

# The Nutritional Impact of Diversified Cropping Systems

Comparing diversified cropping patterns in Rangpur, Bangladesh

Research note 42

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## ABOUT THIS NOTE

Bangladesh relies heavily on rice-based cropping systems to ensure food security. However, this dependence limits crop diversification, which is vital for improving agricultural productivity in a densely populated country with limited arable land. This trial summarizes the nutritional yield results from diversified cropping systems after one complete cycle. The study area was selected based on factors such as food security, nutrition adequacy, environmental degradation, and climate challenges—key considerations for achieving TAFSSA's goals. The research aims to promote crop diversification and identify strategies for cultivating nutrient-rich crops that provide essential macro- and micronutrients.

## KEY STUDY FINDINGS

1. After one full cropping cycle, all diversified cropping systems enhanced both macronutrient and micronutrient levels, crucial for a healthy diet.
2. The nutritional yield of carbohydrates increased by adding maize along with potato. Although rice is a cereal crop, it does not significantly increase the nutritional yield of carbohydrate due to its lower overall production.
3. Fat significantly increased by adding kharif-1 crops of groundnut. Groundnut and maize are also an important source of protein.
4. Adding maize, napa shak, and potato increased the availability of micronutrients such as zinc (Zn) and iron (Fe). The cropping patterns of *Groundnut-Aman-Potato* (GAP) and *Maize-Aman-Carrot* (MAC) significantly increased the nutritional yield of zinc (Zn)
5. Subsequently, the cropping patterns of *Maize-Aman-Carrot* (MAC) and *Groundnut-Aman-Napa shak* (GAN) significantly outperformed in iron (Fe) content. Biofortified rice Aman did not have any significant effects on zinc (Zn) and iron (Fe).
6. The nutritional yields of vitamins A and C increased by adding leafy vegetables like napa shak, as well as carrot and potato, during the winter Rabi season.

## BACKGROUND

Bangladesh, with its high population density and limited arable land, has seen a significant increase in cropping intensity over the past 50 years (Saif et al., 2024). This reflects more intensive land use for farming (Nasim et al., 2017). A greater number of cropping patterns generally indicates higher crop diversity (Zaman et al., 2017). According to Nasim et al. (2017), Bangladesh has identified 316 distinct cropping patterns. An on-farm trial conducted in the Kaunia and Pirgacha upazilas of the Rangpur district identified 134 cropping patterns. Among these, five rice-based patterns accounted for over 58% of the net cropped area. While rice-based cropping patterns dominate in Bangladesh and contribute to food security, they fall short in addressing the need for nutrient-rich crops, particularly those high in micronutrients.

Bangladesh has made advancements in addressing low birth weight and some progress toward reducing stunting and wasting in children under five. However, despite these efforts, progress toward achieving global nutrition targets remains limited, particularly in reducing anemia among women of reproductive age (Global Nutrition Report, 2021). A significant portion of the population continues to face food insecurity and hunger, with limited access to a sufficiently nutritious and diverse diet. Additionally, many people are unaware of the importance of various nutrients for the human body, as highlighted in Table 1. Food security and proper

nutrition are fundamental human needs. To address this, innovative approaches are required to produce foods that are rich in macronutrients (carbohydrates, proteins, fats) and micronutrients (iron, zinc, and vitamins A and C), while ensuring the efficient use of agricultural land. Micronutrient deficiencies can result from a lack of dietary quality and diversity, even when the macronutrient supply is adequate (DeFries et al., 2015).

Farmers participating in a trial typically obtain household (HH) nutrition from two main sources. The first is market food, which refers to food purchased from the market using income from crop sales. The second source is farm-produced food, grown on their own land and directly consumed by the household. This form of subsistence farming helps ensure a stable food supply, reducing dependence on external markets. Additionally, farmers may sell their crops at the market, and this exchange of produce is also categorized as market food (see Figure 1).

The Rangpur district was selected based on key factors, including food and nutrition insecurity, biodiversity loss, environmental concerns, sustainable agriculture, and climate challenges. Additionally, it examines the prevalence of commodities and agricultural systems with the highest potential to meet TAFSSA's goals (Cheesman et al., 2022). This trial, therefore, aims to emphasize crop diversification to identify strategies for increasing the cultivation of nutrient-rich crops high in micronutrients, conserving natural resources, and maintaining or enhancing biodiversity.

