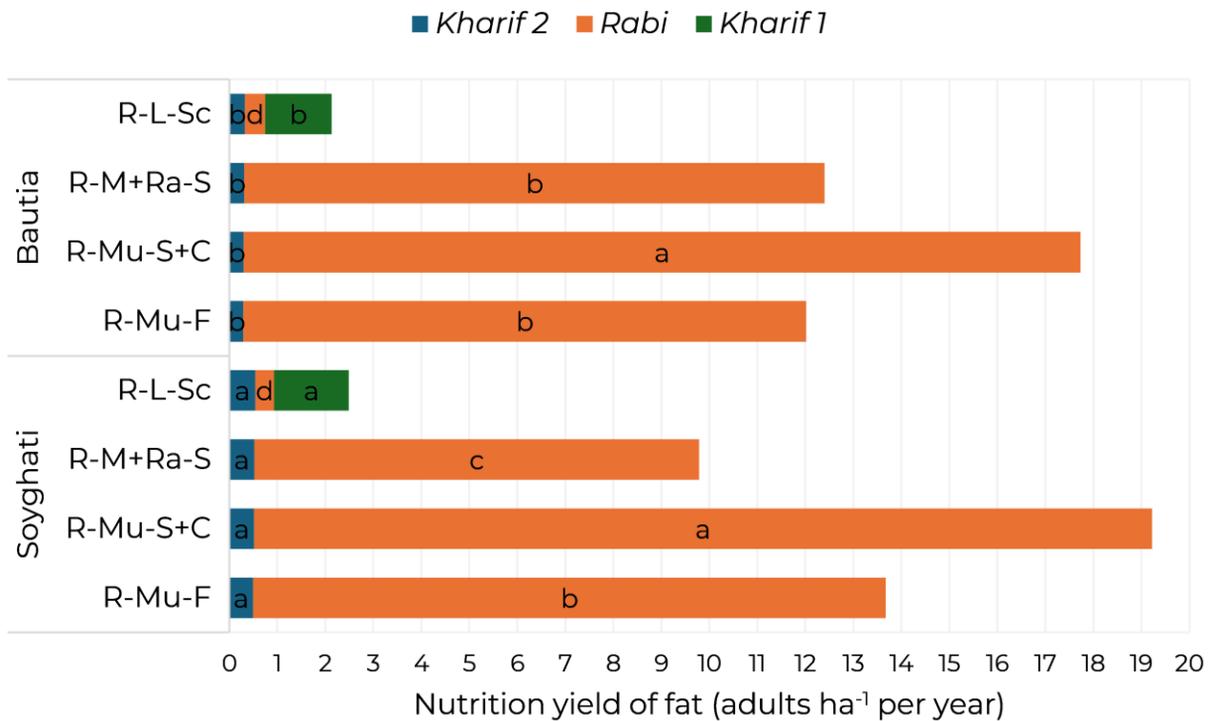


**Figure 4:** Nutrition yield of protein (adults ha$^{-1}$ per year ) by component crops and cropping systems in Bautia and Soyghati villages, Rajshahi, 2022-23

**Note:** R-L-Sc: Rice-Lentil-Sweet Corn; R-M+RA-S: Rice-Maize intercrop with read amaranth-Sole Sorghum (fodder), R-Mu-S+C: Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with Cowpea (Fodder), R-M-F: Rice-Mustard (BARI Mustard 18)-Fallow. Means followed by the same lower-case letters in the same color bars are not significantly different (at $p < 0.05$) according to Tukey's HSD test.

## NUTRITION YIELD OF FAT

A small amount of fat is essential for a healthy, balanced diet. Fat is a source of essential fatty acids, which the body cannot produce on its own. Additionally, fat helps the body absorb fat-soluble vitamins such as A, D, and E, which can only be absorbed with the help of fats (MOA, 2015). Therefore, it is crucial to include oil crops in cropping systems. The highest NY of fat (19 adults ha$^{-1}$ per year) was observed in the R-Mu-S + C cropping system at both locations. This high NY of fat is attributed to the inclusion of an oil crop (mustard) in the rabi season at both locations. In Kharif 2, all plots were planted with rice (BINA dhan 20) with no significant difference among treatments; however, there was a significant difference between locations due to weather constraints in Bautia (Figure 5 and Table 6). To meet the local demand for edible oil, this system may be effective in reducing dependence on imported soybean oil. Government agencies are also providing incentives to include mustard in existing cropping systems in this area.



