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Effect of Organic Nutrients on the Yield and Quality of Banana cv. Nendran (*Musa* spp., AAB)

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ABSTRACT

A study was undertaken at Banana Research Station, Kannara, Kerala Agricultural University, Thrissur, India during 2011–12 to 2017–18 in five seasons to standardize an organic nutrient schedule for Nendran banana. Eleven treatments involving various sources of organic nutrients (T_1 to T_{10}) were tried against inorganic source of nutrients as control (T_{11}). T_1 to T_4 involved organic manures viz., FYM, neem cake, vermicompost and wood ash in different proportions. While T_5 was absolute control, T_6 and T_7 included triple green manuring and biofertilizers alone respectively. T_8 to T_{10} had organic manures along with triple green manuring or biofertilizers or both. The results showed that a combination of FYM (10 kg), neem cake (1.25 kg), vermicompost (5 kg), wood ash (1.75 kg), triple green manuring with cowpea and biofertilizers (AMF @ 25 g±*Trichoderma harzianum* @ 50 g±PSB @ 50 g±*Azospirillum* @ 50 g plant^{-1}) recorded the highest bunch weight (9.60 kg) and yield (23.99 t/ha). The treatment was on par with inorganic fertilizer treatment and had a B:C ratio of 1.78. Better quality attributes in terms of extended shelf life and TSS was another notable advantage of the treatment. Soil health was also significantly improved in treatments involving organic nutrient sources as evident from the soil microbial population and enzymatic activity, when compared to inorganic control.

KEYWORDS: Banana, enzymatic activity, Nendran, organic, quality, soil microflora, yield

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1. INTRODUCTION

Banana (*Musa* spp.) is one of the oldest fruit crops known to mankind. India stands first contributing 26% of the world banana production (Archit et al., 2021). The South Indian state of Kerala is home to a wide range of banana cultivars, of which plantain variety, Nendran (AAB) occupies a unique position covering more than 50% of area under banana. The annual production of banana and plantain in the state is 0.11 mha with a production of 0.81 mt (Anonymous, 2021). Banana, is a heavy feeder of plant nutrients especially nitrogen and potassium (Singh et al., 2021) followed by phosphorus (Abdullah et al., 1999). Being nutrient exhaustive, proper scheduling of plant nutrition is very important in banana for realising potential yields (Rajput et al., 2022). The nature of the nutrient source also influences nutritional management and banana production (Guimarães et al., 2020). Moreover, nutrient elements are drawn from a very limited soil depth due to its shallow root system (Hema et al., 2016). Fertilizers are costly, energy intensive (Bashma and Sudha, 2020) and their continuous use in imbalanced proportions damage the environment,plants and human beings. Organic farming involving biofertilizers are an economically attractive and ecologically sound means of reducing chemical fertilizers (Phukan et al., 2016) besides improving the quality of produce and enhances sustainability and biological activity of the soil (Reddy, 2016). Tropical soils are generally low in organic matter content and it decomposes very rapidly (Palaniappan and Annadurai, 2018). India has about 8.84 lakh ha under banana cultivation producing approximately 51.18 million tons of pseudostem waste per year (Anonymous, 2018). They serve as a source of water, nutrients and organic substances (Lima et al., 2020). Studies have shown that vermicomposting can be included in the overall scheme of banana crop waste management (Mago et al., 2021). Kerala is blessed with a tropical humid climate but faces the problem of soil acidity and leaching of bases causing widespread deficiency of nutrients (Bhindhu and Sureshkumar, 2021), particularly micronutrients (Rajasekharan et al., 2018). Organic manures contain macro and micronutrients, plant growth promoting substances like auxins, gibberellins, and cytokinins (Krishnamurthy and Vajrabhiah, 1986). Green manuring enhances the availability of nitrogen (Yang et al., 2018) and can be a substitute for the use of chemical fertilizers (Shabir et al., 2020). Green manure crops are grown mainly for the benefit of the soil and are very commonly referred as soil fertility building crops (Kumar et al., 2020). Cowpea (*Vigna unguiculata* L. (Walp.)) is well adapted to acid upland soils of Kerala (John et al., 1992), besides fixing atmospheric nitrogen and are easily decomposable (Meena et al., 2018). Biofertilizers is internationally accepted as an alternative source to chemical fertilizers (Mahanty et al., 2016) and can be used to ensure a sustainable banana production (Mia et al., 2010; Ghani et al., 2013). The population of added micro-organisms can build up avoiding frequent application of biofertilizers (Kumar et al., 2022). Organic manures give better post-harvest life and quality in terms of starch, protein, crude fibre, β-carotene and tannin content in banana (Meghwal et al., 2021a). The nutritional status of the soil also plays a significant role in determining the quality aspects of the fruit (Roy et al., 1993). However, information regarding the type of organic manure, their optimum dose, and their interaction with bio fertilizers on yield and quality attributes in nendran is limited. In this context, the present investigation was carried out to standardize an organic nutrient schedule for Nendran banana under the agroclimatic conditions of Kerala.