**Table 1:** Some key components of foods and their functions

Nutrients	Functions
Carbohydrates	Produce energy in the body to support metabolic processes
Proteins	Support body maintenance and promote growth and development
Fats	Produce energy and support nutritional development
Zinc	Zinc is crucial for maintaining a healthy immune response, helping the body fight off infections and heal wounds
Iron	Iron is crucial for the production of hemoglobin. Red blood cells help transport oxygen throughout the body. Children, adolescents, and pregnant women suffer more from anemia due to a lack of iron-rich foods
Vitamin C	Vitamin C is essential for skin health, immune function, iron absorption, and overall tissue repair and protection
Vitamin A	Vitamin A is essential for vision, immune function, skin health, cell growth, reproduction, and overall well-being

**Source:** <https://www.pomona.edu/administration/dining/health-wellness/macronutrients>

## OBJECTIVES

This study aims to identify strategies for crop diversification across the region’s farming systems to increase nutritional yield and enhance farm productivity. Preliminary results from the first year of diversified cropping patterns are outlined in this research brief.

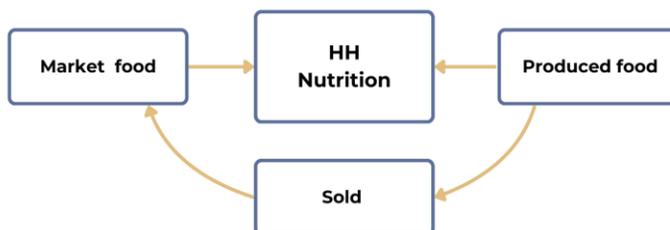
## RESEARCH QUESTIONS

At the farm level, can crop diversification and biofortification be effectively managed to increase the production of nutritious foods, improve the livelihoods of women and men, and conserve resources?

## DATA AND METHODS

The on-farm research trials in the Rangpur district follow a randomized complete block design (RCBD), replicated with 20 farmer households within a village. Each trial farmer allocates 20–30 decimals (~800–1200 m<sup>2</sup>) of their land for the on-farm trial. This area is divided equally among four cropping patterns, with each plot size being approximately 200 m<sup>2</sup>. The allocated area (~800–1200 m<sup>2</sup>) may be in one piece or spread across different fields, but not more than 50–100 m apart. These on-farm research trials are hosted by smallholder farming households in two villages across the Rangpur district of northern Bangladesh (Table 3).

The study selected cropping patterns based on the preferences of 50 farm households, who scored their choices. The top three cropping patterns, as ranked by the farmers, were chosen for comparison with the commonly used cropping pattern. In each village, three diversified cropping patterns—Maize-Aman-Carrot (MAC), Groundnut-Aman-Napa shak (GAN), and Groundnut-Aman-Carrot (GAC)—are being compared with the common farmer practice, Groundnut-Aman-Potato (GAP) (Table 2).



**Figure 1:** Availability of food supportive nutrition across the household (HH)

Agronomic data regarding all above ground biomass, crop production and number of irrigation water applied are among the data collected (for more information see Cheesman et al., 2022).

Nutrient content values are usually given per 100 g of a food sample. This standardized measurement makes it easier to compare the nutrient levels of various foods and assess how much a specific food contributes to daily nutrient intake (Table 4). Where, the dietary reference intake (DRI) refers to the amount of nutrients a person needs daily to meet their requirements for carbohydrates, protein, fat, iron, zinc, vitamin A, and vitamin C (Table 5).

The nutritional yield of a particular nutrient indicates the number of adult equivalents that can meet their 100% recommended dietary intake for that nutrient over the course of a year from the produce of one hectare land (DeFries et al., 2015). To facilitate Nutritional yield, as a measure of nutritional value of the production, is calculated for nutrients such as protein, fat, carbohydrates, iron and zinc, as well as Vitamin A and Vitamin C (Eq. 1).

Data have been computed for each of the three main cropping seasons in Bangladesh (*Kharif-1, Kharif-2, Rabi*) and combined to represent the entire cropping cycle. The nutritional yield is calculated the following equation:

$$NY_{ij} \text{ (adults that obtain DRI/ ha/yr)} = \frac{Y_j \text{ (t/ha)} \times 10^6 \times NC_{ij} \text{ (\%)}}{DRI_i \text{ (g /adult)} \times 365} \quad (\text{Eq. 1})$$

NY = nutritional yield; Y = yield; NC = nutrient content; DRI = daily dietary reference intake; The subscripts “i” and “j” refer to the nutrient of interest and crop, respectively. Note that the source of nutrient contents values is the Food Composition Table for Bangladesh, published in 2013 (Shaheen et al., 2013).

