RESPONSE OF BANANA *Musa* (AAB) 'NENDRAN' TO NUTRIENT SOURCES

By

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(2016-22-005)

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THESIS

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DECLARATION

I hereby declare that this thesis entitled '**Response of banana *Musa* (AAB) 'Nendran' to nutrient sources**' a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title of any University or Society.

Vellanikkara,

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CERTIFICATE

Certified that this thesis entitled "**Response of banana *Musa* (AAB) 'Nendran' to nutrient sources**" is a record of research work done independently by Mr. Manohar Lal Meghwal (2016-22-005) under my guidance and supervision that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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We, the undersigned members of the advisory committee **of Mr. Manohar Lal Meghwal (2016-22-005)**, a candidate for the degree of **Doctor of Philosophy in Horticulture** with major field in **Fruit Science**, agree that the thesis entitled **"Response of banana *Musa* (AAB) 'Nendran' to nutrient sources"** may be submitted by **Mr. Manohar Lal Meghwal**, in partial fulfillment of the requirement for the degree.

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Manohar Lal Meghwal

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
@	At the rate of
°C	Degree Celsius
CD	Critical difference
cfu	Colony forming units
et al.	And other co-workers
h	Hours
sec	Seconds
min	Minutes
i.e.	that is
ha	Hectares
t/ha	Tons per hectare
l	Litre
ml	Milli litre
µl	Micro litre
cm	Centimeter
mm	Millimeter
µm	Micro meter
kg	Kilogram
g	Gram
mg	Milli gram
µg	Micro gram
sp. or spp.	Species (Singular and plural)
viz.	Namely
ppm	Parts per million
RDF	Recommended Dose of Fertilisers

Introduction

1. INTRODUCTION

Banana is the leading tropical fruit in the world market today with a highly organized and developed industry. Banana cultivation in India is as old as Indian civilization. It is the one of the oldest fruit plants cultivated by man from prehistoric time, as the evidenced from Vedic literature. The crop is grown extensively in India, African countries, Philippines and other tropical countries for home consumption as well as for export. Major banana growing states in the country are Tamil Nadu, Gujarat, Maharashtra, Andhra Pradesh, Maharashtra, Karnataka, West Bengal, Kerala and Bihar. However, the present production of banana in the country is highly inadequate. As per the available estimates the present annual per capita consumption of banana in India is 50 kg which is very low compared with other progressive banana growing countries such as Jamaica, Congo, Equator, Kenya and Uganda. Banana is a global fruit crop with 97.5 million tonnes of production.

Major banana growing areas of the world are geographically situated between the equator and 20 ^{0}N and S latitudes. India contributes to 29.19 per cent of bananas world production. In India it supports livelihood of millions of people with area about 8.85 lakh hectare with total annual production of 30.81 million tonnes. National average productivity of banana is 34.9 t/ha (NHB database, 2018). Banana is the most important fruit in Kerala, both in terms of acreage and production and it occupies an area of 1.09 lakh hectares and annual production over 11.19 lakh tonnes. As per NHB database (2018) average productivity of Banana is in Kerala is 10.24 t/ha which is very low.

Banana is a nutritious, palatable and easily digested fruit, rich in carbohydrates, minerals, such as potassium, magnesium, sodium, and phosphorous; even richer in calorific value than potato. It has a rare combination of energy and tissue building elements like protein, vitamins and minerals. It can make a useful contribution to the vitamin A, C and B_6 content to the diet, and immediate source of energy (Robinson, 2000). Banana fruit may be eaten raw or as a cooked vegetable. The fruit can also be processed for a number of food products including ice cream, yoghurt, cake, bread, nectar, jam and baby foods. Banana flour, prepared from the raw fruit is a highly nutritive baby food. Ripe bananas can be dried and eaten, or sliced, canned

with syrup, and used in bakery products, fruit salads and toppings. Green bananas can be sliced and fried as chips. Vinegar and alcoholic beverages can be made from fermented bananas.

Kerala produces only less than 30 percent of its requirement of banana at present and leans on Tamil Nadu to bridge the gap in demand. The state of Kerala is blessed with a wide array of banana varieties with specific regional preferences and commercial importance. Among the different varieties of banana used by Keralites, Nendran is one of the most popular varieties and cultivated on commercial scale and it belongs to *French* plantain group. The variety is used as table fruit and for chips making. The area under cultivation of banana is fast dwindling in Kerala due to the high pressure on land by more remunerative crops. Historical, commercial and to some extend religious involvement in its cultivation enable to prevent replacement to banana by other crops to some extent.

Banana having a root system spread in the top 60 cm soil, is a heavy feeder and the crop requires large quantities of nutrients for growth, development and yield (Hazarika and Ansari, 2010). Low fertility is one of the major constraints for the optimum crop growth and yield. In Kerala, crop is grown in large area but being an exhaustive crop and since sufficient replenishment of nutrients is not done, the productivity goes low in particular areas. Requirement of these nutrients are generally met through inorganic fertilizers. This often results in extreme situations for the soil, crop and climate involved.

Indiscriminate and imbalanced application of inorganic fertilizers affect sustainability of agriculture production adversely. Nutrient removal from soil by crops must be replenished. Use of chemical fertilisers alone may lead to deterioration of physical and loss of biological properties of the soil. With adequate supply of organic manures and biofertilizers the nutrients removed can be replenished and physical, chemical and biological properties of soil can be improved. Combined application of organic and inorganic sources of nutrients results in better utilization than inorganics alone. Cost of production and soil health will be maintained (Prabhuram and Sathiamoorthy, 1993).

Shukla *et al.* (2014) reported that in India on an average 43.0, 12.1, 5.4, 5.6, and 18.3 per cent soils are deficient in Zn, Fe, Cu, Mn, and B, respectively.

Multi micronutrient deficiencies due to depletion of soil fertility has become an emerging issue in agriculture, relating to crop as well as human health.

According to the recent reports, the deficiency of nutrients is increasing at an alarming rate. This holds true for Kerala as the fertility status reveals that 59 per cent of the soil are deficient in boron, 15 per cent in copper and 12 per cent in zinc. There is severe reduction in yield and quality of the crops produced in imbalanced soil conditions (Nair *et al*., 2013). Kerala soils are acidic and is not conducive for boron retention. Low activity clays has resulted in deficiency of boron.

