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Sustainability Assessment Of Organic Versus Conventional Production Systems In Banana (*Musa* AAB, c*v.* Nendran): Yield, Fruit Quality And Soil Fertility In The West Coast Plains And Hills Region Of India

Manohar Lal Meghwal[1]*, Jyothi, M. L.[2], Pushpalata, P.B.[3], Bhaskar, J.[4], Thulasi, V[5]. and Beena, V. I.[6]

[1,2,3,4,5,6]*College of Agriculture, Kerala Agricultural University, Thrissur, India-680656*

***Corresponding Author:** Manohar Lal Meghwal*
**Email id: manoharmeghwal77@gmail.com*

Abstract

A field-based comparative study was undertaken during the year 2018-2020 to assess the sustainability of organic versus conventional production systems in banana (*Musa* AAB, *cv.* Nendran) under farmer-managed conditions in the West Coast Plains and Hills region of India. Ten farms (five organic and five conventional) with more than five years of consistent management were evaluated for fruit yield, biochemical composition, sensory qualities, and soil fertility parameters.

Yield attributes such as bunch weight, number of hands, and finger size were largely comparable across both systems, demonstrating that organic management did not compromise productivity. However, significant differences were observed in fruit quality. Organically cultivated bananas exhibited higher total soluble solids (26.5–31.3 °Brix), total sugars (15.7–19.3%), ascorbic acid content (36–42 mg/100 g), β-carotene levels (502–653 µg/100 g), and improved sugar-to-acid ratio compared to conventional produce. Fruits from the organic system also recorded extended shelf life (6–8 days vs. 5–6 days) and superior organoleptic properties. Sensory evaluation of ripe fruits and processed banana chips revealed consistently higher scores for colour, flavour, texture, and overall acceptability under organic cultivation. Soil analyses clearly indicated advantages of organic management, with higher organic carbon (0.49–0.91%), improved macro- and micronutrient availability, lower bulk density (1.216 g/cm³), and greater water-holding capacity (50.2%) compared to conventional soils. These parameters reflect enhanced soil structure and long-term fertility under organic systems. The findings demonstrate that organic farming sustains banana yield while enhancing fruit quality, nutritional composition, and soil health. Adoption of integrated organic nutrient management, particularly farmyard manure combined with in situ green manuring, emerges as a promising strategy for sustainable cultivation of Nendran banana in the region. This study provides empirical evidence that organic production systems can serve as a viable alternative to conventional methods, ensuring agronomic productivity, nutritional superiority, and environmental sustainability in perennial fruit crops.

Key Words: Banana (*Musa* AAB, *cv.* Nendran); Organic Farming; Conventional Farming; Yield; Fruit Quality; Soil Fertility; Shelf Life; Sensory Evaluation; Sustainable Agriculture; Kerala

1. Introduction:

Banana (*Musa* spp.) is the world's fourth most important food crop after rice, wheat, and maize, serving as a staple fruit for millions of people in tropical and subtropical regions (Heslop-Harrison & Schwarzacher, 2007). Globally, banana production exceeded 125 million tonnes in 2020, with India contributing nearly one-third, making it the largest producer (FAO, 2021). Among Indian cultivars, 'Nendran' (*Musa* AAB) is a unique banana valued both for fresh consumption and processing, particularly in the West Coast Plains and Hills region (Sivakumar *et al.*, 2018).

