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Finger millet: A sustainable breakthrough for rice-based cropping systems in the calcareous soils of Bihar

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Rice is an important crop in Bihar which support about 65% of population for foodgrain production to feed the growing population. The major disadvantage of this cultivation is high water use, increased use of fertilisers and pesticides, greenhouse gas emission, and deteriorating soil health which cause low resource use efficiency. Finger millet-based cropping system is a good alternative to address these issues which requires low input, resilience to pest and more income as compare to rice–wheat cropping system and mitigate the problems in future. Early short duration varieties not only increase production but also sustain the soil health in calcareous soil of Bihar.

Keywords: Millet production, Resource use efficiency, Short duration varieties, Soil health

IN India, the most critical challenges for sustainable development currently revolve around the diminishing availability of land and water resources, and the ever-increasing population. Effectively addressing the pressing need to nourish the continuously growing population within the constraints of limited resources stands as the foremost challenge for farmers, scientists, and policymakers. Rice-based cropping system (RCS) is the predominant cropping system in Indo Gangetic Plains (IGP) area of about 13.5 million hactares (mha). Nearly about 3.22–3.30 mha area is covered under rice cultivation in Bihar (Directorate of Economics and Statistics, Bihar, 2025). The RCS cultivation demands substantial quantities of energy, water, and nutrients, resulting in increased cost of production and greenhouse gas emissions. Additionally, growing apprehensions about yield stagnation or decline, coupled with expanding environmental impacts, have sparked significant debates regarding the sustainability of the RCS system in South Asia, especially in the north-western IGP. Calcareous soils are characterised by pH 8.0–8.5, low organic matter content, deficiency in cationic micronutrients (Fe, Cu, Mn and Zn), with calcium carbonate ($CaCO_3$) concentration more than 15% having calcic horizon, and fixation of nutrients like phosphorus, potassium, iron and zinc that reduces its availability to plants. Finger millet, also known as ragi, has significant nutritional, economic and ecological benefits. Finger millet and maize are viable alternatives to rice-based cropping system of calcareous soil of Bihar. Relative low water requirement, potential productivity and assured high returns makes finger millet cropping system (FCS) more reliable for improvement of livelihood of farmers. Finger millet can also help in utilising the uncultivated and barren land in *kharif* season.

Sustainability issues related to rice-based cropping system

The standing water prevalent in paddy cultivation contributes to greenhouse gas emissions, particularly methane from anaerobic microbial processes (methanogenesis) by methanogenic bacteria during the decomposition of organic matter in waterlogged soils. The RCS districts of Bihar are Rohtas, Aurangabad, Kaimur, Bhojpur, Buxar, Purnea, Khagaria, Saharsa, parts of Siwan, West Champaran, Samastipur and Muzaffarpur. The continuous cultivation of rice in a monoculture format can lead to problems such as degradation of soil health, increased vulnerability to pests, and a higher demand for water resources, i.e. approximately 1,500 mm of water by rice crop, disturbing weed flora and development of herbicidal resistance in crops.

***Water loss*:** Approximately 30% of irrigation water in the RCS loss through deep drainage in Bihar which causes significant loss, especially in soils with coarse textures. Water required to produce 1 kg of rice ranges from 800–5,000 L,



Finger millet crop

with an average of 2,500 L.

***Environmental pollution*:** The residues produced takes long time to decompose which also interfere in the cultivation of succeeding crop. Large quantities of residues can lead to their burning which can raise serious environmental complications.

***Greenhouse gas emissions*:** Greenhouse gases emission viz. CH_4 and N_2O in rice ecosystems generated because of decomposition of organic matter and redox potential in soils of wetland is significantly much higher than in FCS.

***Destruction of soil structure*:** Repeated wet tillage in standing water results in elimination of macro pores, crush soil clods, disperse fine clay particles, helpful for the formation of hardpan with higher soil bulk density and reduce puddled layer strength that affects root proliferation of succeeding wheat crop.

Table 1. Recommended varieties of finger millet suitable for Bihar

Variety	Duration (days)	Specifications
Rajendra Madua - 1	118	Yield: 38 q/ha, Resistant to blast, downy mildew.
RAU - 8	115	Yield: 20–25 q/ha, Excellent moisture stress and drought tolerance
BR – 407	105	Yield: 25 q/ha, Salinity tolerant
OEB 532	110	Yield: 22 q/ha, Semi-dwarf and tolerance to lodging
GPU-28	115	Yield: 40–45 q/ha under irrigated condition, highly responsive to organic and chemical fertilisers
BR-407	115	Yield: 20–25 q/ha
Birsa Marua-2	100	Yield: 25–28 q/ha, Tolerant to low-fertility soils
GPU-45	95	Yield: 25–30 q/ha, Early maturing, escapes drought
GPU-67	120	Yield: 30–35 q/ha, Strong disease resistance profile

Advantages of finger millet-based cropping system

***Low input costs*:** Finger millet has significantly less investment in fertilisers, pesticides, and irrigation. According to research in India's Bastar district, cultivation costs of ₹33,336.02/ha was observed which is significantly lower than major cereals like rice and wheat. The cost of cultivation of seed represents only 1.73%.

***Resilience to adverse conditions*:** Finger millet's drought tolerance and adaptability lowers the risk of crop failure, providing farmers with more consistent and reliable yields. It is invaluable for arid and semi-arid regions due to outstanding drought, heat and temperature tolerance capacity.

***Less greenhouse gases emission*:** Finger millet can reduce the potential GHG emission as compared to rice because cultivation of paddy contributes significant methane emission which pollute the atmosphere.

***Higher water use efficiency*:** Millet requires less water than rice and produces a higher yield per unit of water. The water use efficiency for finger millet is 13.4 kg/ha-mm, compared to 3.70 kg/ ha-mm for rice.

***Resistance to pests*:** Researchers indicated that tannin and phenolic compounds present in finger millet grain increases the resistance to fungal attack. It also acts as a physical barrier to the fungal invasion. The fungal and bacterial growth can be prevented by the seed coat.

***Eco-friendly farming*:** Growing finger millet supports sustainable farming by lowering expenses linked to low resources utilisation. It is climate resilient, reduces carbon footprint, enchances soil health and biodiversity.

***Prevention of erosion*:** It has thick, fibrous roots which help anchor the soil in minimising erosion on hillsides and sloppy land. Finger millet improves soil health with its shallow and strong root system, preventing erosion and improving soil structure.



Inflorescence of finger millet

SUMMARY

Finger millet emerges as a sustainable alternative to rice-based cropping system in calcareous soil of Bihar. Its lower water requirements boost water use efficiency, especially in water scarce areas. Finger millet has the ability to extract nutrients from insoluble sources in calcareous soil. So, cultivation of finger millet not only enhances overall soil health but also breaks the pest cycle. This addresses sustainability concerns like maintaining groundwater loss and environmental pollution. Besides environmental advantages, it brings benefits to farmers, including increased income, lower input needs and enhanced resource use efficiency, offering a holistic solution for farmers of Bihar.

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