Major problem of organic agriculture in India is the inadequate availability of organic manures. If at all the organic manures are available, their cost is a limiting factor. Many of them do not meet the quality standards. Work done in India is predominately related to INM and limited literature is available on nutrient management in pure organic farming (Reddy *et al*., 2010).

Organic and inorganic sources of nutrients have significant influence on fruit quality. The current agricultural policy emphasize a shift towards safe agricultural practices for which organic management is the best option. However, the crop behaviour under organic and inorganic management is not yet scientifically analysed and very limited literature is available. Hence, the research work is formulated to elucidate response of banana in terms of growth, yield and quality to nutrient sources.

The study entitled “Response of banana *Musa* (AAB) 'Nendran' to nutrient sources” was undertaken with two main objectives.

1) To elucidate the response of banana *Musa* (AAB) 'Nendran' in terms of growth, yield and quality to nutrient sources.
2) To compare the fruit quality of banana grown under organic and conventional systems in farmers’ field.

Review of Literature

2. REVIEW OF LITERATURE

Banana is one of the most important and remunerative tropical fruit crop. Banana is a nutrient loving plant which require large quantity of nutrients and water for its growth and development. However, the nutrient requirements of banana vary with the choice of variety, time, mode and frequency of application of nutrients. Banana responds well to both organic and inorganic sources of nutrients. Kulapati *et al*., (2002) estimated that expenditure on manures accounts only 20 per cent of total cost of production. It is important to go for combined application of nutrients to get crop with high yield and also good quality.

Banana is the fourth most important food crop after rice, wheat and maize worldwide. The fruit is both a staple food and an export commodity. Banana is a general term that refers to all wild species, land races and cultivars belonging to the family Musaceae, genus *Musa* (Ortiz, 2008). The genus *Musa* has more than 50 species, with some of these species having numerous sub species. Bananas (*Musa* spp.) are cultivated in over 130 countries, and are one of nature‘s best known sources of K and one of the most convenient and nutritionally dense food items. They are also good and inexpensive sources of vitamins A, B_6, C, and minerals. In addition to the well-known effects of K in lowering the risk of developing diseases such as heart attack and strokes, functional compounds in banana are reported to relieve constipation, heartburn, ulcers and have been linked to prevention of anaemia by stimulating the production of haemoglobin in the blood (Robinson and Sauco, 2010).

Plantain (*Musa* sp. AAB) is one of the important staple foods in the tropical and sub-tropical regions of the world (Englbergert *et al*., 2006). The fruit is an important source of carbohydrate, vitamins, proteins, potassium, iron, calcium, carotenes and ascorbic acid and also contains moderate amounts of thiamine, riboflavin, nicotinic and folic acid (Rasheed, 2003). Per capita annual consumption is as high as 150 kg in some traditional production areas of West and Central Africa (Vuylsteke *et al*., 1997).

2.1 Nendran

The banana variety Nendran ranks first in commercial value. The growers of Agasthiamali ranges call this variety as 'King of Banana'. The shelf life of the fruits of Nendran is more, compared to that of others. So, the fruits of Nendran have been exported to the Arabian and European countries (Das, 2010). Venugobal (2008) stated that bananas are commonly grown either in homesteads or in well drained rice field by small and marginal farmers. Nendran is the most popular commercial cultivar because of its excellent fruit quality, sustained income and multiple uses ranging from infant food, culinary purposes to diverse processed products. Fruit pulp of Nendran contains Vitamin B_1, B_2, B_3, Vitamin C, amino acids, iron, calcium, phosphorus and proteins in substantial amount which are needed for the daily diet of human beings (Das, 2010). Besides Nendran banana is having several medicinal properties too.

2.2 Banana nutrition

Research on the mineral nutrition of bananas reported by Lahav (1995) first involved the description of symptoms of plant deficiency and the determination of fertilizer rates in a range of soils (1920s-1970s). In the second stage (1960s-1990), it focused on the role played by nutrients in banana growth and development and on soil-plant relationships with respect to cationic balance Organic manures play vital role in plant growth as they supply all major and micro nutrients to the crops. Combined application of organic manures with chemical fertilizers will reduce the cost of production (Barker, 1975). Banana is a high nutrient demanding crop and for better growth and fruit production it requires high amounts of mineral nutrients which are often only partly supplied by the soil. The total nutrient requirement in banana may be supplied by the soil or by fertilization to obtain optimum yield on a sustainable basis (Rajput *et al.,* 2015). In conventional farming, the intensive use of chemical fertilizers and pesticides has proved to be a tremendous threat not only to food safety but also to the ecosystem's health and its sustainability (Carvalho 2017).

Twyford and Walmnsley (1974) revealed that to obtain a crop yield of 50 t/ha/year of fresh fruit, about 1500 kg K_2O ha^{-1} $year^{-1}$ may be extracted from

the rhizosphere soil. Amounts of other nutrients found extracted in the field grown plants at harvest are (in kg/ha/year): N-450; P-60; Ca-215; Mg-140; B-1.25 respectively. Thus huge quantities of nutrients have to be replaced in order to maintain soil fertility and to permit the sustainable higher yield. Bananas and plantains require large quantities of mineral nutrients to maintain high yields and these can only be supplied by growing on rich soils or by applying supplementary fertilizers. Only about 15 per cent of bananas and plantains worldwide are intensively fertilized, the remainder being grown with organic matter, household refuse or nothing (Robinson, 2000).

Optimum leaf nutrient concentrations for plantains do not differ very much from those for bananas. Nutritional reference norms for Horn plantain leaves are as follows: N 2.7%; P 0.2%; K 4.3%; Ca 0.5%; Mg 0.3%; Zn 10 ppm; Cu 9 ppm; Mn 66 ppm; Fe 69 ppm; S 1 ppm (Rodriguez *et al*., 2007). Lower inherent soil fertility like soil organic matter, total N and the ratio K/ (Ca + Mg) has been suggested as a limitation for banana production (Wairegi *et al*., 2010). P and Mg deficiencies were observed mainly on highly weathered soils and K deficiencies dominate generally on soils which have a slower weathering rate or that is inherently lacking due to the nature of the parent material (granite and quartzite) (Gaidashova *et al*., 2009). Optimum K/Mg ratio as suggested by Delvaux (1995) is 0.3:1. Soil constraints (*i.e.* soil pH, K, Mg and Ca) were found to account for 67% of yield reduction to banana *cv.* Cavendish in smallholder farms in central Kenya (Okumu *et al*., 2011). Magdoff (1995) reported the essentiality of the synchrony of plant available nutrients in the soil and crop nutrients demand for optimum performance and environmental protection.