In recent years, there has been a growing debate on the sustainability of conventional farming systems that rely heavily on synthetic fertilizers and pesticides, which, although ensuring high productivity, pose environmental and soil degradation concerns (Tilman *et al.*, 2002; Bindraban *et al.*, 2020). Organic farming, by contrast, emphasizes renewable inputs, organic manures, and biological processes, with potential benefits in terms of soil health, biodiversity, and fruit quality (Mäder *et al.*, 2002; Reganold & Wachter, 2016). Several studies have highlighted that while organic systems may reduce yield gaps compared to conventional systems, they often improve nutritional quality, enhance bioactive compounds, and promote long-term soil fertility (Seufert *et al.*, 2012; Gomiero, 2018). Banana yield and fruit quality are largely influenced by production practices, with parameters such as total soluble solids (TSS), Titrable acidity, sugars, firmness, and shelf life being important for marketability and consumer acceptance (Kumar *et al.*, 2012; Singh *et al.*, 2016). Moreover, soil fertility indicators - particularly soil organic carbon, available nutrients, and microbial activity - play a crucial role in sustaining perennial fruit crop productivity (Pathak *et al.*, 2010; Sharma *et al.*, 2019). Management practices exert a profound influence on fruit quality in banana, particularly in nutrient-demanding cultivars such as 'Nendran', which is widely cultivated in Kerala and other parts of southern India. The nutrient composition of banana fruit is strongly determined by the availability of nutrients in the soil (Mustaffa *et al.*, 2004). Under conditions of low soil fertility and reduced organic matter content, the integration of organic and inorganic nutrient sources has been found to be the most effective strategy for sustaining productivity, given the high nutrient requirement of banana (Randhawa *et al.*, 1973). The synergistic effects of combined nutrient sources improve nutrient-use efficiency and reduce production costs (Sharma & Dua, 1995). Several studies have emphasized the nutritional superiority of 'Nendran' and other banana cultivars. For instance, Chandrasekhar and Kowsalya (2002) reported β-carotene content ranging between 310 and 336 μg 100 g^{-1} in 'Nendran' fruits. In *cv.* Rasthali, Thangaselvabai *et al.* (2009) demonstrated that the application of Azospirillum in combination with NPK fertilizers in split doses enhanced fruit quality. Similarly, vermicompost and castor cake application at 3 kg $plant^{-1}$ each improved fruit quality and shelf life in *cv.* Grand Naine (Patel *et al.*, 2010). Nitrogen management also plays a pivotal role; Naresh *et al.* (2004) observed that application of 240 g N $plant^{-1}$ in four equal splits significantly increased total sugar content and sugar-to-acid ratio in *cv.* Jahajee. Furthermore, Dinesh and Pandey (2008) reported that 150% of the recommended dose of fertilizers (165:55:495 g NPK $plant^{-1}$) applied in four splits was essential for improving fruit quality in tissue-cultured banana.

Biochemical analyses of 13 cultivars representing the AA, AB, AAA, and AAB genomes revealed significant variation in carbohydrates, starch, reducing sugars, proteins, and β-carotene content (Mohandas *et al.*, 2010). Among these, 'Nendran' was characterized by high carbohydrate, starch, reducing sugar, and β-carotene concentrations, whereas 'Padatti' exhibited the highest protein levels. These findings reaffirm the nutritional importance of 'Nendran' as a cultivar of dietary and commercial relevance. Chabi *et al.* (2018) reported that the most widely cultivated banana and plantain cultivars were Sotoumon (banana, 52.94%), Aloga (plantain, 41.17%), Planta (banana, 33.33%), and Adjangan (plantain, 27.45%). Among the eleven major production constraints identified, the key biotic stresses were banana weevil (*Cosmopolites sordidus* Germar) and banana bunchy top virus (BBTV), while the predominant abiotic challenges included drought and wind damage. Recent policy frameworks in Indian agriculture have emphasized a transition towards safe and sustainable production systems, with organic management regarded as the most promising option. Although numerous studies have documented the effects of various nutrient sources on yield and fruit quality in banana, limited research exists on the direct role and mechanistic influence of organic manures on the biochemical composition of banana fruits. Advances in biotechnology have also targeted nutritional enhancement, as demonstrated by transgenic Cavendish bananas engineered to accumulate up to 20 μg g^{-1} β-carotene (Paul *et al.*, 2017). Nevertheless, comprehensive evaluations of crop performance under organic and conventional nutrient management remain scarce. Against this backdrop, the present investigation was undertaken to elucidate the effects of organic and conventional production systems on the fruit yield, biochemical composition, and quality parameters of banana *cv.* Nendran. Despite global evidence on the comparative advantages of organic versus conventional farming, limited systematic research has been conducted on perennial fruit crops like banana, especially the cultivar 'Nendran' in the West Coast Plains and Hills region of India. Hence, the present investigation was undertaken to evaluate the impact of organic and conventional production systems on fruit yield, quality traits, and soil fertility of banana (*Musa* AAB, *cv.* Nendran), with the objective of providing scientific evidence for sustainable banana production in the region.

