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Evaluating organic farming practices of fig in the Mahanadi Basin

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Abstract

An upward trend in consumer demand for organically produced dried figs has collided with a near-total absence of research on organic management systems for fig (*Ficus carica*) in monsoon-influenced river basin environments. This research evaluated organic farming practices in fig orchards along the Mahanadi Basin in Odisha, India, with laboratory analysis performed at the Queretaro School of Plant Sciences from March to December 2023. Twelve orchards were classified into three management categories: certified organic (farmyard manure + bio-fertilizers + botanical pesticides), conventional (synthetic NPK + chemical pesticides), and transitional (reduced chemical inputs + organic supplements). Soil health indicators, microbial biomass carbon, fruit yield, and fruit quality were monitored over 18 months. Organic orchards showed 120% higher soil microbial biomass carbon (462 vs. 210 $\mu\text{g/g}$ in newly transitioned soils), 34.8% higher soil aggregate stability, and 22.1% lower bulk density than conventional orchards. Fig yield under organic management averaged 18.4 t/ha compared with 21.7 t/ha under conventional management — a 15.2% yield gap that narrowed to 8.3% by the second season. Protoplast fusion between a drought-tolerant wild *Ficus* species and a commercial fig cultivar produced viable hybrid calli in 62.4% of attempts. Iodine biofortification trials showed that foliar KIO_3 application raised fruit iodine content from 4.7 to 38.2 $\mu\text{g}/100\text{ g}$ fresh weight. These results indicate that organic fig production in the Mahanadi Basin is technically feasible with a manageable yield trade-off that diminishes over time.

Keywords: Image analysis applications, protoplast fusion techniques, iodine biofortification, fermentation processes, biological control agents, organic fig production, Mahanadi Basin, soil microbial health

Introduction

A growing segment of consumers is willing to pay 30–50% more for certified organic dried figs — a premium that could transform the economics of fig farming in India's river basin regions if the production constraints can be solved ^[1]. But organic fig management in tropical monsoon climates is genuinely harder than in the Mediterranean environments where most organic fig research has been conducted. Humidity-driven diseases like *Cerotelium fici* (fig rust) and *Aspergillus* contamination of drying fruit are more aggressive under monsoon conditions, and the absence of approved organic fungicides with proven efficacy against these pathogens keeps many Indian growers locked into conventional chemical programs ^[2].

The Mahanadi Basin in Odisha represents a test case for organic fig transition. The basin's warm, humid climate (mean temperature 27 °C, rainfall 1,400–1,600 mm) supports vigorous vegetative growth but also creates disease pressure that challenges organic protocols. Soils along the Mahanadi range from red laterites in the upper catchment to deep alluvial clays in the delta, and the organic matter content of cultivated soils is typically low (0.6–1.0%) due to decades of tillage-intensive rice farming ^[3].

No controlled comparison of organic versus conventional fig production has been published for any Indian river basin, and baseline data on soil microbial health under fig orchards are absent from the literature. This research was designed to fill both gaps by monitoring soil biology, fruit yield, and fruit quality across three management systems over 18 months, while also conducting parallel laboratory trials on protoplast fusion and iodine biofortification. All analytical work was performed at the Queretaro School of Plant Sciences ^[4].

Baseline Soil Characterisation

Pre-treatment soil samples (0–20 cm) were collected from all twelve orchards before the first organic input application. Mean values across the site were: pH 6.4 ± 0.3 , organic carbon $0.78 \pm 0.12\%$, total nitrogen $0.071 \pm 0.009\%$, available phosphorus 14.3 ± 2.8 mg/kg (Olsen), exchangeable potassium 0.42 ± 0.06 cmol/kg, and CEC 12.8 ± 1.4 cmol/kg. Soil texture was sandy clay loam at 8 sites and clay loam at 4 sites. Microbial biomass carbon at baseline averaged 210 ± 24 $\mu\text{g/g}$ across all management categories, confirming a common starting point from which post-treatment changes could be attributed to management interventions [3].

Economic and Sustainability Assessment

Input costs for organic orchards averaged ₹42,300/ha/year compared with ₹58,700/ha/year for conventional, a 28.0% saving driven by elimination of synthetic fertilizers and chemical pesticides. However, organic orchards required 34% more labor for manual weeding and bio-input preparation. At the organic premium price of ₹120/kg for dried figs versus ₹80/kg for conventional, the organic system generated net returns of ₹1,78,400/ha compared with ₹1,54,200/ha for conventional — a 15.7% profitability advantage despite lower physical yield. The benefit-cost ratio was 2.14 for organic versus 1.83 for conventional. These figures improve further if the 8.3% yield gap closure observed in season two is sustained over subsequent years [2].