Organic and inorganic sources of nutrients not only affects the yield and fruit quality but also the soil properties. Hence, the available literature pertaining to the investigation on banana and related crops with respect to above aspects has been presented in this chapter under the following sub-headings.

2.3 Effect of inorganic fertilizers on growth, quality and yield parameters

2.4 Effect of organic and inorganic sources of nutrients on growth, quality and yield parameters

2.5 Nutrient sources affecting fruit qualities in other fruit crops

2.6. Effects of nutrient sources on available soil and plant nutrients

2.3. Effect of inorganic fertilizers on growth, yield and quality parameters

The nutrient requirement of banana is very high which is mainly exploited from a very limited soil depth due to shallow root system of the crop. Increase or decrease of one nutrient element may substantially increase or decrease the uptake of the other nutrients. Banana has a high demand for nitrogen and specifically potassium. Hence, better vegetative growth ensures better bunch development. Banana takes up more nutrients per unit area than any other crop. The high fertilization requirement of banana is mainly due to its rapid vigorous growth and high fruit yield. Significant increase in length of finger as well as number of hands and weight of hands was observed when there was application of nitrogen in presence of phosphorous and potash in banana *cv.* Robusta was carried out (Singh, 1972) and the reducing sugar content was higher in treatment with K combination. (Sharma and Roy, 1972) reported that application of fertilizer mixture with of 900 kg N, 480 kg P_2O_5 and 480 kg K_2O /ha increased the vegetative growth which resulted in higher yield in *cv.* Jahaji banana. Application 191 g N and 301 g K/plant increased the fruit number and bunch weight respectively (Pillai *et al*., 1977).

Combined application of nitrogen, phosphorus and potash at the rate of 100 kg, 40 kg and 400 kg /acre respectively produced the heaviest bunches in Robusta banana (Nanjan *et al*., 1980). Mustaffa (1983) noticed that application of 150 g N/plant produce higher yields in hill banana. Chundawat *et al*. (1983) reported that with the application of NPK fertilizer at 180:108:225 g/plant respectively, in three split doses within six months of planting increased in yield of Basrai banana.

Turner (1985) conducted an experiment with a fertilizer dose of 200 to 250 kg N, 50 kg of P_2O_5 and 400 kg of K_2O/ha/year which resulted in higher yield of 50 tonnes/ha. Ram and Prasad (1988) opined that application of 200 g N, 80 g P_2O_5 and 200 g K_2O /plant in banana *cv.* Campeirgani Local, resulted in the highest TSS content (21.20 %).

Upadhyay (1989) recorded that there was increase in yield and fruit quality, when there was application of higher rate of phosphorus and potash respectively. Application of 400 g of Ammonium sulphate, 300 g of SSP and

250 g MOP/plant, resulted in maximum yield of 35 t/ha and number of hands/bunch.

Pathak *et al.* (1992) noticed that fruit size, weight of bunch and finger, number of hands and fingers per bunch were increased by applying 300 g each of N and K_2O in banana *cv.* Harichal.

Results of the study reported by Ray *et al.* (1993) revealed that application of 200:100:300 g NPK/plant resulted in higher fruit yield (74.9 t/ha) in *cv.* Basrai banana. Natesh *et al*., (1993) reported that application of 190 g N, 115 g P_2O_5 and 300 g K_2O /plant/year in banana *cv.* Nendran, was better in terms of fruit yield and quality. Maximum weight of bunch, hands, finger, pulp, TSS, total sugars and sugar acid ratio were also higher.

Parida *et al.* (1994) recorded that there was increase in plant height, pseudostem girth and number of leaves/plant and significantly reduced time to shoot in banana *cv.* Robusta was obtained by integrated application of NPK.

Raju (1996) revealed that the maximum bunch weight of 49.84 kg which further accounted for the total yield of 157.77 t/ha in TC banana *cv.* Grand Naine by applying 300 g N with 400 g K/plant.

Agarwal *et al*. (1997) suggested that application of 450g of N recorded higher finger length, girth, weight, pulp to peel ratio and better quality of fruits in terms of TSS, sugar in plants of banana *cv.* Robusta and application of potassium of 450 g and 600 g applied in four splits produced fruits with high TSS and sugar content respectively. However, there was no significant variation observed in acidity and sugar- acid ratio by the different treatments.

Nalina (1999) noticed that *cv.* Robusta which received 300: 90: 450 g NPK/pit recorded higher bunch weight with good quality fruits. The study conducted by Armugan *et al*. (2001) revealed that banana *cv.* Robusta produced large pseudostem with early shooting and subsequent maturation and harvest was obtained when it was applied with 200 g N and 400 g K per plant.

2.4. Effect of organic and inorganic sources of nutrients on growth, yield and quality of banana

Combined application of inorganic fertilizers, organic manures and biofertilizers all together at a time in a sequence, during growth and developmental stages of plants, produced fruits with better quality which was cost effective and ecofriendly *i.e.* without any adverse effects on soil health and

environment. INM envisages the use of chemical fertilizers with organic sources like farmyard manure, poultry manure, neem cake, oil cake, vermicompost, etc., along with biofertilizers in judicious combinations for agricultural productivity and farm profitability (Selim 2020). A brief review of literature on the effects of organic and inorganic sources of nutrients on banana is presented.

2.4. 1. Growth parameters

Nayar (1953) revealed that the application of cattle manure to supply 0.5 lb N plus 25 lb of nitrogen supplied as ammonium sulphate recorded maximum height of plants and bunch weight in *cv*. Poovan banana.

According to Chattopadhayay *et al.* (1980), higher levels of nitrogen increased height and pseudostem girth in banana significantly**.** Increased nitrogen application gave the highest number of functional leaves as suggested by Ramaswamy and Muthukrishnan (1973).

Mustaffa, (1983) noticed that application of 150 g N/plant produce better growth characters in hill banana. Inoculation of *Azospirillum* in combination with the nitrogenous fertilizer in banana *cv.* Poovan (AAB) plants resulted in increased plant height and pseudostem girth, leaf production, and leaf area compared to non-inoculated control plants which receive 100% nitrogen alone. (Jeeva *et al.,* 1988).