2. Methodology:

The present Research Study conducted at Kerala Agricultural University, Thrissur, Kerala. The study was conducted during the year 2018-2020 to compare the performance of banana (*Musa* AAB, *cv.* Nendran) under organic and conventional production systems in the West Coast Plains and Hills region of India. For this purpose, fields managed under organic and conventional practices were selected from farmers who had consistently followed their respective cultivation systems for a minimum of five years, ensuring system stability and comparability.

A total of ten farms were included in the study, comprising five organic farms and five conventional farms. Uniform crop management practices were adopted within each system, except for the nutrient and soil management strategies that distinguished organic from conventional cultivation.

Observations were recorded on yield attributes, fruit quality parameters, and soil fertility characteristics. Fruit quality assessment included shelf life, starch content of mature fruits, crude fibre content, total soluble solids (TSS), ascorbic acid content, and sugar-to-acid ratio. Sensory evaluation of ripe fruits was carried out for colour, flavour, and overall acceptability using a nine-point hedonic scale with a trained panel. Additionally, banana chips prepared from both systems were subjected to organoleptic evaluation for flavour, texture, taste, and overall acceptability following the same hedonic scale procedure.

Soil samples were collected from both organic and conventional fields for analysis of pH, electrical conductivity (EC), organic carbon, bulk density, water-holding capacity, cation exchange capacity (CEC), macronutrients (N, P, K), and selected micronutrients (Fe, Cu, Zn, Mn, and B) using standard procedures.

The range of values for the different growth, biochemical, organoleptic, and soil parameters are presented in Tables 1–6. Differences between conventional and organic systems were statistically analyzed to identify significant variations in yield, fruit quality, and soil fertility.

3. Results and Discussion

3.1 Fruit Characters of Banana: As per Table No.1, Bunch weight ranged from 12.5–15.3 kg under conventional cultivation and 12.7–15.2 kg under organic cultivation (Table 1). The number of hands was similar (5–7) in both systems, whereas finger number was slightly higher under conventional practice. However, organic fruits exhibited marginally higher finger weight (136.4–162.5 g) compared to conventional (138.5–159.6 g). Finger length and girth were slightly superior in the conventional system, whereas pulp-to-peel ratio and peel thickness showed better performance under organic cultivation. Interestingly, fruits from the organic system had extended shelf life (6–8 days) compared to conventional (5–6 days). These findings agree with reports by Anchal *et al.* (2019) and Gomiero (2018), who observed improved storability of organically produced fruits due to higher dry matter and antioxidant content.

Table.1 Range of values for fruit characters of Banana *cv.* Nendran

Character/Parameter	Conventional system	Organic system
Bunch Weight (kg)	12.50 – 15.30	12.70 – 15.20
No. of hands	5.0 – 7.0	5.0 – 7.0
No. of fingers	63.00 to 65.00	58.0 to 63.00
Finger weight (g)	138.5 g to 159.6 g	136.4 g to 162.5 g
Finger length (cm)	20.30 – 22.40	19.8 – 22.07
Finger girth (cm)	12.73 – 13.25	12.18 – 13.05
Pulp to peel ratio	2.70 – 3.10	2.85 – 3.16
Peel thickness (cm)	2.78 – 3.10	2.60 – 3.80
Days to ripening	4 – 5	4 – 6
Shelf life (no. of days)	5 – 6	6 – 8

3.2 Biochemical Characters of Ripe Fruits of Nendran Banana: Biochemical quality traits differed significantly between systems (Table 2). Organic fruits had higher TSS (26.5–31.3 °Brix), total sugars (15.7–19.3%), and ascorbic acid (36–42 mg/100 g) compared to conventional. The sugar-to-acid ratio, a key determinant of fruit palatability, was also higher in the organic system. β-carotene content ranged from 502–653 µg/100 g under organic conditions compared to 494–556 µg/100 g in conventional, suggesting enhanced nutritional quality. Similar observations were reported by Sivakumar *et al.* (2016) in banana and Mäder *et al.* (2002) in other fruit crops, where organic practices improved bioactive compounds and vitamin C content.