**Table 2:** Description of the diversified cropping patterns and first year results for different crop yield (t/ha) in Rangpur district

Village	Treatment	Cropping pattern	Average Yield (t/ha)		
			Kharif 1	Kharif 2	Rabi
Chargonai	MAC	Maize-Aman-Carrot	9.96	3.27	23.90
	GAN	Groundnut-Aman-Napa shak	2.78	3.27	16.42
	GAC	Groundnut-Aman-Carrot	2.82	3.25	24.65
	GAP	Groundnut-Aman-Potato	2.88	3.20	36.30
Shibdeb	MAC	Maize-Aman-Carrot	10.26	3.42	25.19
	GAN	Groundnut-Aman-Napa shak	2.73	3.38	14.52
	GAC	Groundnut-Aman-Carrot	2.76	3.37	25.37
	GAP	Groundnut-Aman-Potato	2.84	3.32	37.57

**Note:** Aman (biofortified and short duration) refers to rice grown in the monsoon kharif-2 season



**Above:** Carrots harvested in Chargonai village; photo: Alanuzzaman Kurishi

**Table 3:** Villages hosting on-farm research trials

SL	District	Upazila	Union	Village	Latitude	Longitude
1	Rangpur	Kaunia	Tepamadhupur	Chargonai	25.74775	89.46054
2	Rangpur	Pirgachha	Chhaola	Shibdeb	25.67345	89.50165

**Table 4:** Macro and micronutrients in different crops

Crop	Macronutrient contents (g 100 <sup>-1</sup> g)			Micronutrient contents (mg 100 <sup>-1</sup> g)			
	Carb	Protein	Fat	Zinc	Iron	Vit-C	Vit-A
Maize	64.7	9.9	3.4	3.27	2.9	-	0.011
Groundnut	14.8	22.5	46.6	3.39	2.9	-	-
Carrot	6	0.9	0.3	0.07	0.4	1.4	0.329
Napa Shak	0.5	3	0.5	0.9	2.2	21.6	0.409
Potato	14	1.2	0.2	0.79	0.5	19.1	0.002
BINA dhan 20	76.8	6.5	-	2.65	2.55	-	-

## STATISTICAL ANALYSES

Statistical analyses were performed using R 4.4.1 (R Core Team, 2024). The data were analyzed using a Randomized Complete Block Design with 20 farmer's fields in each location considering replication as a random effect. The village, treatment, and their interaction are considered fixed effects. (Gomez et al., 1984). The inputs and outputs of component crops and systems means were compared using Tukey's HSD significant difference test at  $P \leq 0.05$ . Data were expressed as the mean  $\pm$  standard error.

**Table 5:** Dietary reference intake (DRI) or recommended intake per day (adult). All nutrients value are given as gram (g)

	Carb	Protein	Fat	Zinc	Iron	Vit-C	Vit-A
DRI	431.5	56	96	0.012	0.012	0.08	0.0007

**Note:** DRI of carbohydrate, protein, fat referred by DeFries et al., (2015) and Zn, Fe, vit A & C referred by Mahjabin et. al., (2021)

## STUDY FINDINGS

ANOVA revealed a significant effect of location ( $P < 0.05$ ) on the nutritional yield of carbohydrates, but there were no significant effects on protein, fat, zinc, iron, or vitamins C and A (Table 6). Shibdeb produced the highest significant results for carbohydrates (42 adult/ha/yr) compared to Chargonai. The villages of Chargonai and Shibdeb follow the same cropping patterns, and their agronomic management is identical, which is why there was no significant difference except for carbohydrates. Analysis indicated highly significant differences ( $P < 0.001$ ) among the treatments. The *Maize-Aman-Carrot* cropping pattern (MAC) significantly increased the nutritional yield of carbohydrates (67 adult/ha/yr) compared to other diversified cropping patterns (Table 6 and Figure 2). Across the seasons,

maize and rice, as cereal-based crops in Kharif 1 and Kharif 2 respectively, produced the highest nutritional yield. According to Table 4, 100 g of maize and rice contain 64.7 g and 76.8 g of carbohydrates, respectively. In Kharif 1, maize yielded well, producing the maximum nutritional yield (42 adult/ha/yr) of carbohydrates. Additionally, the yield of BINA dhan 20 was lower than expected, resulting in a lower nutritional yield (17 adult/ha/yr) of carbohydrates compared to maize. Although maize is a highly nutritious crop, it is primarily used in Bangladesh for poultry, fish, and animal feed.