2. MATERIALS AND METHODS

The experiment was conducted under the ICAR – All India Coordinated Research Project on Fruits during 2011–12 to 2017–18 in five seasons at Banana Research Station, Kannara, Kerala Agricultural University Thrissur, (10° N 76° E). The soil type is laterite, acidic (pH 5.2) with medium to high organic carbon and potassium and high phosphorus levels. Magnesium and boron are generally deficient in the soil. The region enjoys a tropical humid climate receiving an average annual rainfall of 2800 mm. The experimental material consisted of three month old healthy suckers of cultivar Nendran and planted at a spacing of 2 x 2 m in Randomized Block Design with three replications. Treatments applied were as follows:

T_1 FYM 10 kg±Neem cake 1.25 kg±Vermicompost 5 kg±Wood ash 1.75 kg plant^{-1}, T_2- FYM 10 kg±Neem cake 1.25 kg±Vermicompost 5 kg±Wood ash 3.75 kg plant^{-1}, T_3- FYM 15 kg±Neem cake 1.875 kg±Vermicompost 7.5 kg±Wood ash 0.625 kg plant^{-1}, T_4- FYM 15 kg±Neem cake 1.875 kg±Vermicompost 7.5 kg±Wood ash 2.625 kg plant^{-1}, T_5- Absolute Control, T_6- Triple green manuring with Cowpea, T_7- Biofertilizers / bioagents - AMF (25 g)±*Azospirillum* (50 g) ±PSB (50 g) ±*T. harzianum* (50 g) plant^{-1}, T_8- T_1±T_6, T_9- T_1±T_7, T_{10}- T_1±T_6±T_7, T_{11}- 300 g N±100 g P±300 g K plant^{-1} as inorganic (fertilizer control).

FYM, neem cake and biofertilizers / bioagents were applied as basal. Vermicompost and wood ash were applied at 3rd and 5th month after planting respectively. Cowpea seeds were sown (@ 20 g plant^{-1}) one month after planting in the interspaces and incorporated into the soil 40 days after sowing. This was repeated twice to ensure triple green manuring to the main crop. Other management operations were given as per Package of Practices Recommendation for the crop (Anonymous, 2016).

Vegetative growth parameters viz., plant height, pseudostem girth, leaves per plant, suckers per plant, leaf area index (LAI) were recorded at bunching. LAI was calculated by multiplying the product of number of leaves, leaf length and width (at the broadest part of the third leaf from the top (index leaf)) by the factor 0.8 and dividing by the area occupied by the plant (Murray, 1960). Observations on bunch characters (bunch weight, hands per bunch and fingers per bunch) were taken at harvest (full maturity). Middle finger in the top row of the second hand (from the base of the bunch) was designated as the index finger or D finger for studying the finger characters viz., finger weight (g), finger length (cm) and finger girth (cm). Fruit quality parameters like TSS was estimated after harvest on ripening (Ranganna, 1986). Shelf life of the fruit was estimated under ambient room temperature as the days taken for the fruits from ripening to loosing their edible quality as evident by over softening and onset of decay was taken and expressed in number of days. Soil microflora in terms of the population of bacteria, fungi and actinomycetes were recorded before and after (at harvest) the experiment as per Pelczar et al. (1993) and expressed as colony forming units per gram of dry weight of soil.

The experiment was conducted for five seasons and statistical analysis of data on all characters were analysed by analysis of variance (Panse and Sukhatme, 1967).

3. RESULTS AND DISCUSSION

3.1. Growth and yield characters

Data recorded on vegetative characters as influenced by nutrient sources are given in Table 1.