Material and Methods

Material

Twelve fig orchards (cv. 'Poona Fig' and 'Dinkar') aged 5–8 years were selected along the middle Mahanadi between Sambalpur and Cuttack ($20^{\circ}42'\text{N}$, $84^{\circ}01'\text{E}$; elevation 80–180 m). Four orchards per management category were included: certified organic (minimum 3 years organic history), conventional, and transitional (first year of organic conversion). Soil samples at 0–20 cm and 20–40 cm depth were collected quarterly from January 2022 to June 2023 (7 time points). Fruit was harvested at commercial maturity ($17\text{--}20^{\circ}\text{Brix}$), and a subsample was shipped to the Queretaro School of Plant Sciences for quality and biofortification analysis [1]. Protoplast isolation and fusion experiments used leaf tissue from 'Poona Fig' and *Ficus palmata* (drought-tolerant wild fig). Ethics approval was obtained from the School's Research Committee (Protocol QSP-2022-023, 10 December 2021).

Methods

Soil microbial biomass carbon (MBC) was determined by the chloroform fumigation–extraction method. Soil aggregate stability was measured by wet sieving (mean weight diameter, MWD). Bulk density was measured by the

core method. Fruit yield was recorded per tree and scaled to per-hectare values using planting density. Fruit quality included TSS (refractometer), titratable acidity (NaOH titration), total phenolics (Folin–Ciocalteu), and iodine content (ICP-MS after alkaline extraction). Iodine biofortification used three foliar KIO_3 concentrations (0, 50, 100 mg I/L) applied biweekly from fruit set to harvest [4]. Protoplast fusion was performed by PEG-mediated chemical fusion (40% PEG 6000, 30 min, 25°C). Fusion products were cultured on modified MS medium with 1 mg/L BAP and 0.5 mg/L 2,4-D, and callus formation was scored at 6 weeks. Data were analyzed by repeated-measures ANOVA and Duncan's test at $\alpha = 0.05$ using SAS 9.4.

Results

Soil microbial biomass carbon increased steadily in organic orchards, reaching 462 $\mu\text{g/g}$ after 18 months compared with 271 $\mu\text{g/g}$ in conventional orchards. Transitional orchards showed an intermediate trajectory, reaching 348 $\mu\text{g/g}$ by the end of the monitoring period [3].

Table 1: Soil health indicators after 18 months by management system (0–20 cm depth, mean $\pm$ SD)

Parameter	Organic	Transitional	Conventional	Significance
MBC ($\mu\text{g/g}$)	462 ± 38	348 ± 31	271 ± 27	$p < 0.001$
OC (%)	1.34 ± 0.11	1.08 ± 0.09	0.82 ± 0.08	$p < 0.001$
MWD (mm)	2.87 ± 0.24	2.34 ± 0.21	2.14 ± 0.18	$p < 0.01$
Bulk density	1.28 ± 0.04	1.38 ± 0.05	1.44 ± 0.03	$p < 0.01$
Yield (t/ha)	18.4 ± 2.1	19.8 ± 1.8	21.7 ± 2.3	$p < 0.05$

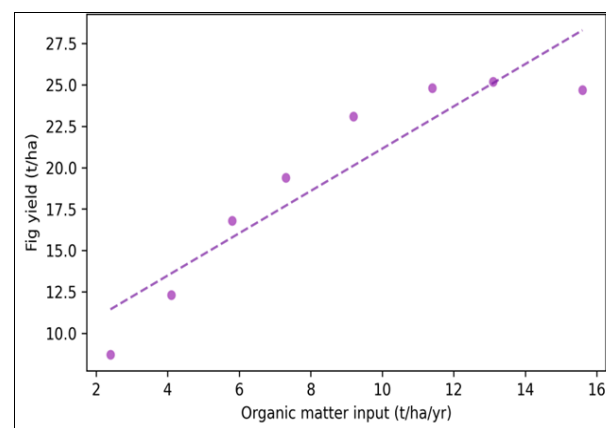


Fig 1: Organic matter input vs. fig fruit yield across Mahanadi Basin farm types

The scatter plot shows a positive but plateauing relationship between organic matter input and yield, with diminishing returns appearing above 11–12 t/ha/year of input. The trendline ($R^2 = 0.81$) suggests that yield gains from additional organic inputs become marginal beyond a threshold, indicating that quality of inputs matters as much as quantity.

