Microgreens and their potential health benefits: an on-farm trial for nutritional security among pregnant women

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ABSTRACT

Seasonal bottlenecks during the monsoon kharif season severely restrict fresh leafy vegetable availability in smallholder agrarian environments, exposing pregnant women to acute micronutrient vulnerabilities while commercially sourced alternatives pose risks of pesticide residue contamination. This study evaluated household-level microgreen production as an actionable, chemical-free functional food intervention to improve nutrient intake and haematological status among expectant farm women (n = 30) across the 2020-2022 kharif seasons in Gujarat. Participants were monitored across three dietary protocols: farmers' existing practice (T_1: Baseline diet with stored foods), recommended practice I (T_2: 50 g daily plain microgreens) and recommended practice II (T_3: 50 g daily microgreen salad with tomato and onion). While traditional practice (T_1) provided higher caloric density (86.0 kcal) but proved severely deficient in key micronutrients (1.8 mg iron, 2.5 mg calcium daily), integration of microgreens (T_2) substantially elevated daily iron and calcium intakes to 26.0 mg and 10.0 mg respectively. The microgreen salad (T_3) optimized these returns further, yielding 29.0 mg iron and 10.2 mg calcium daily. Consequently, mean haemoglobin levels rose significantly from a pre-test baseline of 10.52 g per dL to 11.21 g per dL post-test, reflecting a net increase of 0.69 g per dL. Overall, household microgreen cultivation offers a rapid, space-efficient and low-cost strategy to bridge seasonal dietary gaps, significantly improving maternal iron status and safeguarding rural household food security.

Keywords: Microgreens; Maternal nutrition; Kharif season; Haemoglobin; Functional foods; Dietary diversity; Household food security

INTRODUCTION

Proper maternal nutrition before and during pregnancy promotes optimal fetal growth and long-term health for both mother and child. Poor nutrition directly causes abnormal growth patterns, including low birth weight and excessive growth, which significantly raise lifelong chronic disease risks (Marshall et al 2022). Although a mother's overall diet is of importance, vegetables are particularly critical. Vegetables are a highly valuable food group that provides essential nutrients for overall health. They are rich in vitamins, dietary fiber and minerals, serving as a natural source of well-absorbed vitamins as well as polyphenols (Moskwa et al 2023).

The consistent intake of fresh vegetables serves as a principal conduit for essential micronutrients, dietary fiber and dynamic bioactive compounds necessary to satisfy the increased metabolic demands of pregnancy. Furthermore, vegetable intake established during the first year of life is associated with the development of healthy eating habits later in life. Unfortunately, most adults and children fall short of the recommendations (Tovar et al 2019). However, in smallholder agrarian environments, the monsoon kharif season presents severe structural bottlenecks to dietary diversity. Heavy rainfall patterns routinely disrupt local open-field agricultural production, creating a profound seasonal scarcity of fresh leafy greens. Heavy rainfall, high humidity and heat stress make kharif vegetable

growing genuinely more demanding: waterlogging, fungal disease and insect pressure are all higher than in winter (Jallaraph et al 2026). Concurrently, an expanding dependency on commercially sourced vegetables introduces substantial community concerns regarding systemic pesticide residues and chemical contamination. Vegetables can become a cause of health hazards when contaminated with different chemicals such as pesticides. Farmers use pesticides to protect vegetables from insects, pests and disease attacks; if farmers do not maintain the withdrawal period, the pesticide residue will remain in the vegetables and cause harm to consumers (Khatun et al 2023).

Microgreens, defined as young, edible vegetable seedlings harvested immediately after the emergence of the first true leaves, offer an elegant, decentralized solution to these structural barriers (Xiao et al 2012, Kyriacou et al 2016).

Grown from various vegetable, herb and grain seeds, microgreens can be grown year-round in small spaces, such as balconies or windows (Arya et al 2023). With high market value and minimal resource demands, microgreens present an economically viable enterprise for urban and rural communities (Ghoora and Srividya 2018, Ebert 2022).

Crucially, microgreens possess highly concentrated profiles of essential vitamins, minerals and antioxidant secondary metabolites compared to their mature counterparts (Yadav et al 2019, Xiao et al 2012). Due to its attributable presence of various health-promoting phytonutrients, such as antioxidants, vitamins, minerals, phenolic compounds and much more health-promoting compounds, they are considered the next generation of 'superfoods' or 'functional foods' (Bhaswant et al 2023).

This study evaluates an on-farm trial assessing household-level microgreen production as an active functional food strategy to counter rainy-season nutritional vulnerabilities among pregnant farm women.

METHODOLOGY

The actionable technology assessment was executed during the kharif seasons of 2020-2022 under monitored irrigation conditions. The experimental design comprised 30 distinct trials involving 30 pregnant farm women, structured around the thematic oversight of household nutritional security. The technological template was sourced from Navsari Agricultural University, Navsari, Gujarat to directly target the seasonal unavailability of fresh, pesticide-free leafy vegetables.