Inorganic fertilizer treatment (300 : 100 : 300 g NPK plant^{-1}) recorded the maximum plant height, pseudostem girth, leaves plant^{-1}, suckers plant^{-1}, leaf area index (LAI) and minimum phyllochron. The same was also on par with several treatments receiving organic nutrient sources as well. In general, application of FYM (10 kg) ±neem cake (1.25 kg) ±vermicompost (5 kg) ±wood ash (1.75 kg) along with additional application of triple green manuring (T_8) or biofertilizers (T_9) or both (T_{10}) performed on par for growth attributes with inorganic chemical fertilizer (T_{11}). These treatments were also the earliest to bunch and harvest, while absolute control (T_5), biofertilizers alone (T_6) and triple green manuring alone (T_7) took the maximum days to bunch. T_9 was the earliest to bunch (224.92 days) and harvest (313.94 days) and was on par with T_8, T_{10}, T_{11}, T_1, T_2, T_3 and T_4, which means that nutrient sources did not exert any significant influence on crop duration. Shorter crop duration might be due to higher net assimilation rate on account of better vegetative growth leading to the production of endogenous metabolites earlier in optimum level, initiating early flower bud initiation and allowing early shooting.

Table 1: Effect of nutrient sources on vegetative characters of banana cv. Nendran

Treatment	Plant height (cm)	Pseudostem girth (cm)	Leaves plant^{-1}	Suckers plant^{-1}	Phyllochron (days)	LAI	Days to bunching (days)
T_1	275.69	44.80	8.77	5.72	7.95	2.11	234.92
T_2	267.34	43.78	8.68	5.34	8.06	2.02	237.89
T_3	262.61	42.26	8.09	5.27	9.00	1.71	238.26
T_4	263.43	41.93	8.28	4.86	8.31	1.80	242.47
T_5	211.50	34.08	7.32	2.79	10.79	1.22	279.43
T_6	240.24	38.30	8.10	4.05	9.19	1.59	266.74
T_7	240.62	37.16	7.66	3.68	9.76	1.61	267.90
T_8	283.58	44.99	8.85	5.472	8.44	2.20	229.20
T_9	284.93	44.73	9.16	5.56	8.08	2.43	224.92
T_{10}	233.79	45.08	8.91	5.55	8.44	2.21	234.83
T_{11}	295.43	45.78	8.63	5.50	8.28	2.51	234.64
SEm±	10.89	0.42	0.19	0.19	0.31	0.06	9.66
CD (p=0.05)	46.18	1.75	0.81	0.81	1.30	0.27	4.19

Production of an optimum number of leaves and leaf area before the onset of flowering is an essential requisite for flowering and proper crop maturity in banana (Barker and Steward, 1962). Leaf is an important index of vigour that influences the consequential yielding capacity of a cultivar (Phukan et al., 2016). Phyllochron was found to be favourably influenced by the treatments. The variation in phyllochron of a cultivar of the same genomic constitution could be ascribed to several attributes of which nutritional status (Murray, 1960) plays a very significant role. This view was in the tune with that of Turner (1998) who had reported that leaf emergence rate would serve as a good index of the vegetative growth rate of a banana plant.

Bunch weight and yield was maximum in T_{10} (organic manures±biofertilizers±triple green manuring), which was on par with T_{11} (fertilizer control) and T_9 (organic manures±biofertilizers). Hands bunch^{-1}, fingers bunch $^{-1}$, finger weight, finger length and finger girth was also significantly high for these treatments (Tables 2 and 3).

There was no significant difference for pulp:peel ratio among the treatments. Bunch weight, hands bunch $^{-1}$, fingers bunch $^{-1}$, finger weight, finger length and finger girth, all of them are the sum total effects of growth as a whole. The significant increase in bunch weight was due to increased leaf area during the cropping period which accelerated the process of photosynthesis and carbohydrate formation. The relatively higher accumulation of carbohydrates in the leaves could promote growth rate and in turn increase the bunch yield. Leaf area have a positive correlation with the bunch weight. Leaf parameters especially phyllochron and chlorophyll level in banana leaves gets improved when organic manures alone

Table 2: Effect of nutrient sources on yield and yield characters of banana cv. Nendran

Treatment	Bunch weight (kg)	Yield (t ha^{-1})	Days to harvest	Hands bunch^{-1}	Fingers bunch^{-1}	B:C ratio
T_1	7.00	17.50	319.81	4.86	45.53	1.35
T_2	7.45	18.62	322.68	4.90	46.20	1.45
T_3	7.11	17.77	322.25	4.73	45.57	1.32
T_4	7.14	17.86	325.18	4.91	44.82	1.24
T_5	4.42	11.05	357.68	4.05	31.90	0.91
T_6	5.20	13.01	347.69	4.62	39.75	1.08
T_7	4.78	11.94	349.96	4.34	38.08	0.98
T_8	8.81	22.04	316.43	5.13	48.09	1.71
T_9	9.24	23.12	313.94	5.16	49.47	1.73
T_{10}	9.60	23.99	320.12	5.30	50.66	1.78
T_{11}	9.54	23.86	317.54	5.38	50.86	2.59
SEm±	0.12	0.31	3.28	0.09	0.66	-
CD (p=0.05)	0.52	1.30	13.89	0.38	2.82	-

