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# Yield and Fruit Quality of Banana *Musa* (AAB) Nendran as Influenced by Nutrient Sources

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***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

***Conflict of interests:*** The authors have declared that no conflict of interest exists.

## Abstract

The present study was conducted at Banana Research Station, Kannara, Kerala Agricultural University Thrissur, Kerala, India during 2017-2018. Evaluation was conducted by raising the crop under different manurial combinations. Banana yield and fruit quality characters were found to be influenced by the different treatments. Analysis was conducted for the biochemical constituents of mature and ripe Nendran banana fruits. Maximum starch (99.61 mg), protein (5.53 mg), crude fibre (3.95%) and tannin content (0.81 g) in mature fruits were obtained in Treatment-8 (FYM @ 29 kg, lime @ 0.5 kg and wood ash @ 4 kg plant$^{-1}$ as basal dose+fertigation with extract of 14 kg FYM till one month after bunch emergence, once in four days+*in situ* green manuring). This treatment also recorded lowest titrable acidity (0.38%), highest β-carotene content (595.67 µg) in ripe banana fruits. Maximum TSS content (26.23 °brix) was obtained in Treatment-6 in which fertilizers applied as modified package of practices (POP) recommendation of KAU as per soil test). Maximum yield (160.88 kg plot$^{-1}$) and fruit quality parameters; maximum total sugars (17.55%) and reducing sugars (11.38%), sugars/acid ratio (45.07) of ripe banana fruits were obtained in Treatment-3 where 15 kg FYM and 0.5 kg lime as basal+Poultry manure @ 14 kg plant$^{-1}$+ash @ 4 kg plant$^{-1}$ applied in two splits *i.e*. one as basal and one 3 MAP+*in situ* green manuring practised. It was evident from the study that application of organic manures improved fruit quality characters in Nendran banana.

***Keywords:*** Banana, fruit quality, nendran, nutrients, organic manures

## 1. Introduction

Management practices have a significant influence on fruit quality in banana. The current agricultural policy emphasize a shift towards safe agricultural practices for which organic management is the best option. Nendran is a popular variety of banana in Kerala and other parts of southern India. Nutrient composition of banana fruit depends on the available nutrients in soil (Mustaffa et al., 2004).

Under low fertility and organic matter situation and notably the high nutrient requirement of banana, combined use of organic and inorganic sources of fertilization seems to be the best option (Randhawa et al., 1973). The synergistic effects of organic and inorganic nutrient sources enhance the plant use efficiency with less input cost (Sharma and Dua, 1995). Vijayaraghavan and Ayyamperumal (2000) observed that foliar application of 1% urea and 2% MOP as a mixture increased the bunch weight and fruit quality. In a study carried out in India, Nendran

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was found to contain 310 and 336 µg of β-carotene 100 g (Chandrasekhar and Kowsalya, 2002). Tirkey et al. (2003) found that application of 300g N in 5 splits significantly increased the TSS (23.8 °brix), reducing sugar (6.38%), total sugar (17.48%) and sugar acid ratio in tissue cultured raised banana *cv*. Dwarf Cavendish. Meena and Somasundaram (2004) reported that in var. Poovan, 150% recommended N and K in 3 or 4 splits registered maximum TSS (19.6%), lower acidity (0.25%) or sugar-acid ratio (51.2%) compared to the control (15.9%, 0.30% and 37.7%, respectively). Naresh et al. (2004) reported that application of 240 g N plant$^{-1}$ in four doses at 2, 4, 6 and 8 month after planting recorded high total sugar content and sugar acid ratio in banana *cv.* Jahajee. Dinesh and Pandey (2008) found that application of 150% RDF of NPK (165: 55: 495 g plant$^{-1}$) in four split viz., 2,4,6 and 8 months after planting was essential to increase the quality of tissue cultured banana.