**Figure 5:** Nutrition yield of protein (adults ha$^{-1}$ per year ) by component crops and cropping systems in Bautia and Soyghati villages, Rajshahi, 2022-23

**Note:** R-L-Sc: Rice-Lentil-Sweet Corn; R-M+RA-S: Rice-Maize intercrop with read amaranth-Sole Sorghum (fodder), R-Mu-S+C: Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with cowpea (fodder), R-M-F: Rice-Mustard (BARI Mustard 18)-Fallow. Means followed by the same lower-case letters in the same color bars are not significantly different (at $p<0.05$) according to Tukey's HSD test.

**Table 6:** Nutrient yield assessed by cropping systems options for carbohydrate, protein, and fat  in Bautia and Soyghati, Rajshahi, 2022-23

| Source | Nutrition yield (adults ha$^{-1}$ per year) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Carbohydrate | Protein | Fat | Zinc | Iron | Vit-A | Vit-C |
| **Village (V)** | | | | | | | |
| Bautia | 29.41b | 40.72b | 11.07 | 56.34 | 68.61b | 27.55b | 27.63b |
| Soyghati | 35.53a | 43.99a | 11.29 | 63.29 | 78.78a | 34.98a | 35.24a |
| **Cropping system (T)** | | | | | | | |
| R-L-Sc | 30.12b | 42.35b | 2.31d | 45.44b | 48.17c | 0.78b | 7.45b |
| R-M+Ra-S | 61.83a | 71.8a | 11.09c | 110.26a | 144.33a | 124.17a | 55.41a |
| R-Mu-S+C | 19.59c | 30.86c | 18.48a | 45.92b | 57.21b | 0.07b | - |
| R-Mu-F | 18.33c | 24.42d | 12.85b | 37.64c | 45.08c | 0.05b | - |
| **V × T** | | | | | | | |
| Bautia, R-L-Sc | 25.27c | 39.84d | 2.13d | 39.88d | 43.17de | 0.76c | 7.01c |
| Bautia, R-M+Ra-S | 63.5a | 75.05a | 12.4b | 114.81a | 142.19a | 109.33b | 48.24b |
| Bautia, R-Mu-S+C | 14.87d | 27.15f | 17.73a | 39.3d | 50.48cd | 0.07c | |
| Bautia, R-Mu-F | 13.97d | 20.85g | 12.02b | 31.36e | 38.59e | 0.05c | |
| Soyghati, R-L-Sc | 34.97b | 44.86c | 2.49d | 51.01c | 53.18c | 0.81c | 7.89c |
| Soyghati, R-M+Ra-S | 60.15a | 68.55b | 9.79c | 105.7b | 146.46a | 139a | 62.59a |
| Soyghati, R-Mu-S+C | 24.31c | 34.58e | 19.22a | 52.53c | 63.93b | 0.07c | |
| Soyghati R-Mu-F | 22.69c | 27.99f | 13.68b | 43.92d | 51.56cd | 0.05c | |
| **Sources of variation** | value of probability | | | | | | |
| V | <.001 | <.001 | 0.464 | <.001 | <.001 | 0.002 | 0.001 |
| T | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 |
| V × T | <.001 | <.001 | <.001 | <.001 | 0.103 | <.001 | 0.002 |