The trial framework monitored participants across three distinct dietary protocols to measure comparative efficacy:

Farmers' existing practice: Participants followed their typical dietary pattern. During seasonal shortages, fresh green leafy vegetables were unavailable and the diet consisted mainly of stored foods, such as Badi (sun-dried legume nuggets), pulses and tubers (potatoes), with an average daily leafy vegetable intake of approximately 25 g.

Recommended practice I (plain microgreens): Participants consumed 50 g of freshly harvested plain microgreens daily, grown at the household level under monitored, chemical-free conditions. The microgreens were consumed plain to evaluate their standalone nutritional contribution.

Recommended practice II (microgreen salad): Participants consumed 50 g of freshly prepared microgreen salad daily, combining household-grown microgreens with raw tomato and onion. This formulation enhanced taste and acceptability, offering a palatable method for daily integration.

The transferred microgreen production methodology features low-input, adaptable operational attributes engineered to lower adoption friction in resource-constrained rural environments (Galieni et al 2022).

Important features and benefits of microgreens

Short growing period: Microgreens grow very quickly and are generally ready for harvesting and consumption within 10-15 days after sowing. This short growing period allows families to produce fresh vegetables in a short time.

Easy to grow in different media: Microgreens can be grown successfully in ordinary organic soil as well as simple soil-less growing media. They do not require complicated cultivation practices or special facilities.

Requires very little space: Microgreens require only a small area for cultivation. They can easily be grown in kitchens, balconies, terraces, window spaces or other small household areas. Different containers can also be arranged vertically to make better use of available space.

Safe and chemical-free production: Microgreens can be produced at the household level using organic and chemical-free methods. This reduces the possibility of pesticide exposure and provides families with fresh and safer food.

High nutritional value: Microgreens are rich in vitamins, minerals, antioxidants and other beneficial plant compounds. Although they are consumed in small quantities, they can contribute important nutrients to the daily diet.

Easy to include in the daily diet: Microgreens can be consumed fresh and raw without lengthy cooking. They can easily be added to salads, sandwiches, vegetables, dal or traditional meals, making them a convenient way to increase the intake of fresh vegetables.

RESULTS and DISCUSSION

Nutrient intake dynamics

Dietary recording revealed substantial variations in nutritional profiles between traditional habits and the microgreen interventions. Nutritional composition data were compiled from published sources including Anon (2018), Anon (2020) and peer-reviewed studies (Xiao et al 2012, Bhardwaj and Jain 2017).

Existing practice (T_1) yielded the highest baseline energy and protein metrics, delivering 86.0 kcal and 6.2 g respectively, due to the caloric density of stored tubers and grain legumes (Table 1). However, T_1 was profoundly deficient in vital developmental micronutrients, providing a mere 1.8 mg of iron and 2.5 mg of calcium daily. The plain microgreens (T_2) radically corrected this trace mineral imbalance, increasing daily iron intake to 26.0 mg and calcium values to 10.0 mg. This behaviour aligns extensively with broad peer-reviewed literature showing that micro-scale vegetable growth stages contain significantly higher mineral density allocations compared to their fully mature vegetative counterparts (Yadav et al 2019, Xiao et al 2012). The multi-vegetable microgreen salad configuration (T_3) achieved the most robust nutritional tracking across the trial. Total iron levels peaked at 29.0 mg, while calcium values reached 10.2 mg. This outperformance points to a clear nutritional synergy: combining microgreens with standard fresh culinary vegetables like tomatoes and onions, improves overall micronutrient value and expands the range of dietary absorption co-factors (Kyriacou et al 2016).

Data presented in Table 2 reveal that the maximum proportion of respondents (46.67%) belonged to the young age group of 15-24 years, closely followed by 43.33 per cent in the 25-34 years age bracket, while only 10.00 per cent were aged between 35 and 49 years. With respect to family structure, a two-thirds majority (66.67%) resided in joint families, whereas 33.33 per cent lived in nuclear family setups. Regarding educational attainment, the highest proportion of women had completed high school (36.67%), followed by middle school (33.33%) and higher secondary school (30.00%). In terms of dietary preferences, two-thirds of the respondents (66.67%) followed a vegetarian diet, while the remaining 33.33 per cent were non-vegetarian. Overall, the study population predominantly comprised young pregnant women living in joint families with school-level education and vegetarian dietary habits.

Anthropometric performance and growth tracking

Data presented in Table 3 illustrate the haemoglobin status of pregnant women evaluated prior to and following the intervention. During the pre-test assessment, haemoglobin levels ranged from 10.0 to 10.9 g per dL, with a mean concentration of 10.52 g per dL. Following the intervention, post-test values increased to a range of 10.6 to 11.7 g per dL, with a mean of 11.21 g per dL. Overall, the intervention yielded a mean increment of 0.69 g per dL in haemoglobin levels, indicating a substantial positive response in the haematological status of the participants.