Another cropping pattern, *Groundnut-Aman-Potato* (GAP), produced the second-highest nutritional yield of carbohydrates compared to the GAN and GAC cropping patterns. However, there was no significant interactive effect of location and treatment across the year (Table 6).



**Above:** Potatoes harvested in Chargonai village; photo: Md. Arifur Rahaman

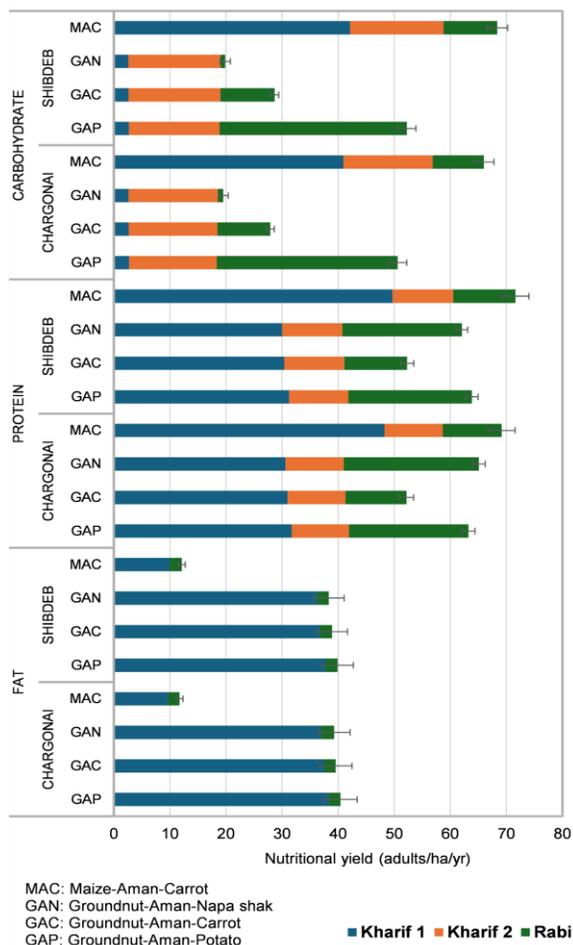
In the GAP cropping pattern, potatoes play a significant role in increasing the nutritional yield of carbohydrates (33 adult/ha/year) (Figure 2). According to Table 4, 100 g of potato contains 14 g of carbohydrates, which is not as high as cereals but still has a substantial effect on nutritional yield due to its large production compared to maize and rice, thereby contributing to the overall increase in the nutritional yield of carbohydrates.

In terms of protein, the MAC cropping pattern produced a significant nutritional yield (70 adult/ha/year) because maize is a good source of protein. Maize alone contributed a protein yield of 49 adult/ha/year, with the remainder of the nutritional yield coming from aman and carrot. Furthermore, a significant effect was observed when considering the interaction between location and treatment throughout the year (Table 6).

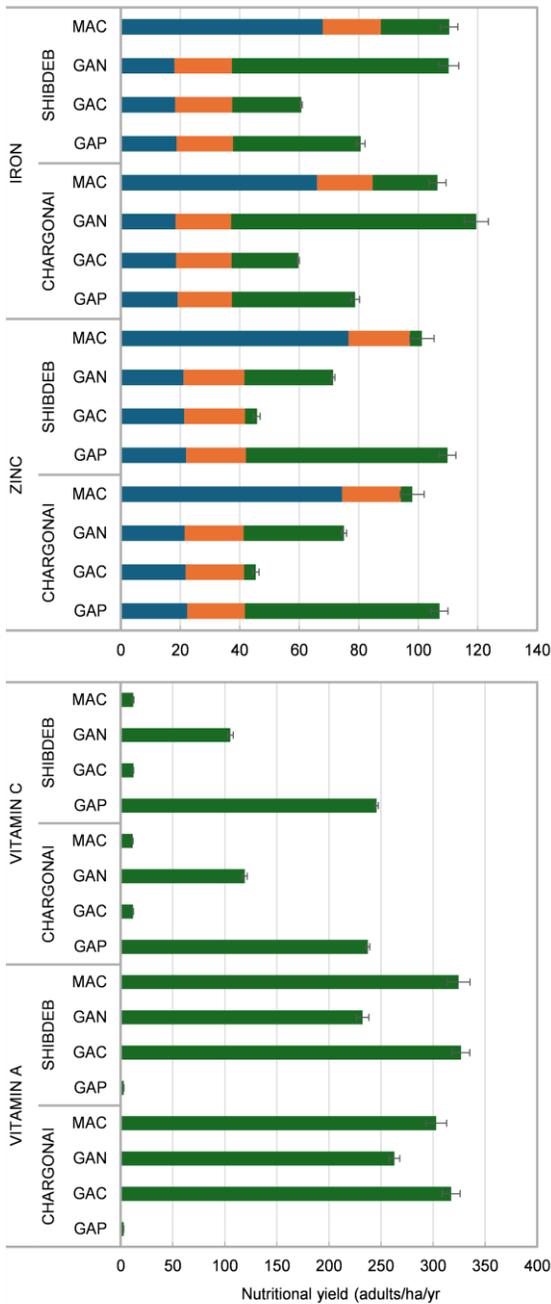
Regarding fat, the cropping patterns GAN, GAC, and GAP significantly increased the nutritional yield of fat compared to the MAC treatment. Groundnut, an oil-producing crop, contains 47 g of fat per 100 g sample (Table 4), contributing to the overall increase in nutritional yield. However, no significant differences were observed in fat yield between locations, nor was there a significant interaction effect with treatment throughout the year (Table 6).