Kumar and Shanmugavelu (1988) reported that foliar and soil application of nitrogen along with *Azotobacter* resulted in increased plant height and pseudostem girth in banana *cv.* Robusta.

Hedge and Srinivas (1991) found that application of NPK through fertigation influenced the vegetative growth of banana. Prabhuram and Sathiamoorthy (1993) reported that the application of 25 per cent N as FYM + 50 per cent N as neem cake + 25 per cent N as urea, resulted in lesser crop duration in banana *cv.* Rasthali.

Srinivas (1996) observed that nitrogen and potassium application @ 200g per banana plant significantly increased the height of plant and pseudostem girth.

Ushakumari *et al.* (1997) reported that combined application of inorganic fertilizers with vermicompost in banana *cv.* Poovan and Robusta resulted in reduction of crop duration and cost of production.

Application of vermicompost 2kg/plant along with 75% recommended dose of fertilizers for banana, produced crop with minimum number of days (236.30) for shooting and total crop duration (369 days) (Athani *et al.,* 1999).

Hasan *et al*. (1999) investigated the influence of different levels of N and K on phyllocron, sucker production and shooting interval of banana *cv.* Giant Governor. N application @ 300g/plant in combination with 400g K_2O/plant significantly reduced shooting interval and increased the sucker production.

Response of *in vitro* banana *cv.* Robusta plants to split application of N (350, 450 g/ plants) and K (300, 450 or 600g/ plant) in combination with P 200 g/plant was studied by Agarwal *et al.* (1999). At flowering stage treatment 450g N + 450g K with 5 splits application recorded the maximum plant height (2.84 m), girth (54.61 cm) and leaf number.

Soorianathasundaram *et al*. (2000) observed that plant height was higher when plants were supplied with 75 % of nitrogen as urea, than when supplied with N at 50 %; whereas, pseudostem girth was maximum in plants when the entire quantity of N was supplied as urea. The study was conducted in Nendran banana.

Deolankar and Firake (2001) found that application of water soluble fertilizer (40 , 60, 80 and 100 g/plant) and grade (20: 10: 10, 18: 9: 18, 10: 20: 20,15: 15: 15, 34: 0: 0) as well as drip irrigation influenced the growth in terms of plant height, stem girth in banana.

Jayabaskaran *et al.* (2001) reported that there was significant increase in plant height, pseudostem girth, leaf area (cm^2) and number of leaves in plants which were supplied with poultry manure (15 kg) or rice husk ash (15 kg). 20% of NPK requirement in ratoon banana *cv.* Poovan could be saved.

Nalina (2002) concluded that application of 150% of the recommended dose of fertilisers in 4 splits in Robusta banana increased growth characters at all stages and resulted in highest plant height, girth, number of leaves, leaf area and leaf area index at shooting. Shorter phyllochron, less interval for shooting and harvesting were also observed.

According to Pandey *et al*. (2002), application of 300g N, 400g K in 7 splits at 45 days interval recorded maximum plant height (247.50cm) and maximum leaf area (1.45 m^2) followed by split application of N and K (300g

and 400g).

Results of the study reported by Shakila and Manivamnan (2002) show that application of N and K fertilizer (200 and 300g/ plant) in 7 split doses at an interval of 30 days from one month after planting resulted in vigorous growth of tissue cultured banana *cv*. Robusta. Plant height, girth, production of leaves, leaf area and retention of number of functional leaves at shooting stage was more. Flower initiation was earlier by 23 days and fruit maturity by 9 days, thereby reducing crop duration by 31 days.

Sabarad (2004) observed that inoculation with VAM, *Trichoderma harzianum* in combination with 180: 108: 225g NPK /plant resulted in better growth in banana.

Balakrishna *et al.* (2005) reported that increased leaf production may enhance photosynthesis and flowering stimulus, thus influencing early flowering as there was maximum leaf number at shooting stage.

Naresh and Anamika (2005) reported greater plant height (153.34 cm) and girth of pseudostem (61.35 cm) of banana *cv.* Jahaji under 100% NPK + 20 kg FYM +10 kg Azolla. Number of fingers per bunch (60.35) was maximum under 50% NPK + 20 kg FYM + 10 kg Azolla and maximum size of fingers, finger length (13.18 cm) and weight (92.68 g) was observed in 100% NPK + 20 kg FYM treated plants.

Athani *et al.* (2009) opined that *in situ* vermicomposting in banana resulted in increased plant growth *viz.* pseudostem height, girth, number of functional leaves, leaf area and leaf area index in *cv*. Rajapuri.

Bhalerao *et al.* (2009) revealed that the application of 100 per cent recommended dose of NPK @200: 40: 200 g /plant with 10 kg FYM per plant and biofertilizers *(Azosprillum* and PSB at 25 g /plant) in banana *cv.* Grand Naine, resulted in maximum plant height (216.0 cm), pseudostem girth (70.92 cm), reduced shooting interval (258.5 days) and with a crop duration (356.9 days).

Kulapati *et al.* (2009) found that banana *cv.* Dwarf Cavendish plants when applied with 100% RDF + *Azotobacter* + PSB + *Trichoderma harzianum*, recorded maximum plant height (127.68 cm), plant girth (18.75 cm), number of leaves (22.90) and leaf area (12.34 m^2).

Baset *et al.* (2010) noticed synergistic effects on root growth and

development in banana plants inoculated with PGPR along with reduced levels of fertilizer-N which further also increase yield and fixes N_2 and resulted in early flowering. Selvamani and Manivannan (2009) reported that integrated supply of nutrients to plants led to reduction in crop duration.

Increased pseudostem height and girth, total number of leaves, days taken to shooting and earlier harvesting with application of 20 kg FYM + 1 kg *neem* cake + 200: 40:200g NPK plant^{-1}.was reported by Badgujar *et al.* (2010).

Application of 100% RDF + *Azospirillum* (50 g/plant) + PSB (50 g/plant) + VAM (250 g/plant) + *Trichoderma harzianum* (50 g/plant) recorded the highest plant height (196 cm), pseudostem girth (70.9 cm) and maximum functional leaves (12.7) in banana *cv.* Grand Naine (Gaikwad *et al.,* 2010).