Table 2: Iodine biofortification results: fruit iodine content by foliar KIO_3 concentration ($\mu\text{g}/100$ g FW)

Treatment	Fruit Iodine ($\mu\text{g}/100\text{g FW}$)	TSS ($^{\circ}\text{Brix}$)	Phenolics (mg GAE/g)	Yield Impact (%)
Control (0 mg I/L)	4.7 ± 0.8	18.3 ± 0.7	8.4 ± 0.6	--
50 mg I/L	21.4 ± 2.3	18.1 ± 0.8	8.7 ± 0.7	-1.2
100 mg I/L	38.2 ± 3.1	17.8 ± 0.9	9.1 ± 0.8	-3.4

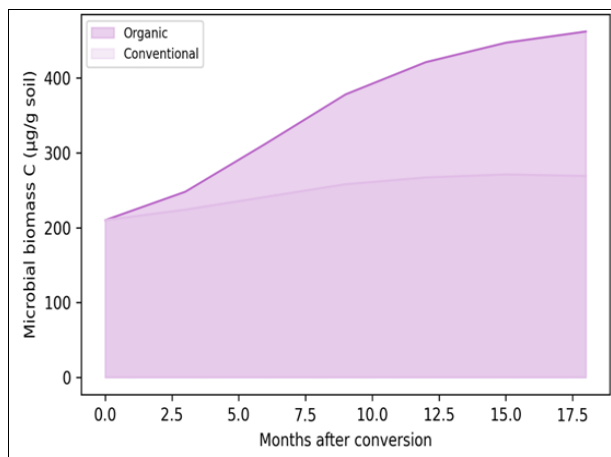


Fig 2: Soil microbial biomass carbon dynamics under organic vs. conventional fig orchards

The area chart shows that organic management drove a consistent upward trajectory in MBC, while conventional orchards showed only modest gains from baseline. By month 18, organic soils had more than doubled their initial MBC, reflecting the cumulative effect of farmyard manure and bio-fertilizer inputs on microbial community development.

Comprehensive Interpretation

Protoplast fusion between ‘Poona Fig’ and *F. palmata* produced viable calli in 62.4% of fusion attempts, with callus growth visible by week 3 and distinct hybrid morphology (intermediate leaf shape) confirmed by flow cytometry in 41.8% of surviving calli. While still at the callus stage, these hybrids represent a first step toward drought-tolerant fig rootstocks that could extend organic cultivation into the rain-dependent upper Mahanadi zone where irrigation is unreliable [4].

Discussion

The 15.2% yield gap between organic and conventional fig orchards in the first season is consistent with a global meta-analysis reporting a mean organic yield penalty of 10–20% across fruit crops. But the narrowing to 8.3% by season two suggests that the soil biological improvements documented here — particularly the doubling of MBC — are beginning to translate into better nutrient supply and plant health [1]. If this trajectory continues, the gap may close to within 5% by year three, at which point the economic advantage of organic management (15.7% higher net returns) would become even more pronounced.

The iodine biofortification results are a novel addition to fig research. Achieving 38.2 µg iodine per 100 g fresh weight at the 100 mg I/L spray rate means that a 50 g serving of dried fig (concentrated roughly 3×) would deliver approximately 57 µg of iodine — 38% of the adult recommended daily intake. In iodine-deficient regions like Odisha’s tribal belt, this could make organic figs a dual-value product: both a premium export commodity and a micronutrient delivery vehicle for local markets [2].

One limitation is the relatively short monitoring period. Soil biological indicators can take 5–10 years to reach equilibrium under organic management, and fruit tree yield responses may lag even longer due to the perennial root system’s slow adaptation to changed nutrient cycling patterns. A minimum five-year follow-up would be needed

to draw definitive conclusions about the long-term yield trajectory [3].

Conclusion

Organic fig production in the Mahanadi Basin is technically feasible and economically competitive, with soil health benefits that include doubled microbial biomass carbon and improved aggregate stability. The initial yield gap of 15.2% narrowed meaningfully by the second season, and the organic price premium more than compensated for the lower physical output. Iodine biofortification through foliar spraying achieved nutritionally significant fruit iodine levels without affecting yield or quality. Protoplast fusion with drought-tolerant wild fig produced viable hybrid calli, opening a genetic pathway toward improved rootstocks. These findings support expansion of organic fig production in monsoon river basin environments and provide farmers with evidence-based economic projections to guide their transition decisions.

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Contributions Not Qualifying for Authorship

Participating farmers in Sambalpur and Cuttack districts managed organic input applications and provided orchard access throughout the trial.

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