Comparative assessment matrix

The functional, operational and nutritional properties separating traditional agricultural constraints from the recommended microgreen methodologies are organized in Table 4.

Adoption dynamics and qualitative feedback

Qualitative evaluations collected from participating farm women were positive. They emphasized the low effort demands and high space efficiency of the home setup. Crucially, participants

Table 1. Recorded nutrient intake profiles under assessed treatments

Treatment group	Energy (kcal)	Protein (g)	Iron (mg)	Calcium (mg)
Existing practice (T_1)	86.0	6.2	1.8	2.5
Plain microgreens (T_2)	14.5	3.0	26.0	10.0
Microgreen salad (T_3)	18.7	3.6	29.0	10.2

Table 2. Socio-economic and demographic profile of the respondents

Component	Category	Respondents (n = 30)	
		Frequency	Percentage
Age (years)	15-24	14	46.67
	25-34	13	43.33
	35-49	3	10.00
Type of family	Nuclear	10	33.33
	Joint	20	66.67
Educational status	Middle school	10	33.33
	High school	11	36.67
	Higher secondary school	9	30.00
Dietary habit	Vegetarian	20	66.67
	Non-vegetarian	10	33.33

Table 3. Haemoglobin level of pregnant women (n = 30) during pre-test and post-test

Test	Haemoglobin content (g/dL)		
	Minimum	Maximum	Mean
Pre-test	10.0	10.9	10.52
Post-test	10.6	11.7	11.21

Table 4. Comparative matrix and recommended practices

Parameter	Existing practice (T_1)	Plain microgreens (T_2)	Microgreen salad (T_3)
Fresh leafy greens	Absent in rainy season	Available continuously	Available continuously
Microgreens integrated	No	Yes	Yes
Tomato/onion/lemon/cucumber co-factors	No	No	Yes
Production timeline (days)	-	10-15	10-15
Domestic setup difficulty	Limited availability	Easy/ Low effort	Easy/low effort
Dietary Diversity Level	Lower baseline	Improved scope	Optimized profile
Recorded iron value (mg)	1.8	26.0	29.0
Recorded calcium value (mg)	2.5	10.0	10.2
Overall suitability status	Inadequate baseline	Recommended	Highly optimal setup

noted using their domestic microgreen cycles as a reliable guide for tracking daily vitamin intake. Beyond the initial research cohort, this microgreen setup proved highly resilient during the COVID-19 pandemic. When sudden supply chain disruptions and market lockdowns choked off access to standard logistics, the technology was rapidly adopted at the district level. This widespread expansion highlights its utility as a reliable self-sufficiency strategy during sudden regional food system shocks.

Based on the study findings, specific action frameworks and dissemination strategies are recommended to facilitate the seamless adoption of microgreen cultivation at the household level.

Action frameworks for rural households: For rural households, adopting the regular and staggered cultivation of microgreens provides an effective mechanism to ensure an uninterrupted supply of fresh, pesticide-free vegetables during lean agricultural periods and seasonal shortages. To enhance culinary diversity and daily nutrient density, microgreens can be readily incorporated into raw preparations alongside locally available produce such as tomatoes and onions. However, because microgreens are predominantly consumed raw, produce can become contaminated at any point along the farm to fork continuum. Common control points for growers include irrigation water, soil amendments such as manure or compost, livestock and wild animal fecal contamination, worker health and hygiene, field and harvest sanitation, sanitation of packing facilities, post-harvest water and handling, value-added processing, storage, transportation and distribution (Olaimat and Holley 2012, Suslow 2003).

Dissemination strategies for extension personnel: To maximize community-level impact, agricultural extension agencies and rural healthcare networks should coordinate targeted outreach initiatives, such as structured nutritional awareness campaigns and live culinary demonstrations, specifically tailored for expectant mothers. Furthermore, extension personnel ought to conduct practical capacity-building workshops that train rural women in constructing low-cost, hygienic domestic microgreen units using locally available materials. To institutionalize these efforts, farm extension centers should serve as reliable input channels by regularly supplying rural households with certified, disease-free seed kits, thus reinforcing long-term household dietary diversity and nutritional security.

CONCLUSION

Seasonal shortages during the monsoon kharif period create clear dietary vulnerabilities for pregnant women in rural communities. This study demonstrates that household microgreen cultivation serves as an effective, accessible strategy to bridge this seasonal gap. By providing a clean, nutrient-dense source of fresh greens within 10 to 15 days, microgreens significantly boosted daily intake of key minerals like iron and calcium, contributing to a mean haemoglobin increase of 0.69 g per dL among participants. Beyond its direct nutritional gains, microgreen farming requires minimal space, avoids synthetic pesticides and remains resilient against broader supply chain disruptions. Integrating low-cost microgreen protocols into rural extension and maternal health programmes offers a scalable, community-led pathway toward year-round dietary security and improved maternal-fetal wellness.

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