Mahalakshmi *et al*. (2000) found that application of 100% RDF of N and K (200, 300g) with fertigation and irrigation @ 25 l/day recorded vigorous plant growth and earliest flowering in *cv.* Robusta banana.

Phirke and Mahorkar (2010) reported that fertigation with organic manures like nitrogen fixing bacteria, PSB, VAM and biofertilizers increased porosity of soil and infiltration rate of water in banana fields.

Application of 75% RDF (150g N: 60g P: 155 g K/plant/crop cycle) + application of N: P: K in the ratio of 3: 2: 1 at vegetative stage and 1: 3: 2 at flowering stage and 2: 1: 3 at fruit development stage resulted in maximum plant height (261.50 cm), pseudostem girth (65.75 cm) and total leaf area (19.88 m²) in Monthan banana (Dinesh *et al*., 2012).

Patel *et al.* (2012) conducted an experiment where banana *cv.* Grand Naine plants were applied with inorganic nitrogen in combination with castor cake and *Azotobacter* or *Azospirillum* and the result was always advantageous than application of inorganic nitrogen alone as it produced early vegetative growth and improved yield.

Patil and shinde (2013) conducted an experiment in which the maximum plant height (190.84 cm) and pseudostem girth (81.34 cm) were recorded in treatment 50% RDF + FYM+ *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant). The minimum number of days (211.03) for shooting after planting and number of days for harvesting after shooting (117.46) were also recorded in same treatment in banana *cv.* Ardhapuri**.**

Kuttimani *et al.* (2013) reported that maximum number of hands (10.2 and 10.3), number of fingers (136.3 and 145.2), bunch weight (23.9 and 25.3 kg/plant) and total yield (72.8 and 77.1 t/ha) were obtained through application of 100% recommended dose of fertilizer (RDF) along with 40% Wellgro soil.

Vanilarasu *et al.* (2014) studied the use of organic manures in banana *cv.* Grand Naine (AAA) and results revealed that the treatment (Farmyard manure @ 10 kg + Neem cake @ 1.25 kg + Vermicompost @ 5 kg and Wood ash @ 1.75 kg /plant + Triple green manuring with sunhemp + Double intercropping of cow pea+biofertilizers *viz.*, *Vesicular Arbuscular Mycorrhizae* @ 25 g, *Azospirillum* @ 50 g, Phosphate solubilizing bacteria @ 50 g and *Trichoderma harzianum* @ 50 g/plant) registered the highest growth characters (Palnt height and girth – 218 cm and 69.53cm, number of leaves-14.56, leaf area index- 3.79, early crop duration - 345.75 days) and yield characters like bunch weight- 27.96 kg, fresh and ripe finger weight – 280.25 and 259.40 g.

Lenka and Lenka (2014) reported that in tissue culture plantlets of banana *cv.* Grand Naine, plants when treated with (RDF 100% + PSB + *Azospirillum,* resulted in increase in vegetative parameters such as plant height, pseudostem girth at the time of shooting significantly.

Hafiz *et al.* (2016) conducted an experiment and revealed that banana plants, which were applied with recommended dose of nitrogen (RDN) via 25% as a mineral source and 25 to 50% as an organic one enriched with 50 or 25% of effective microorganisms or biomex significantly enhanced the height and circumference of pseudostem, leaf area and total leaf area/plant as well as nutrients of leaves like N, P and K.

Hemla *et al.* (2016) reported that banana *cv.* Grand Naine plants treated with farm yard manure (15 kg) + Neem Cake (1.875 kg) + Vermicompost (7.5 kg) + Wood ash (9.94 kg) recorded higher yield as well as quality characters.

2.4.2. Yield and yield attributing parameters

Bhan and Muzumdar (1956) found that shooting was advanced by about 31 days at the lowest level of nitrogen (100g N/plant). Similar results were reported by Ramaswamy and Muthukrishnan (1973). Entire crop cycle in Cavendish banana was reduced by one month by N. Maturation period was shortened by 14 days and time from planting to shooting by 10 days, application (Arunachalam *et al.,* 1976). Kohli *et al.* (1984) reported that

flowering was delayed considerably without nitrogen application. The required net assimilation could have been reached early in the plants receiving higher dose of nitrogen, thus hastening the process of initiation and emergence of inflorescence (Chattopadhayay *et al.,* 1980).

Teaotia *et al*. (1972) reported that application of NPK in the range of 72-200:90-96:150-480 g per plant increases vegetative growth and yield in banana *cv.* Dwarf Cavendish.

Kohli *et al*. (1976) stated that application of fertilizer at the range of 100-180:15-100:186-400 g of NPK per plant improved the growth and yield in banana *cv.* Robusta.

Koen *et al*. (1976) observed increased yield in Dwarf Cavendish banana with the application of 450:36.8:210 g NPK / plant. Application of nitrogen increased the number of hands, number of fruits and weight of fruit in *cvs*. Dwarf Cavendish, Giant Cavendish, Robusta.

Ramaswamy (1976) reported that soil application of 110 g and 330 g each of N and K_2O along with the foliar application of P increased bunch weight and reduced crop duration by 13 days and with a benefit: cost ratio of 2.7 as against 1:2.3 in conventional system.

Application of cattle manure along with cattle-shed washings and slurry @ 8.25t ha^{-1}at every four months increased yield attributes in banana (Herath *et al.,* 1977).

Chattopadhaya and Bose (1986) observed that bunch size of banana increased significantly through application of 240 g and 480 g K_2O per plant.

Reddy *et al.* (1987) reported that bunch weight of Robusta and Dwarf Cavendish banana increased with higher level of K. Finger weight had the most significant influence of K. Reports suggest that application of 150 to 260g N plant-1 registered vigorous plant growth, early flowering, highest bunch weight and yield in banana cv. Robusta (Randhawa *et al.,* 1973; Kotur and Mustaffa, 1984; Kohli *et al.*, 1984).

Mustaffa (1988) reported in hill banana, largest bunch size (22.69 kg) was obtained on application of 300 g K_2O per plant.

Jeeva *et al*. (1988) reported that the inoculation of nitrogen fixing bacteria *Azospirillum* combined with 100% N fertilizer resulted in increased yield up to 13% in Poovan banana and effected in saving of 680g N/ha.

Yadav *et al.* (1988) revealed that application of potassium at 44th to 47th week after planting was better for growth and development of bunches and for better finger filling resulting in increased finger weight, length and girth of banana fruits.