Thangaselvabai et al. (2009) recommended application of *Azospirillum* along with NPK in two splits for increasing fruit quality in *cv*. Rasthali. Application of vermicompost and castor cake each @ 3 kg plant$^{-1}$ produced superior quality fruits and enhanced shelf life in *cv*. Grand Naine (Patel et al., 2010). Mohandas et al. (2010) conducted biochemical analysis of 13 cultivars of banana belonging to AA, AB, AAA and AAB genomes, respectively. Analysis involved estimation of carbohydrates, starch, reducing sugars, proteins as well as β carotene. The cultivars which were studied were Kadali, Matty (AA), Annanvazha, Rasakadali (AB), Red banana, Robusta (AAA), Palayamkodan, Nendran, Poovan and Padatti (AAB). Among the cultivars Nendran had high carbohydrates, starch, reducing sugars as well as β carotene and Padatti had maximum proteins.

In India, many studies have been conducted to reveal the effects of different nutrient sources on yield and fruit quality, but there are no previous studies which were conducted to examine the direct role and mechanism of organic manures involving the composition of biochemical constituents in banana fruits**.** An attempt to increase the level of provitamin A to 20 µg g$^{-1}$ of β-carotene has been achieved in transgenic Cavendish bananas (Paul, et al., 2017). Crop behaviour under organic and inorganic management is not yet scientifically analyzed. Hence, this research was conducted to elucidate the changes in fruit quality characters of Nendran banana under different nutrient sources.

## 2. Materials and Methods

The present investigation was conducted at Banana Research Station Kannara, Kerala Agricultural University Thrissur, Kerala India during November, 2017 to September, 2018. For the experiment, 45 days old tissue cultured plants of Nedunendran clone *Musa* Nendran were planted in the pits at 2×2 m$^2$ spacing. Total nine treatments replicated thrice with randomized block design statistically. Plot size was 16 plants per treatment and observations were recorded from 4 plants in the inner rows to avoid border effect. Mature fruit bunches of banana were harvested depending upon attainment of maturity. The physiologically matured fruit samples were drawn from central four plants of the plot from each treatment.

### *2.1. Treatment details*

$T_1$: POP recommendation of KAU for TC banana (N:$P_2O_5$:$K_2O$ @ 300 g:115 g: 450 g+Lime 1.0 kg+FYM 15.0 kg plant$^{-1}$). $T_2$ : POP recommendation of KAU with organic manures 15 kg FYM and 0.5 kg lime as basal+FYM @ 28 kg plant$^{-1}$+ash @ 4 kg plant$^{-1}$ which were applied in two splits *i.e.* one as basal and one at 3 MAP)+*in situ* green manuring (Per plant). $T_3$: POP recommendation of KAU with organic manures 15 kg FYM and 0.5 kg lime as basal+poultry manure @ 14 kg plant$^{-1}$+ash @ 4 kg plant$^{-1}$ which were applied in two splits *i.e*. one as basal and one 3 MAP+*in situ* green manuring (Per plant). $T_4$: Best treatment from AICRP trials at Banana Research Station, Kannara (FYM 10 kg+Neem cake 1.25 kg+vermicompost 5 kg+wood ash 1.75 kg+biofertilizers (AMF 25 g+Azospirillum 50 g+PSB 50 g+*Trichoderma harzianum* 50 g pit$^{-1}$)+0.5 kg lime) (Per plant). $T_5$: Best treatment from AICRP trials at BRS, Kannara with native isolates of biofertilisers (FYM10 kg+Neem cake 1.25 kg+vermicompost 5 kg+wood ash 1.75 kg+biofertilizers (native isolates of AMF 25 g+Azospirillum 50 g+PSB 50 g+*Trichoderma viridae* 50 g pit$^{-1}$)+0.5 kg lime (Per plant). $T_6$: Modified POP recommendation of KAU including micro nutrients as per soil test (Per plant). $T_7$: Fertigation with inorganic manures (*adhoc* recommendation): FYM @ 15.0 kg plant$^{-1}$ (Per plant). $T_8$:Fertigation with organic sources 29 kg FYM, 0.5 kg lime and 4 kg ash as basal; Extract of 14 kg FYM through irrigation water till one month after bunch emergence, once in four days+*in situ* green manuring (Per plant). $T_9$: Control (without manures and fertilisers).