Table 3: Effect of nutrient sources on fruit and quality characters of banana cv. Nendran

Treatment	Finger weight (g)	Finger length (cm)	Finger girth (cm)	Shelf life (days)	TSS (˚Brix)	Pulp: peel ratio
T_1	155.03	20.34	11.54	7.30	27.63	2.95
T_2	155.7	20.07	11.77	8.13	27.05	3.17
T_3	149.74	20.06	11.51	6.97	28.22	3.00
T_4	156.93	20.46	11.69	7.28	27.04	3.23
T_5	122.992	16.90	9.69	7.71	26.67	2.77
T_6	132.86	18.27	10.44	8.27	28.13	2.96
T_7	123.81	17.22	9.9	7.31	28.27	2.92
T_8	187.28	21.94	12.78	7.87	28.43	3.29
T_9	187.82	22.05	12.93	8.53	28.92	3.16
T_{10}	188.89	21.870	12.96	8.22	28.93	3.37
T_{11}	187.61	22.55	13.42	6.60	27.11	3.07
SEm±	3.59	0.40	0.28	0.19	0.25	0.06
CD (p=0.05)	15.21	1.71	1.17	0.81	1.06	NS

were used when compared to integrated use of manures and fertilisers (Meghwal et al., 2021b). The correlation between bunch weight and leaf area was documented by Murray (1961). The increase in bunch weight was also found to be associated with corresponding increase in hands bunch^{-1} and fingers bunch^{-1}. Higher length, girth, volume and weight of fingers might also be due to better filling of fruits. Pathak et al. (1992) corroborated that more number of leaves increase the photosynthetic activity resulting in higher accumulation of carbohydrates for translocation to the sink for better filling of fruits. Meghwal et al. (2021a) observed that a combination of FYM (15 kg plant^{-1}) as basal along with poultry manure (14 kg plant^{-1}), ash (4 kg plant^{-1}), and *in situ* green manuring improved yield and fruit quality in nendran banana. Pushpakumari et al. (2008) confirmed that different organic sources could be effectively used as a substitute for chemical fertilizers without any reduction in bunch yield in cv. Nendran.

3.2. Quality characters

Shelf life of banana is an important parameter and influenced directly by the pre-harvest nutritional status of the fruits. The influence of nutrients derived from organic sources had a positive effect on the post-harvest characters of nendran banana as revealed from the significantly higher TSS and increased shelf life when compared to inorganic fertilizer control. In the present investigation, maximum shelf life (yellow life) of 8.53 days was recorded for T_9 (on par with T_{10}) which was almost 2 more days that the shelf life observed in T_{11} viz., inorganic chemical control (6.60). The extended shelf life observed in the present study might be due to the consequence of physiological processes like reduced respiration and transpiration. This is in conformity with the findings of Hema et al. (2016), who also observed that the fruit quality parameters like TSS, total sugars and shelf life were higher in plants treated with organic amendments as compared to inorganic. Higher total sugars, reducing sugars, sugar: acid ratio and β-carotene content was observed in ripe nendran fruits by Meghwal et al. (2021a) when provided with organic manures alone viz., FYM, poultry manures and wood ash.

3.3. Effect of green manuring, organic manures and biofertilizers/ bioagents

Application of green manures in the form of cowpea, organic manures like neem cake, vermicompost, ash and biofertilizers have played a significant role in achieving good yield and quality in banana. Hema et al. (2016) reported that combined application of organic nutrient sources viz., FYM (15 kg) ±neem cake (1.875 kg) ±vermicompost (7.5 kg) ±ash (9.94 kg) recorded better yield characters apart from producing fruits with high TSS content, better shelf life and higher sugar content. Soil application of powdered neem seed or neem cake at 100 g plant^{-1} at planting and subsequently at 3 or 4 months interval reduced the population of nematodes and pseudostem weevil affecting banana apart from increasing the growth and yield (Chabrier and Queneherve, 2003). Mayadevi (2016) reported that vermicompost application augmented the growth of banana plants. This may be attributed to the humic acids present in the compost which might have increased the number of lateral roots, thereby stimulating nutrient uptake and plant development. Use of vermicompost also reduced days to bunching and total crop duration along with better quality in terms of increased total sugars, reducing sugars, non-reducing sugars and lower titratable acidity (0.29%) in banana cv. Nendran.