Zinc is an important micronutrient essential for boosting our immune system and metabolic function. The study found that the cropping patterns MAC and GAP significantly improved the nutritional yield of zinc

compared to GAN and GAC. Additionally, a significant effect was observed when considering the interaction between location and treatment (Table 6).



**Figure 2:** Nutritional yield of two different locations assessed by cropping pattern for carbohydrates, proteins, fats



MAC: Maize-Aman-Carrot  
 GAN: Groundnut-Aman-Napa shak  
 GAC: Groundnut-Aman-Carrot  
 GAP: Groundnut-Aman-Potato

■ Kharif 1 ■ Kharif 2 ■ Rabi

**Figure 3:** Nutritional yield of two different locations assessed by cropping pattern for zinc, iron, vitamin A & C

Maize, groundnut, and biofortified rice are important sources of zinc. However, biofortified rice (3.3 t/ha) and groundnut (2.8 t/ha) do not have significant effects due to their lower yields compared to maize (10.1 t/ha) (Table 2). Although potato contains a smaller amount of zinc (Table 4), its effect was significant due to the high yield of potato (36 t/ha) during the rabi season (Table 2).

According to Table 6, the cropping patterns GAN and MAC significantly improved the nutritional yield of iron compared to other cropping patterns, as well as the interaction between location and treatment. Table 4 indicates that maize, biofortified rice, groundnut, and leafy vegetables like napa shak contain good amounts of iron. However, Figure 3 shows that only maize and napa shak had significant effects on increasing the nutritional yield of iron, while groundnut (2.8 t/ha) and biofortified rice (3.3 t/ha) did not have significant effects due to their lower yields.

The diversified cropping patterns GAN and GAP, which include crops like potato and napa shak, contributed to increased nutritional yields of vitamin C at both locations. Significant results were found both among the treatments and in the interaction with location (Table 6).

On the other hand, our diversified cropping patterns MAC, GAN, and GAC significantly increased the nutritional yield of vitamin A compared to GAP (Table 6). This is because the diversified rabi crops, such as carrot and napa shak, contain good amounts of vitamin A, which ultimately enhances the nutritional yield of this vitamin (Table 4 and Figure 3).