### *2.2. Analysis of fruit quality parameters of Nendran banana*

Mature and ripe nendran banana fruits were analysed for the biochemical constituents. The physiologically matured fruit samples were drawn from central four plants of the plot from each treatment. The middle three fruits of third hand from the top were selected and cut into small slices. These fruit slices were air dried and oven dried at 70°C temperature till it attained constant weight. The dried fruit samples were ground in mortar and pestle and used for their nutrient concentration. Starch content was estimated calorimetrically using Anthorne reagent, as suggested by Sadashivam and Manickam (2008). Protein content of matured banana fruits was estimated by Lowry's method. The blue colour developed by the reduction of the phosphomolybdic components in the Follin–Ciocalteau reagent by the amino acids tryosine and tryptophane present in the protein plus the colour developed by the biuret reaction of the protein with alkaline cupric tartrate were measured in the Lowry's method as suggested by Sadashivam and Manickam (2008). Determination of total dry matter content of fruits was made according to the methods suggested by Piper (1967). Tannin content was estimated by Folin-Denis method which is based on non-stoichiometric oxidation of the

molecules containing a phenolic hydroxyl group as suggested in Sadashivam and Manickam (2008). Crude fibre content was estimated by acid –alkali digestion method as suggested by Chopra and Kanwar (1978). Total soluble solids (TSS) was estimated using a hand refractometer having a range of 0 to 32 °Brix and expressed in degree brix (°Brix) (Ranganna, 1977). Titrable acidity was determined by the procedure proposed by Ranganna in 1977. An aliquot from the known volume of fruit sample was titrated against 0.1N Sodium hydroxide (NaOH) solution using phenolphthalein as an indicator and expressed in percentage (%). Ascorbic acid content of ripe fruit was estimated by the method of AOAC (1980) using 2, 6-dichlorophenol indophenol dye and expressed as milligram per hundred gram of fruit (mg 100 $g^{-1}$). Total sugars of the sample was estimated by the method described by A.O.A.C. (1980). Total sugar content was expressed as percentage on fresh weight basis. Reducing sugars of the fruit samples were determined by following copper reduction method using Fehling's solution (AOAC, 1980). The reducing sugars was expressed as percentage. Sugar- acid ratio was arrived at by dividing the value of total sugars and titrable acidity of the corresponding sample. β-carotene content was estimated using method AOAC (1980). 5 g weighed fruit sample ground in mortar using pestle and test portion was extracted with 40 ml acetone, 60 ml petroleum ether, and 0.1 g magnesium carbonate, and then blended for 5 min. Filtration was done with the aid of a suction pump and sample was decanted into separator. Residue was washed with two reagents; 25 ml portions acetone, then with 25 ml petroleum ether, and then extracts were combined. The combined extract was evaporated to dryness and residue was re-dissolved in acetone. Volume was made up to 1 to 5 ml using acetone depending upon the matrix. The sample was then analysed by high performance liquid chromatography (HPLC).

## 3. Results and Discussion

### *3.1. Yield and fruit quality parameters of mature and ripe banana fruit of Nendran*

Data on effect of nutrient sources on yield and fruit quality parameters of mature and ripe banana fruits of *Musa* (AAB) Nendran is presented in the Table 1.

#### *3.1.1. Yield plot$^{-1}$*

Bunch weight of *Musa* Nendran of total sixteen plants in each treatment expressed as yield per plot. Yield of Nendran banana was influenced by different organic and inorganic sources of nutrients is presented in Table 1. Highest yield (160.88 kg plot$^{-1}$) was recorded in $T_3$- POP recommendation

Table 1: Yield and fruit quality parameters of mature and ripe Nendran banana fruits affected by nutrient sources