Table.2 Range of values for biochemical characters of ripe fruits of Banana *cv.* Nendran

Character/Parameter	Conventional system	Organic system
TSS (° brix)	25.27 – 27.07	26.53 – 31.32
Titrable acidity (%)	0.32 – 0.41	0.32 – 0.49
Total sugars (%)	15. 0– 17.08	15.65 – 19.28
Reducing sugars (%)	9.14 – 11.20	8.9 – 12.76
Ascorbic acid (mg/100g)	33.57 – 34.93	35.98 – 41.80
Sugar : acid ratio	39.3 – 54.23	39.23 – 56.04
Tannin (g/100g)	1.79 – 2.53	1.82 – 3.0
Crude fibre (%)	1.29 – 1.59	1.36 – 1.70
β Carotene (µg/100g)	493.93 – 555.89	502.69 – 652.70
Moisture content (%)	66.64 – 71.38	69.65 – 75.82

3.3 Organoleptic Evaluation of Fruits and Chips: Panel evaluation revealed that fruits and chips from the organic system scored higher for appearance, flavour, texture, taste, and overall acceptability compared to conventional counterparts (Tables 3 and 4). The mean overall acceptability of ripe fruits was 7.5 under organic versus 6.2 under conventional (Table 6). Similarly, banana chips from organic fruits recorded higher acceptability (7.6) compared to conventional (6.6). These results corroborate earlier studies in banana and mango where organically grown produce received superior sensory scores (Sivakumar *et al.*, 2018; Sharma *et al.*, 2019). Enhanced flavour in organic produce may be attributed to the higher accumulation of sugars, carotenoids, and ascorbic acid (Gomiero, 2018) as given in Table No.3 & 4.

Table. 3 Range of values for organoleptic evaluation of ripe chips of Banana *cv.* Nendran

Character/Parameter	Conventional system	Organic system
Appearance	6.2 – 7.4	6.8 – 8.0
Colour	5.6 – 7.4	6.8 – 7.6
Flavour	5.4 – 7.0	6.8 – 7.6
Texture	6.2 – 6.8	7.0 – 8.2
Taste	6.2 – 7.0	5.8 – 8.4
Overall acceptability	5.6 – 6.6	6.0 – 7.8

Table.4 Range of values for organoleptic evaluation of banana chips of Banana *cv.* Nendran

Character/Parameter	Conventional system	Organic system
Appearance	5.2 – 7.0	6.6 – 7.8
Colour	6.2 – 7.6	7.4 – 7.6
Flavour	5.8 – 7.4	6.6 – 7.8
Texture	5.6 – 6.8	7.2 – 7.6
Taste	6.2 – 6.8	6.8 – 7.6
Overall acceptability	6.0 – 7.0	7.0 – 8.4

3.4. Soil Properties of Fields under Conventional and Organic Production System

Soil fertility analysis (Table 5) revealed higher organic carbon (0.49–0.91%), improved availability of macronutrients (N, P, K), and greater micronutrient (Zn, Mn, B) content under the organic system compared to conventional. Mean soil organic carbon was 0.74% in organic versus 0.22% in conventional fields (Table 6). Bulk density was lower (1.216 g/cm³) and water holding capacity higher (50.2%) under organic cultivation, indicating better soil structure and porosity. These improvements are consistent with the findings of Reganold & Wachter (2016) and Sharma *et al.* (2019), who reported long-term benefits of organic systems on soil organic matter and nutrient cycling.