Application of biofertilizers enhances the growth, yield and quality in banana (Thangaselvabai et al., 2009). In the present study, soil bacteria, fungi, actinomycetes and soil dehydrogenase activity showed a significantly higher values in treatment involving organic nutrient sources, when compared to inorganic control (Table 4).

Jadhav et al. (2016) observed significantly higher soil acid phosphatase activity and dehydrogenase activity in banana which received 100% N in equal proportion through FYM, neem cake and vermicompost. Dehydrogenase activity can be considered to be a good measure of microbial oxidative activity in soils. The greater biological activity coupled with stabilization of extracellular enzymes through complexation with humic substances might be the reason for continuous availability of substrates for enzymes (Adak et al., 2014).

Application of organic manures and biofertilizers (*Azospirillum brasilense* and Phosphobacteria) either singly or in combination with fertilizers resulted in positive influence on microbial biomass carbon, N mineralization, soil respiration and enzyme activities (Dinesh and Pandey, 2010). In addition, organic inputs improve the biological activity in the rhizosphere zone, thus increasing populations of arbuscular mycorrhizal fungi, favouring plant growth, promoting rhizobacteria, actinomycetes and beneficial free living nematodes and inducing better plant tolerance to biotic and abiotic stresses. Beyond this, soil organic carbon serve as a food for soil fauna and flora and play an important role in the food web by controlling the number and types of soil inhabitants, which serve important functions such as nutrient cycling and availability, assisting root growth and plant nutrients uptake (Chan, 2010).

The best treatment in terms of yield and quality characters in the experiment viz., T_{10} involved a combined application of organic manures as well as biofertilizers / bioagents namely arbuscular mycorrhizal fungi (AMF), PSB, *Azospirillum* and *Trichoderma harzianum*. Each biofertilizer / bioagent has played an important role in achieving the same. AMF

Table 4: Effect of nutrient sources on soil microflora and enzymatic activity

Treatment	Total bacteria (10^5 CFU g^{-1})	Total fungi (10^2 CFU g^{-1})	Total actinomycetes (10^3 CFU g^{-1})	Dehydrogenase activity (mg TPF day^{-1} kg^{-1} soil)
Initial	26	16	83	5.87
T_1	36	21	32	11.93
T_2	29	19	46	15.07
T_3	36	19	33	25.13
T_4	22	12	44	47.53
T_5	35	11	26	3.40
T_6	36	16	61	13.67
T_7	32	18	85	27.40
T_8	38	15	64	29.07
T_9	54	17	65	15.00
T_{10}	51	16	68	31.20
T_{11}	12	13	32	17.93
SEm±	1.61	1.51	1.84	1.45
CD (p=0.05)	4.53	2.59	8.76	4.68

is a symbiotic fungi where it positively affect plant growth parameters. Singh and Singh (2004) observed that AMF influenced growth attributing characters like plant height, girth, production of functional leaves and yield contributing factors like hands $bunch^{-1}$, fingers $bunch^{-1}$, finger length and bunch weight. Mineral uptake, especially N, P and K was enhanced due to the symbiotic effect of AMF. Hazarika et al. (2011) recorded maximum fingers $hand^{-1}$, finger length, volume, circumference and finger weight in Grand Naine treated with *Azospirillium,* PSB, VAM and *Trichoderma harzianum*. This is due to their ability to fix atmospheric nitrogen and transform native soil nutrients like phosphorus, potassium, zinc, copper, iron, sulphur from the non-usable fixed to usable form and decomposed organic wastes through biological process which in turn release nutrients in a form which can be easily assimilated by plants resulting to produce more numbers of fingers. Biological nitrogen fertilization could be used to reduce the total cost of the chemical nitrogen requirements to 50 per cent or less in point of fact which will facilitate in health along with better return with eco-friendly approach. *Trichoderma* spp. produces antimicrobial compounds that could be used in biological control as an antifungal against several plant pathogens (Contreras-Cornejo et al., 2016). Srivastava (2004) reported that root colonization by *Trichoderma* strains enhances root growth and development.

4. CONCLUSION

Organic production of nendran banana in Kerala could be enhanced through the adoption of a nutrient schedule involving a combination of FYM (10 kg)±neem cake (1.25 kg)±vermicompost (5 kg)±wood ash (1.75 kg $plant^{-1}$) along with triple green manuring and biofertilizers / bioagents to get a comparable yield with inorganic fertilizer treatment and better quality in terms of TSS and extended shelf life.

5. FURTHER RESEARCH

Further studies in terms of the reaction to pest and disease incidence and their management using organic / biological methods is essential to arrive at a complete package for organic banana cultivation is to be streamlined.

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