| Treat-ment | YP | SC | P | TSS | A | TS | RS | AA | S:A R | TC | | CF | | βC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Mature | Ripe | Mature | Ripe | |
| $T_1$ | 136.44 | 59.98 | 7.66 | 23.79 | 0.43 | 15.19 | 9.49 | 28.46 | 36.16 | 0.62 | 1.97 | 2.88 | 1.12 | 430.08 |
| $T_2$ | 159.19 | 70.84 | 9.27 | 25.51 | 0.46 | 16.34 | 10.70 | 35.80 | 36.41 | 0.69 | 2.09 | 3.31 | 1.30 | 532.67 |
| $T_3$ | 160.88 | 80.92 | 9.21 | 24.95 | 0.39 | 17.55 | 11.38 | 36.58 | 45.07 | 0.75 | 2.04 | 3.19 | 1.35 | 537.42 |
| $T_4$ | 144.67 | 71.80 | 9.57 | 24.82 | 0.42 | 17.42 | 11.25 | 33.31 | 41.84 | 0.70 | 2.14 | 3.56 | 1.37 | 563.25 |
| $T_5$ | 143.85 | 77.32 | 9.60 | 25.61 | 0.43 | 16.33 | 11.45 | 32.44 | 38.80 | 0.70 | 2.10 | 3.42 | 1.50 | 551.75 |
| $T_6$ | 153.37 | 67.37 | 8.12 | 26.23 | 0.43 | 16.76 | 11.33 | 35.39 | 39.24 | 0.68 | 2.41 | 3.38 | 1.52 | 512.17 |
| $T_7$ | 131.00 | 79.47 | 8.38 | 23.95 | 0.40 | 15.90 | 10.02 | 36.67 | 40.48 | 0.78 | 2.47 | 3.36 | 1.74 | 514.75 |
| $T_8$ | 160.22 | 99.61 | 9.53 | 25.31 | 0.38 | 16.23 | 11.11 | 35.72 | 43.19 | 0.81 | 2.42 | 3.95 | 1.86 | 595.67 |
| $T_9$ | 114.13 | 68.83 | 7.21 | 23.66 | 0.45 | 14.66 | 9.18 | 28.32 | 34.38 | 0.64 | 1.74 | 2.77 | 1.30 | 445.58 |
| SEd± | 8.73 | 8.54 | 0.40 | 0.75 | 0.04 | 0.65 | 0.62 | 3.67 | 3.56 | 0.06 | 0.26 | 0.24 | 0.22 | 34.77 |
| CD (*p*=0.05) | 18.67 | 18.25 | 0.84 | 1.59 | NS | 1.39 | 1.36 | NS | NS | NS | NS | 0.52 | NS | 7.34 |

YP: Yield plot$^{-1}$ (kg); SC: Starch content (mg $g^{-1}$); P: Protein (mg $g^{-1}$); TSS: TSS ($^o$brix); A: Acidity (%); TS: Total sugars (%); RS: Reducing sugars (%); AA: Ascorbic Acid (mg 100 $g^{-1}$); S:A R: Sugar/Acid ratio; TC: Tannin content (g 100 $g^{-1}$); CF: Crude fibre (%); βC: β carotene (µg 100 $g^{-1}$)

of KAU with organic manures FYM @15 kg+Poultry manure @ 14 kg plant$^{-1}$+wood ash @ 4 kg plant$^{-1}$ with *in situ* green manuring followed by $T_8$ fertigation with organic manures. Pushpakumari et al. (2008) revealed that application of coir pith compost increased bunch weight (18.9 t ha$^{-1}$) compared to application of FYM (17.4 t ha$^{-1}$), poultry manure (17.9 t ha$^{-1}$) or vermicompost (17.0 t ha$^{-1}$) in banana. They also confirmed that different organic sources could be effectively used as a substitute for chemical fertilizers without any reduction in bunch yield in *cv.* Nendran. Bhalerao et al. (2009) studied the influence of 100% organic manures (FYM+*in situ* green manuring+neem cake 1.0 kg+bio-fertilizer) on *cv*. Grand Naine

and found lesser yield of banana over that with INM practices. Anusuya (2009) found that application of vermicompost alone gave equally good performance with reference to bunch weight, on par with 100% recommended dose of fertilizers.

*3.1.2. Starch content*

The results showed that there was significant difference for starch content of mature banana fruits among the treatments. Highest starch content (99.61 mg) was found in $T_8$ followed by $T_3$ (80.92 mg), and the treatments $T_7$ (79.47 mg) and $T_5$ (77.32 mg) were found to be on par with each other. Lowest starch content (59.98 mg) was obtained in $T_1$. Starch content was found to be high in treatments where organic manures alone were given. Thangaselvabai et al. (2009) reported high starch content with vermi-composting in banana. Mohandas et al. (2010) reported similar results in Nendran banana.