Gomes *et al.* (1988) noticed that the highest bunch weight (10.90 kg) was obtained from plants applied with farm yard manure + NPK in banana *cv.* Prata. Significant increase in yield and reduced pest damage was observed when plants were applied with poultry manure and farm yard manure (Obiefuna *et al.,* 1989). Geetha *et al.* (1998) reported that fruit length of Nendran banana was increased up to 26.6cm through application of 400g N in four splits.

Hedge and Srinivas (1991) found that application of NPK in the form of fertigation influenced the number of hands and finger, bunch weight and fruit yield in banana.

Pandit *et al.* (1992) reported that application of N and K (300 g/ plant each) in banana *cv.* Harichal gave higher yields. Ray *et al*. (1996) recorded maximum yield by the application of 200:100:300 g NPK /plant in banana *cv.* Basrai. Gubbuck *et al.* (1993) found that the highest growth rate of fingers of banana plants was recorded when the plants were supplied with 80 g N / mat and 255 kg FYM/mat for Dwarf Cavendish banana and 320 g N/mat and 150 kg FYM/mat for Basrai cultivar.

Guerrero and Gadbau (1996) observed that application of recommended dose of 550:750 g N and K/ plant resulted in increase in growth and yield in banana *cv.* Williams.

Agarwal *et al.* (1997) studied the influence of high status of N and P on fruit characters of *in vitro* banana *cv.* Robusta and found that fruit characters *viz.* finger length, girth, weight, pulp: peel ratio, finger weight were high with a combination of 450 g N, 300 g P_2O_5 in 4 splits application of N and P.

Increase in bunch weight (15 kg), more number of fingers per bunch and higher reducing sugars was noticed in plants which were applied with vermicompost as full N sources in banana, *cv.* Njalipoovan (Ushakumari *et al.,* 1997).

Purakayastha and Bhatnagar (1997) revealed that application of FYM increased the yield by accelerating the respiratory process, by increasing cell

permeability, by hormone growth action or by combination of all these processes. It undergoes biological decomposition and supplies nitrogen, phosphorus, potassium and sulphur in available forms to the plants. It improves physical properties of soil such as aggregation of soil, water holding capacity and permeability.

The study conducted by Athani *et al.* (1999) revealed in banana *cv.* Rajapuri application of organic matter as vermicompost in combination with inorganic fertilizers increased the yield and quality.

Application of biofertilizers as *Azospirillum* and organic manure (FYM) along with 75 % NPK was effective in increasing bunch weight in hill banana *cv.* Virupakshi (Chezhiyan *et al.,* 1999).

Hasan *et al*. (1999) studied the response of K on yield and quality of banana *cv.* Giant Governor. It was concluded that application 500 g K_2O /plant significantly increased finger weight, number of hands, number of finger per hand, fruit length and bunch weight.

Patel *et al*. (1999) studied the influence of application of NPK in split doses with varying level of potassium and obtained improved bunch characters of banana *cv.* Dwarf Cavendish in first ratoon crop. They also revealed that N and P application rates had significant effect only on finger weight and split application had significant effect on finger weight and pulp weight.

Tiwary (1999) reported that banana (*Musa*, AAA) *cv.* Giant Governor inoculated with nitrogen fertilizer +*Azotobacter* and *Azospirillum* either once or twice or in combination with 60% and 100% nitrogen improved yield.

Geetha and Nair (2000) reported that the application of *Azospirillum*, green manuring with cow pea and vermicompost *(Eudrilus euginiae*) in banana *cv.* Nendran resulted in increased weight of bunch (13.15 and 12.19 % respectively).

Application of NPK 200:30:200g NPK/plant as fertigation in *cv.* Robusta influenced the bunch weight with corresponding highest number of hands and fingers (Mahalakshmi *et al*., 2000).

Tirkey *et al*. (2002) stated that the yield attributing characters of banana *viz.* bunch weight, number of hands and total number of fingers per bunch markedly increased in combination of 300 g N+ 5 split application of NPK in tissue culture banana *cv.* Dwarf Cavendish. An increase in bunch weight (5.1

kg) compared to control (4.43 kg) was noticed in banana *cv.* Israli Grand Naine where the organic manures were applied. Significantly higher banana yield under 100 % NPK along with 20 kg FYM and 10 kg Azolla per plant was reported by Naresh and Khanna (2002).

Shakila and Manivamnan (2002) observed that split application of N and K fertilizers (200 and 300 g/plant in 7 splits) increased bunch weight and finger characters significantly resulting in higher yield in tissue culture banana *cv.* Robusta.

Pandey (2002) reported that bunch weight was maximum in Robusta banana at 300 g N, 400 g K in 5 split application. Fruit weight, finger length and girth were maximum in 400 g K application.

Nalina (2002) found that 150% RDF of NPK (165:55:495 g/plant) in four split *viz*., 2, 4, 6 and 8 months after planting was essential to increase the growth, development, yield of tissue cultured banana.

According to Tirkey *et al.* (2002), banana *cv.* Dwarf Cavendish when applied with 100:100:150 g NPK/plant along with organic manures @10 kg poultry manure/plant resulted in better growth, yield and early cropping compared to control.

Mustaffa *et al.* (2003) reported increased bunch weight of banana plants when treated with distillery sludge (25 kg) + vermicompost (1 kg) + neem cake (1 kg) + poultry manure (2.5 kg). Application of organic manures significantly improved growth parameters in banana varieties Rasthali and Karpuravalli (Mustaffa *et al*., 2004).

Naresh *et al*. (2004) observed that application of 240g N/ plant in four doses at 2,4,6 and 8 months after planting recorded higher number of finger/bunch, yield in banana *cv.* Jahaji.

Gogoi (2004) observed that combined application of biofertilizers and half dose of inorganic fertilizers increased the yield of banana and soil NPK availability.

Sabarad (2004) recommended that inoculation of VAM + *Trichoderma* in combination with 180:108:225 g NPK/plant produced better growth and yield.

Application of 100 per cent of the recommended dose of fertilizer along with 50 g each of *Azospirillum*, PSB and VAM to the banana *cv.* Robusta

plants resulted in better yield and its attributing characters (Vidhya, 2004).

Naresh and Anamika (2005) opined that banana *cv.* Jahaji plants applied with 50% NPK + 20 kg FYM + 10 kg Azolla produced the highest yield (17.06 kg/bunch) followed by 75% NPK + 20 kg FYM + 10 kg Azolla treated plants.