**Note**: R-L-Sc: Rice-Lentil-Sweet Corn; R-M+RA-S: Rice-Maize intercrop with read amaranth-Sole sorghum (fodder), R-Mu-S+C: Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with cowpea (Fodder), R-M-F: Rice-Mustard (BARI Mustard 18)-Fallow. Means followed by the same lower-case letters in a column are not significantly different (at p<0.05) according to Tukey's HSD test.
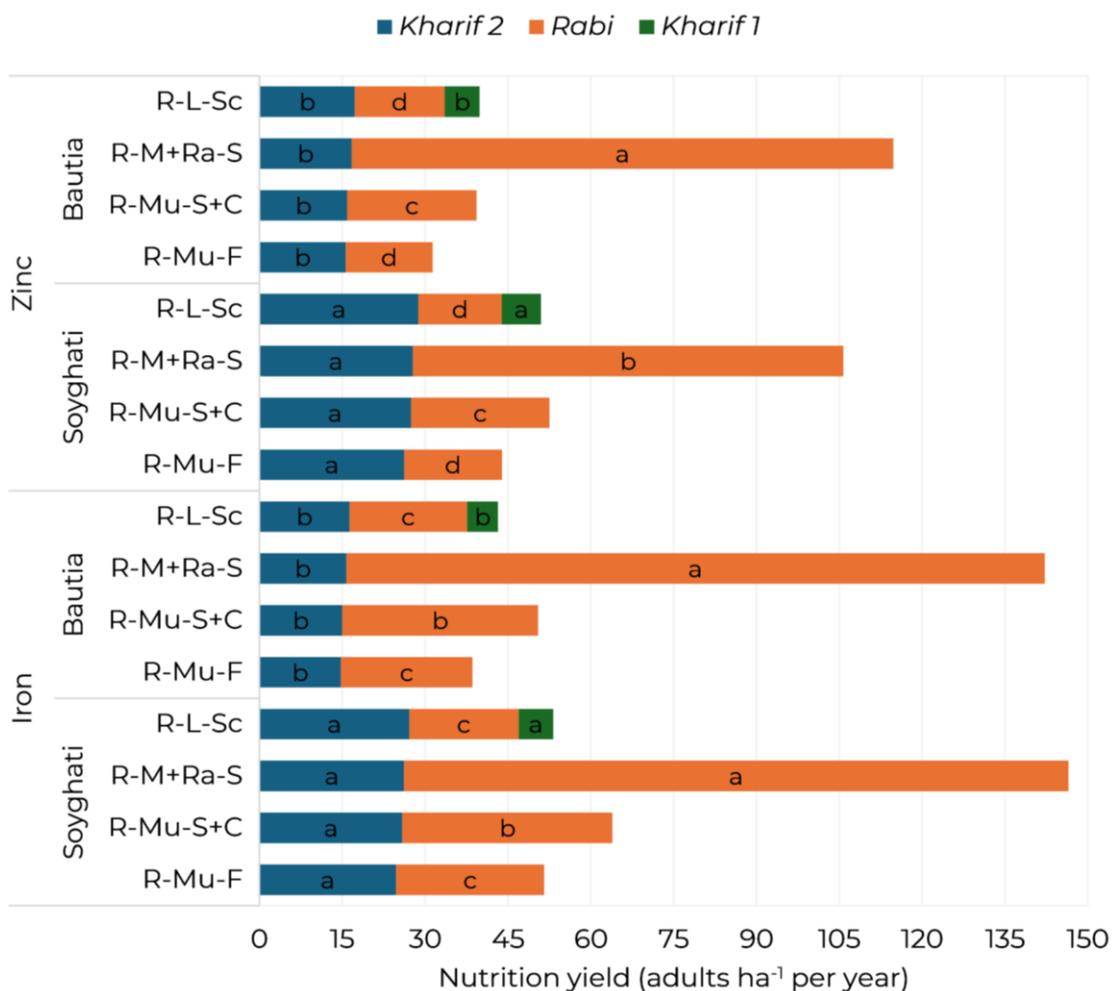


**Above**:  BARi mustard 14 on the left and BARI mustard on the right side, trial plot *rabi*,  2022-23 in Bautia, Rajshahi, Bangladesh; photo: Juel Rana