*3.1.3. Protein content*

Significant differences among the treatments were observed with regard to protein content of mature green fruits. Highest protein content (9.60 mg) was observed in $T_5$, which was followed by $T_4$ (9.57 mg, and the treatments $T_8$ (9.53 mg) and $T_2$ (9.27 mg) were on par with each other. Lowest protein content (7.21 mg) was obtained in control ($T_9$). Protein content in Nendran banana was found to be high in treatments receiving organic manures which could be due to the continuous supply of nitrogen from the synthesis of amino acids and other organic acids. Vanilarasu and Balakrishnamurthy (2014) reported that the absorbed nitrogen ultimately leads to the formation of complex nitrogenous substances like proteins and amino acids to build up new tissues. Similar results on the influence of organic manures on improving protein content were reported by Kulkarni et al., 2010; Mohandas et al., 2010.

*3.1.4. Tannin content*

No significant difference were observed among the treatments for tannin content of mature green banana fruits. Tannin content of 0.81 g was obtained in $T_8$, while lowest tannin content (0.62 g) was recorded in $T_1$. Tannin content was found to be high in treatments in which organic manures were applied and this might be due to the sufficient quantities of micronutrients like zinc, copper and iron, which led to the availability of increased tannin content in the fruits. Athani and Hulamani (2000) reported that *in situ* vermi composting did not significantly influence the tannin content of banana fruits *cv.* Rajapuri.

*3.1.5. TSS content*

Significant differences were observed in TSS content of ripe fruits among the treatments. Highest TSS content (26.23 °brix) in ripe fruits was observed in $T_6$ followed by $T_3$ (24.95 °brix), $T_4$ (24.82 °brix) and $T_5$ (25.61 °brix) were found to be on par. Lowest TSS content (23.66 °brix) was recorded in control ($T_9$). Highest TSS in ripe banana in treatment receiving inorganic manures may be due to the availability of nutrients like nitrogen, potassium, boron, copper applied based on soil test. This could also be due to the hydrolysis of starch into sugar during ripening (Garcia and Lajolo, 1988). In tissue-culture raised banana *cv*. Dwarf Cavendish, application of 300g nitrogen in 5 splits significantly increased the TSS (23.8 °brix), reducing sugars (6.38%), total sugars (17.48%) and sugar acid ratio (Tirkey et al., 2003).

Increase in TSS of banana fruits can be attributed to the hydrolysis of starch in to soluble sugars such as glucose, sucrose and fructose, (Stover and Simmonds, 1987) and Kulkarni et al. (2010). Mahato et al. (2014) investigated the impact of the application of various doses of nitrogen and potassium on vegetative growth, yield and fruit quality on plantain *var.* Nendran, and reported that high total sugars and TSS/acid ratio were found significantly increasing with increased N and K application rates.

*3.1.6. Titrable acidity*

Titrable acidity of banana is primarily used to indicate consumption quality. No significant differences were observed for titrable acidity of ripe banana among the treatments. Minimum titrable acidity (0.38%) was found in $T_8$, in which fertigation has been practised with FYM. Highest titrable acidity (0.45%) was recoded in control ($T_9$). Ushakumari et al. (1997) obtained least amount of titrable acidity by applying vermicompost with inorganic fertilizers.

The higher acidity of the plants grown under recommended dose of fertilizers was due to the high acid content of chemical fertilizers Mahato, et al. (2014), Sreedevi and Suma, (2015). Mayadevi (2016) also reported similar results.

*3.1.7. Total sugars*

Significant difference were recorded in total sugars of ripe banana fruits among the treatments. Highest total sugars (17.55%) was obtained in $T_3$, which was followed by $T_4$ (17.42%). Lowest total sugars (14.66) was obtained in control ($T_9$). Ushakumari et al. (1997) observed similar results as that of present study. They obtained significantly high total sugars when vermicompost was used to supply the entire quantity of nitrogen in banana *cv*. Njalipoovan. Kumar and Pandey (2008) recorded statistically significant values of TSS, total sugars and reducing sugars with application of 75% recommended dose of fertilizers (RDF) and the increased total sugars in banana mightbe due to higher uptake of nitrogen and potassium by the plant.