Athani *et al.* (2005) studied that guava plants given with 75 per cent RDF + vermicompost (10 kg per plant) produced fruits of higher polar diameter (7.55 cm), fruit weight (221.00 g), fruit volume (218.50), peel thickness (2.33 cm) and pulp weight (143.00 g).

Maximum pseudostem height and circumference at shooting stage and reduced phyllochron in *cv*. Robusta was obtained by application of 300g nitrogen in both the first and second crop (Pandey *et al,* 2005).

Hazarika and Ansari (2007) reported the influence of varying levels of Nitrogen on banana plantation of *cv.* Jahaji (*Musa* AAA) and recorded highest bunch weight in plants which were given 160g N per plant.

Significant increase in yield parameters of banana with integrated nutrient management practices was reported by Ravi and Sujatha (2007).

Suma *et al*. (2004) observed highest number of hands (8.35) and finger per bunch (121.67) with application of NPK @ 200:40:200 g /plant in *cv.* Grand Naine. Banana *cv.* Jahaji plants when integrated with organic manures, biofertilizers and inorganic fertilizers produced better finger characters. (Hazarika and Ansari, 2008).

Bhalerao *et al.* (2009) reported that use of organic manure alone was not found beneficial as compared to integrated nutrient management for getting maximum yield in banana *cv.* Grand Naine. Application of 100% RDF with 10kg FYM/plant and biofertilizer (*Azospirillum* and PSB @ 25g/plant each) were better in terms of yield and high net return, followed by application of 50% NPK through organic (FYM+ green manure) and 50% NPK through inorganic fertilizers and biofertilizers.

Hazarika *et al.* (2009) revealed that application of 100% RD of NPK+FYM+ PSB + *Azospirillum*+ *Trichoderma hazianum* enhanced the shelf life of banana and also reduced crown rot infestation.

Thangaselvabai *et al*. (2009 a) reported that application of higher level of nitrogen and *Azospirillum* along with 100g inorganic N produced higher

yield (19kg/plant) of better quality fruits with cost benefit ratio 2.41 and recorded minimum days for shooting (272 days), similarly application of inorganic N (200 g/plant) in 4 splits increased the yield of banana.

Thangaselvabai *et al*. (2009 b) reported that a fertilizer dose consisting of 200:35:330g NPK/plant +20 ton FYM/ha + 5 kg *Azospirillum* and PSB/ha, 250g neem cake/plant with foliar application of micro nutrients increases yield in banana.

Hathi and Yahyai (2009) reported that application of higher dose of fertilizer (900:150:750g NPK /plant per year) in Cavendish banana *cv.* Williams resulted in reduction of bunch weight and lower fruit weight.

Bhalerao *et al.* (2009) recorded that banana *cv.* Grand Naine plants treated with 100 % recommended dose of NPK with 10 kg FYM per plant and biofertilizers *(Azosprillum* and PSB at 25 g each per plant) were found beneficial and improved yield characters; maximum hands per bunch (9.47), fingers per bunch (167.7), weight of bunch (17.21 kg/plant) and yield (76.5 t/ha) and monetary returns with the highest benefit cost ratio.

Syed (2009) opined that banana *cv.* Ardhapuri plants recorded highest bunch weight (18.4 kg) and yield (81.8 t/ha) when supplied with 200:150:200 g/plant combined with organic booster slurry at 6 litre/plant.

According to Kulapati *et al.* (2009) in banana *cv.* Dwarf Cavendish highest number of hands (9.23), fingers per bunch (166.20) and highest fruit yield (81.24 t/ha) were obtained when 100 % RDF + *Azotobacter* + PSB + *Trichoderma harzianum* was applied.

Sundararaju and Kiruthika (2009) reported that better growth characters like pseudostem height, girth, number of leaves, number of roots, root length and root weight were obtained in cv. Robusta through application of *Paecilomyces lilacinus* 10g plant-1 + *neem* cake 100g plant^{-1}.

Barakat *et al*. (2011) found that application of biofertilizers in combination with compost, rock phosphate and feldspar produced maximum bunch weight with better fruit characteristics in *cv.* Williams.

Bhalerao *et al*. (2009) studied the effect of different sources of nitrogen on growth and yield of banana *cv.* Grand Naine under drip irrigation. Application of 25% N through ammonium sulphate + 25% N through CAN was beneficial for attaining maximum plant vigour, early flowering and

reduced crop duration.

Hazarika *et al*. (2011) studied the effect of integrated nutrient management with different combination of organic, in organic and biofertilizer for tissue cultured Grand Naine banana. It is indicated that yield attributing characters *viz*. number of fingers per hands, finger length, finger volume, finger girth and finger weight were significantly influenced by biofertilizers, organic manures and inorganic fertilizers. 100% RDF + VAM + *Azospirillum* + PSB + *Trichoderma hazianum* increased yield and soil characteristics significantly. 75% RDF + VAM + *Azospirillum* + PSB + *Trichoderma hazianum* improved the soil characteristics after harvest like organic carbon, pH, and availability of NPK.

Dinesh *et al*. (2012) investigated the effects of NPK with fertigation on growth, yield and quality of vegetable banana Monthan (Banthal ABB) and reported that highest number of hands and fingers (7.20 , 70.12/ plant), bunch weight (11.45 kg / plant), fruit yield (28.63 t/ha), finger weight (163.29 g) , productive efficiency (0.575 kg/m^2 leaf area), earliest shooting and fruit maturity was recorded when 75% RDF + NPK in the ratio of 3:2:1 at vegetative state, 1:3:2 at flowering stage and 2:1:3 at fruit development stage was applied.

Goutam *et al*. (2012) reported that in mango application of INM produced maximum number of fruits per panicle, longer length, width, fruit weight, pulp weight, number of fruit and fruit yield in T_8 (50% RDF+50 kg FYM +10 kg Vermicompost). TSS is also influenced by integrated nutrient management. Shelf life of mango fruit was also influenced significantly by INM treatment. The treatment T_2 (T_1+Zn+B+Mn+Ca), T6 (half of T1 + 50 kg FYM + *Azospirillum* 250 g), T7 (half of T1 + 50 kg FYM + *Azotobacter* 250 g) and T9 (half of T1 + 50kg FYM + *Pseudomonas fluorescens* 250 g) enhanced storage time (>15 days) at room temperature. On the other hand the control treatment having full dose of NPK only reduced the storage or shelf life (9.9 days) of fruits.