## NUTRITION YIELD OF MINERALS

Among minerals, iron and zinc in the diet are very important for human health. Therefore, biofortified crops enriched with Zn and Fe included in cropping systems are crucial for health. The NY of iron and zinc varied significantly due to the effect of different cropping system options, villages, and their interactions (Table 6). The highest NY of Zn (106-115 adults ha⁻¹ per year) and Fe (142-146 adults ha⁻¹ per year) were found in the R-M + Ra-S cropping system at both locations. The highest NY of iron and zinc in the R-M + Ra-S cropping system is attributed to the significantly highest grain yield and intercropping with the component crop, maize, in the rabi season at both locations (Figure 6 and Table 6).
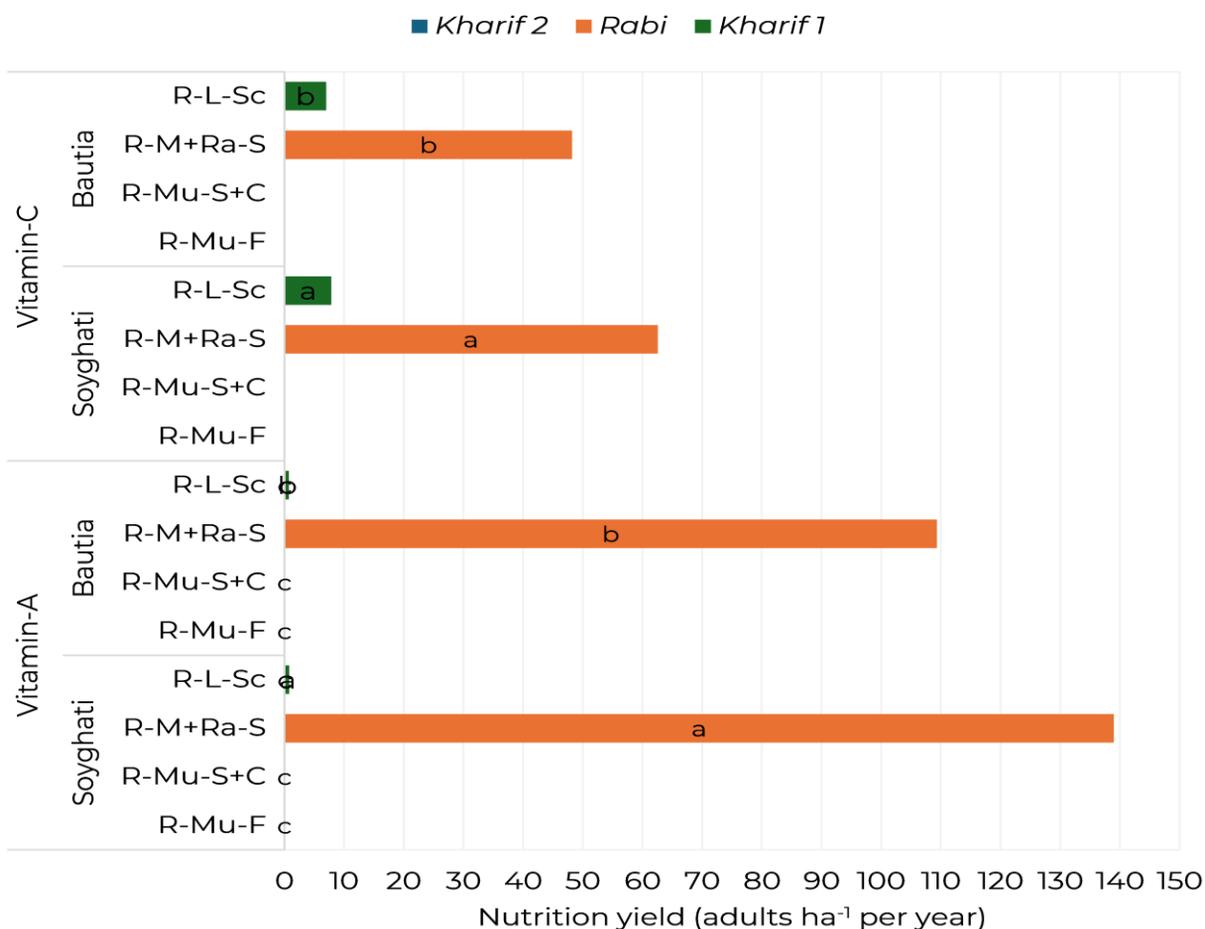


**Figure 6:** Nutrition yield (adults ha⁻¹ per year of zinc, and iron) by component crops and cropping systems in Bautia and Soyghati villages, Rajshahi, 2022-23

**Note: R-L-Sc**: Rice-Lentil-Sweet Corn; R-M+RA-S: Rice-Maize intercrop with Read Amaranth-Sole Sorghum (fodder), R-Mu-S+C: Aman Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with Cowpea (Fodder), R-M-F: Rice-Mustard (BARI Mustard 18)-Fallow. . Means followed by the same lower-case letters in same color bars in the same mineral between two village, Bautia and Soyghati are not significantly different (at p<0.05) according to Tukey's HSD test.