During ripening, the concentration of total sugars increases due to hydrolysis of stored starch and accumulation of sugars. The increased sugar content in poultry manures treated plants proved the direct effect of availability of vital nutrients and indirect effect of sustained release of growth hormones and vitamins (Butani and Chovatia, 2014).

*3.1.8. Reducing sugars*

There was no significant difference in reducing sugars. Highest reducing sugars (11.38%) in banana was recorded in $T_3$ (fertigation with organic manures) while lowest reducing

sugars (9.18%) was recorded in control ($T_9$). Ushakumari et al. (1997) obtained significantly high reducing sugars content when vermicompost+inorganic fertilizers were applied. Similar results for reducing sugars content were reported by Venkatesh, 1995; Hazarika and Ansari, 2008; Kulkarni et al., 2010; Mayadevi, 2016.

*3.1.9. Ascorbic acid*

The results for ascorbic acid content of ripe banana fruits was non-significant among the treatments. Highest amount of ascorbic acid (36.67 mg) was found in $T_7$ in which fertigation with inorganic manures has been practised followed by $T_3$ (36.58 mg). Lowest ascorbic acid (28.32 mg) of ripe banana fruits was recorded in control ($T_9$). Higher rate of nitrogenous fertilizers are reported to decrease the ascorbic acid content in fruits (Lee and Kader, 2000).

From nutritional point of view, horticultural crops grown under low nitrogen supply may be preferred due to high concentrations of ascorbic acid and low concentrations of nitrate (Lee and Kader, 2000). However, Hazarika and Ansari (2008) reported higher use of inorganic fertilizers decreases the ascorbic acid content in banana. Mayadevi (2016) studied the ascorbic acid of ripe banana *cv*. Nendran fruits increased with combined application of mineral fertilizers and farmyard manure.

*3.1.10. Sugar acid ratio*

There was no significant difference for sugar acid ratio of ripe banana fruits between the treatments. Maximum sugar/acid ratio (45.07) was recorded in $T_3$ and lowest sugar acid (34.38) in control. Higher sugar acid ratio was observed in treatments receiving organic sources and this may be due to the different conversion rate of starch and sugars. Mayadevi (2016) r obtained more sugar acid ratio of Nendran banana when integrated use of fertilizers practised with organic manures.

*3.1.11. Crude fibre*

Significant difference in crude fibre content of mature fruits of Nendran banana were observed among the treatments. Highest crude fibre (3.97%) was obtained in $T_8$, which was followed by $T_4$ (3.56%). Treatments $T_5$ (3.42%), $T_6$ (3.38%) and $T_2$ (3.31%) were on par with each other. Lowest crude fibre content of mature green fruits (2.77%) was observed in control. Crude fibre content is influenced by nutrition with biofertilizers and organic manures. However crude fibre content in ripe Nendran banana fruits was found to be non-significant. Among all pre-harvest treatments, 5kg vermicompost, NPK (400+60+300 g tree$^{-1}$) was found to be superior in respect of higher crude fibre content in sapota fruits (Dhaval and Naik, 2010).

*3.1.12. β-carotene content*

Among the major Indian banana cultivars, the edible portion of orange-fleshed banana cultivar Nendran (AAB) was reported to contain the highest β-carotene content (Dhandapani et al., 2017).

The results indicated that there were significant differences in β Carotene content among the treatments. The highest β-carotene content (595.67 µg) was obtained in $T_8$ where manures were given in organic form as fertigation which was followed by $T_4$ (563.25 µg). The treatments $T_5$ (551.75 µg) and $T_3$ (537.42 µg),) were found to be on par. Lowest β-carotene content (430.08 µg) was found in $T_1$.

## 4. Conclusion

Fertigation with organic manures in Nendran banana improved yield and fruit quality parameters like increase starch, protein, crude fibre and tannin content in mature banana fruits. Highest total sugars, reducing sugars, sugars acid ratio and β-carotene content in ripe banana fruits was achieved with the application of organic manures like FYM, poultry manures and wood ash. Fertigation with inorganic fertilizers resulted in highest amount of ascorbic acid and crude fibre content of ripe Nendran banana fruits.

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