**Table 6:** Nutritional yield of carbohydrate, protein, fat, zinc, iron, vitamin C, and vitamin A in Rangpur district

Source	System nutritional yield (adults/ha/yr)						
	Carbohydrate	Protein	Fat	Zinc	Iron	Vitamin C	Vitamin A
<b>Village (V)</b>							
Chargonai	40.99 b	62.42	32.74	81.40	91.13	94.98	222.70
Shibdeb	42.30 a	62.46	32.31	82.07	90.49	93.84	221.60
<b>Treatment (T)</b>							
MAC	67.18 a	70.40 a	11.91 c	99.62 b	108.44 b	11.76 c	316.09 a
GAN	19.69 d	63.59 b	38.82 b	73.21 c	114.90 a	112.28 b	247.58 b
GAC	28.28 c	52.23 c	39.23 b	45.60 d	60.19 d	11.99 c	322.04 a
GAP	51.43 b	63.55 b	40.16 a	108.51 a	79.73 c	241.61 a	2.89 c
<b>V × T</b>							
Chargonai, MAC	65.98	69.18 a	11.71	97.98 b	106.46 b	11.46 e	307.79 a
Chargonai, GAN	19.51	65.09 b	39.3	75.04 c	119.54 a	119.19 c	262.82 b
Chargonai, GAC	27.88	52.18 d	39.55	45.39 e	59.70 d	11.81 e	317.35 a
Chargonai, GAP	50.60	63.24 bc	40.41	107.18 a	78.82 c	237.46 b	2.84 c
Shibdeb, MAC	68.38	71.63 a	12.10	101.26 b	110.41 b	12.08 e	324.39 a
Shibdeb, GAN	19.87	62.08 c	38.34	71.38 d	110.25 b	105.38 d	232.34 b
Shibdeb, GAC	28.67	52.28 d	38.91	45.80 e	60.68 d	12.16 e	326.74 a
Shibdeb, GAP	52.26	63.87 bc	39.89	109.83 a	80.64 c	245.75 a	2.94 c
<b>F-values</b>							
V	30.74***	ns	ns	ns	ns	ns	ns
T	4891***	354***	5933***	2733***	960***	10383***	853***
V × T	ns	8.09***	ns	8.37***	12.88***	18.60***	4.06*

**Note:** MAC-Maize-Aman-Carrot; GAN-Groundnut-Aman-Napa shak; GAC-Groundnut-Aman-Carrot; GAP-Groundnut-Aman-Potato; \*, \*\*, and \*\*\* indicates  $P < 0.05$ ,  $0.01$ , and  $0.001$ , respectively. Values in columns not separated by sources of variation sharing the same letter are significantly different according to Tukey's HSD test at  $P \leq 0.05$  and ns = not significant. Trials were placed in 20 farmers each at Chargonai and Shibdeb in Rangpur district. Standard error were calculated based on three seasons data.



**Above:** Napa shak harvested in Shibdeb village; photo: Alanuzzaman Kurishi

## CONCLUSIONS AND RECOMMENDATIONS

The findings in this research brief are based on a full cropping cycle that occurred over the course of a year. The results from this study indicate that the diversified cropping pattern MAC significantly increased the nutritional yields of carbohydrates and proteins, with maize being the main contributor to this enhancement. Additionally, while potato had a significant effect on the nutritional yield of carbohydrates, its average yield was 36 t/ha in the trial villages. However, the nutritional yield was not as high due to its lower carbohydrate content compared to maize. The oil-producing crop groundnut significantly increased the nutritional yield of fat in the cropping patterns GAN, GAC, and GAP. Furthermore, the cropping patterns MAC and GAP significantly improved the nutritional yield of zinc, with maize and potato serving as key factors in this increase.

Moreover, the MAC and GAN cropping patterns enhanced the nutritional yield of iron, particularly through the contributions of maize and napa shak. The cropping patterns GAN and GAP also increased the nutritional yield of vitamin C, especially with the inclusion of potato and napa shak. The nutritional yields of vitamin A were increased by the cropping patterns MAC, GAN, and GAC, as both carrot and napa shak are rich in vitamin A and significantly contributed to its nutritional yield.

Despite these positive outcomes, the study highlights the challenge of selecting a single cropping pattern to optimize specific nutrients, as different cropping patterns impact different

nutrients. For example, while BINA dhan 20 is rich in zinc and iron, its impact is limited by low yield and farmers' reluctance to adopt it. To promote its growth, initiatives should raise awareness of its health benefits, especially for women and children, through government programs, NGOs, and local media. Encouraging large-scale cultivation can help reduce pest damage, as this variety is shorter than local types. Collaboration with rice millers can ensure stable markets and premium prices, while training on sustainable pest management can help farmers reduce losses and boost profits.

Several challenges in groundnut production, including low prices, lack of quality seeds, and traditional market systems, need to be addressed. To resolve this, it is essential to establish a marketing channel that ensures both types of groundnut growers have access to quality seeds and receive fair prices. Regarding carrots, a strong market channel needs to be established, as traders prefer to buy bulk amounts of carrots with good color and shape. These challenges need to be overcome for the successful growth of biofortified rice, carrots, and groundnuts.

Diversified crops such as maize, biofortified rice, carrot, napa shak, and potato have increased the availability of micronutrients. However, it's too early to draw definitive conclusions at this point. We currently have data from only one full cropping cycle, which is not enough. It is important to consider that a more comprehensive analysis over multiple years, including the environmental impact, is necessary to validate these results.

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## ABOUT TAFSSA

TAFSSA is One 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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*Note: Generative A.I. was used to improve the grammar of this document.*