## NUTRITION YIELD OF VITAMINS

Among the vitamins, Vitamin A and Vitamin C in the diet are very important for human health. The NY of Vitamin A and Vitamin C varied significantly based on different cropping system options and villages (Table 6). The highest NY of Vitamin A (139 adults ha⁻¹ per year) and Vitamin C (63 adults ha⁻¹ per year) were found in the R-M + Ra-S cropping system in Soyghati. The highest NY of vitamins A and C in the cropping system is attributed to red amaranth intercropped with the component crop, maize, in the rabi season at both locations (Figure 4). The same trends of results were observed among the component crops of the systems in the rabi crops. In Kharif 2, all plots are with Rice (BINA dhan 20) with no vitamins in the Kharif 2 season (Figure 7 and Table 6). The inclusion of leafy vegetables in the systems may increase the sources of vitamins and minerals in the diet.



**Figure 7:** Nutrition yield (adults ha⁻¹ per year) of vitamin C and vitamin A by component crops and cropping systems in Bautia and Soyghati villages, Rajshahi, 2022-23

**Note:** R-L-Sc: Rice-Lentil-Sweet corn; R-M+RA-S: Rice-Maize intercrop with Read Amaranth-Sole Sorghum (fodder), R-Mu-S+C: Aman Rice-Mustard (BARI Mustard 14)-Sorghum intercrop with cowpea (Fodder), R-M-F: Rice-Mustard (BARI Mustard 18)-Fallow. Means followed by the same lower-case letters in same color bars in the same vitamin between two villages, Bautia and Soyghati are not significantly different (at p<0.05) according to Tukey's HSD test.

## CONCLUSIONS AND RECOMMENDATIONS

This research brief presents findings on the nutritional yield (NY) of macro and micronutrients from various cropping system options. The studied systems included: Rice-Lentil-Sweet Corn, Rice-Maize intercropped with red amaranth and sorghum (as fodder), Rice-Mustard intercropped with sorghum and cowpea (as fodder), and the conventional Rice-Mustard-Fallow system. These systems were assessed to promote dietary diversity and healthier food options. The Rice-Mustard-Fallow system is traditionally followed by farmers, while the other three represent more intensive and diverse cropping alternatives. The study was carried out across 40 farmers' fields in two villages in the Rajshahi district of Bangladesh.

Results indicated that the NY of macro and micronutrients was significantly greater in the intensive and diversified cropping systems compared to the farmers' practice of the Rice-Mustard-Fallow system commonly used in Rajshahi. Notably, the Rice-Maize + Red Amaranth-Sorghum (Fodder) system achieved the highest nutritional yield, surpassing other systems in carbohydrates, protein, fat, zinc, and iron. Specifically, it demonstrated an increase of 260% in carbohydrates, 202% in protein, 44% in fat, 203% in zinc, and 226% in iron compared to the traditional Rice-Mustard-Fallow system. Additionally, this system showed notable improvements in vitamin A and vitamin C compared to other cropping options. The enhanced nutritional performance of the Rice-Maize + Red Amaranth-Sorghum system is attributed to the high grain yield from maize and the inclusion of nutrient-rich leafy vegetables like red amaranth, which elevated vitamin and mineral content. Although maize is primarily used for poultry and livestock feed rather than human consumption, poultry remains a key protein source in this region.

These findings highlight the benefits of intensifying and diversifying rice-based cropping systems, particularly when incorporating biofortified rice varieties enriched with zinc and iron, as opposed to traditional practices like Rice-Mustard-Fallow. This approach could significantly enhance smallholder dietary diversity, provide a more balanced diet, and reduce malnutrition risks, particularly for children and pregnant women. These insights hold considerable importance for millions of small-scale farmers across the region and in Bangladesh.



**Above**: BRRI Dhan 51 on the left and BINA dhan 20 on the right side, trial plot *kharif* 2, 2023 in Soyghati, Rajshahi, Bangladesh; photo: Juyel Rana

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## 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.

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