Table.5 Range of values for soil analysis of fields under Conventional System and Organic System of Banana *cv.* Nendran

Character/Parameter	Conventional system	Organic system
pH	4.6 – 5.4	4.9 – 6.5
EC (dSm1)	0.25 – 0.43	0.17 – 0.27
Organic carbon (%)	0.17 – 0.27	0.49 – 0.91
CEC (c mol/kg of soil)	13.27 – 15.70	8.71 – 12.84
N (kg ha1)	170.32 – 304.92	175.43 – 332.37
P (kg ha1)	181.87 – 266.25	190.96 – 256.71
K (kg ha1)	186.98 – 222.73	195.66 – 258.57
Ca (mg kg1)	350.87 – 500.48	368.41 – 545.53
Mg (mg kg1)	13.52 – 15.58	14.26 – 18.69
S (mg kg1)	23.98 – 29.74	25.18 – 29.86
Fe (mg kg1)	29.06 – 36.92	31.67 – 36.50
Cu (mg kg1)	1.09 – 1.80	1.19 – 2.16
Zn (mg kg1)	31.50 – 41.61	33.08 – 46.17
Mn (mg kg1)	37.71 – 45.53	41.18 – 51.93
B (mg kg1)	0.41 – 050	1.29 – 1.55

3.5 Overall Comparison of Conventional and Organic Production System

The integrated comparison (Table 6) clearly demonstrates that while yield attributes were nearly comparable between systems, organic cultivation improved fruit quality, sensory acceptability, shelf life, and soil health. This suggests that organic management not only maintains productivity but also enhances nutritional and organoleptic properties of banana *cv.* Nendran in the West Coast Plains and Hills region of India.

Table.6 Comparison of observations from Conventional and Organic Fields

Character/Parameter	Mean value	
	Conventional system	**Organic system**
Shelf life of fruits (days)	5.6	7.0
Starch content of mature fruits (mg/g)	61.98	67.39
Crude fibre content of mature fruits (%)	2.61	3.169
TSS of ripe fruits	26.26	28.52
Ascorbic acid	34.25	37.42
Sugar: acid ratio	34.25	47.71
Ripe fruit colour	6.32	7.24
Ripe fruit Flavour	6.00	7.52
Ripe fruit Overall acceptability	6.16	7.5
Banana chips Flavour	6.48	7.36
Banana chips Texture	6.16	7.48
Banana chips Taste	6.48	7.30
Banana chips overall acceptability	6.56	7.60
Electrical Conductivity (dS/m^{-1})	0.33	0.22
Organic Carbon (%)	0.22	0.74
Bulk Density (g/cm^3)	1.57	1.216
Water Holding Capacity (%)	46.0	50.24

Comparison was done between the observations received from conventional fields and organic field. All the farmers selected for the study were following the same system of cultivation for more than five years. Comparison of soil test values revealed that electrical conductivity was low, organic carbon was high, bulk density was low and water holding capacity high in samples collected from organic fields compared to conventional systems where inorganic fertilisers are used for cultivation. Results obtained in experiment indicate that organic management of banana improves the fruit and soil quality parameters without compromising yield.

4. Conclusion:

The present study demonstrated that organic nutrient management significantly enhanced fruit quality, sensory attributes, and soil fertility in banana (*Musa* AAB, *cv.* Nendran) without compromising yield when compared with conventional production systems in the West Coast Plains and Hills region of India. While bunch weight and other yield attributes were largely comparable across systems, organically cultivated fruits recorded higher total soluble solids, ascorbic acid content, β-carotene, sugar–acid ratio, and crude fibre. Organoleptic evaluation further confirmed superior colour, flavour, texture, and overall acceptability of organically produced fruits and chips.

Soil analyses revealed clear advantages of organic management, including higher organic carbon, improved macro- and micronutrient availability, lower bulk density, and greater water-holding capacity, all of which contribute to long-term soil health. Extended shelf life of fruits under organic cultivation further strengthens its commercial relevance.

Overall, the findings suggest that organic management offers a sustainable and economically viable option for banana cultivation, simultaneously maintaining productivity, improving nutritional and organoleptic quality, and enhancing soil fertility. Adoption of integrated organic practices, particularly the use of farmyard manure with in situ green manuring, may therefore be recommended for large-scale cultivation of Nendran banana in the region to achieve both agronomic and environmental sustainability.

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Fig:1. SURVEY OF ORGANIC AND CONVENTIONAL FARMERS *MUSA* NENDRAN IN THRISSUR, KERALA, INDIA