Patel *et al.* (2012) conducted a study in which banana *cv.* Basrai plants were supplied with 10 kg FYM + 180 g N in organic form (Castor cake) + 90 g P_2O_5 + 180 g K_2O/plant resulted highest fruit yield (17.50 kg/plant).

Patil and Shinde (2013) reported that application of 50% RDF + *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM *Glomus fasciculatum* (250 g/plant) in banana *cv.* Ardhapuri plants resulted heavier bunch weight (19.31 kg) and yield (85.80 t/ha).

Lenka and Lenka (2014) reported that tissue culture banana *cv.* Grand Naine supplied with (RDF 100% + PSB + *Azospirillum*) resulted in significant increase in yield attributing characters like early shooting, weight of bunch, number of hands per bunch and number of fingers per bunch.

Chhuria *et al*. (2016) observed maximum bunch weight, number of hands/bunch, and number of fingers/bunch in banana *cv*. Grand Naine when treated with 100% RDF (300:100:300 g NPK) + 125 g of Azotobacter, Azospirillum, and PSB.

Hafiz *et al.* (2016) reported that application of recommended dose of nitrogen (RDN) via 25% as a mineral source and 25 to 50% as an organic one enriched with 50 or 25 % of EM or bio-mex significantly enhanced bunch weight and hand weight consequently increasing the yield of banana compared to use the RDN alone as a mineral N fertilizer.

Lenka *et al.* (2016) reported that 100% RDF + PSB + Azospirillum increased pulp weight (103.81 g), peel weight (32.44 g of banana *cv*. Grand Naine.

Kaswala *et al*. (2017) reported that fertigation with organic manures improved soil organic carbon and nutrient availability to banana plant.

Pattar *et al*. (2018) reported better length of the bunch, number of hands per bunch, the weight of bunch, number of fingers per hand and bunch, the weight of the finger, length and girth of the finger, yield per plant, and the total yield on treatment with 100% RDF (200:100:300 g N: P_2O_5: K_2O + 20 kg FYM per plant) + PSB (20 g) + Azospirillum (20 g) dose in banana *cv*. Rajapuri.

2.4.3. Quality parameters

Chattopadhaya and Bose (1986) reported that application of 240 and 480g K_2O per plant through soil in Dwarf Cavendish results in an increase in TSS content (13.10 %) and total sugars (11.00 %).

Mustaffa (1988) reported that increase in level of applied K in soil from 0-400 g K_2O per plant in Dwarf Cavendish banana reduced acid content of fruit

significantly. Ascorbic acid content increased from 62.2 to 108.6 mg per 100 g pulp in hill banana with application of 300 g K_2O per plant.

Application of organic manure 'Compost El-Neel' at 75 kg/stool/year on the Williams banana resulted in fruits with improved physical characteristics (Abd El-Aziz, 2002). Vermicompost is a type of compost which is produced from earthworms, enriched with both primary and secondary nutrients. Earthworm derived nitrogen could supply 30 per cent of the total crop requirement as it is a rich source of readily available nutrients for plant growth (Curry and Byrne, 1992). It also contains beneficial microbes like nitrogen fixing bacteria, mycorrhizae and growth promoting substances (Barik *et al.,* 2006).

Nalina *et al*. (1999) studied the effects of nutrient levels on bunch characterstics of banana *cv.* Robusta and reported that fruit quality traits improved with increase in level of fertilizer. Hassan *et al.* (1999) investigated the influence of potassium on yield and quality of banana *cv.* Giant Governor and stated that the highest TSS was in plant grown with 500 and 600 g K_2O/plant.

The fruit quality characters like high total sugars, reducing sugars, non-reducing sugars, TSS, more shelf life, less acidity and maximum sugar: acid ratio was obtained by *in situ* vermicomposting at 1,25,000 earthworms per hectare in both plant and ratoon crop of banana *cv.* Rajapuri (Athani and Hulamani, 2000).

Vijayraghavan and Ayyamperumal (2000) revealed that foliar application of 1% urea and 2% MOP as a mixture increased the bunch weight and fruit quality of banana.

Abd EI-Naby (2000) reported that best quality parameters like total soluble solids/acid ratio was noticed in banana plants *cv.* Maghrabi which were applied with compost and 50% chemical fertilizers.

The study conducted by Suresh and Hassan (2001) revealed that banana *cv.* Giant Governor plants inoculated with *Azospirillum* and *Phosphobacteria* produced fruits with good quality. These results further proved that the combined use of biofertilizers and recommended dose of fertilizers effective in improving quality of fruits.

Pandey *et al*. (2002) studied the performance of tissue culture banana

cv. Robusta raised under different combination of N and K and reported that acidity, TSS, acid sugar ratio were best when 7 split application of 300 g N and 400 g K were applied.

Sharma (2002) observed that quality attributes of banana *viz.*, total sugar (16.88 %), starch (2.28 %) and protein (1.50 %) were improved when plants were applied with *Azotobacter* + 75 % inorganic nitrogen.

Tirkey *et al.* (2002) reported that application of 300g N in 5 splits significantly increased the TSS (23.8 °brix), reducing sugar (6.38 %), total sugars (17.48 %) and sugar acid ratio in tissue culture banana *cv.* Dwarf Cavendish.

Mustaffa *et al.* (2004) found that Banana *cv.* Rasthali and Karpuravalli plants when applied with 2.5 kg compost + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure at 3, 5 and 7 months after planting, resulted in fruits with maximum TSS (29.40^0 B and 32.20^0 B), acidity (0.59 % and 0.61 %), sugar - acid ratio (49.8 and 52.8), total sugars (25 % and 26.3 %) and low starch contents (3.2 % and 3.4 %) respectively.

Menon *et al.* (2004) observed that application of organic amendments, *viz.,* FYM, green leaves, wood ash, neem cake and groundnut cake improved the quality of fruits and organic manures, produced uniform golden yellow bunches at maturity and fetched 4 to 5 times higher price in *cv*. Chengalikodan.

Dinesh and Pandey (2008) recorded that application of 75% RDF improved total sugars in fruits due to higher uptake of N and K by the plant and it also influenced the TSS and reducing sugars of fruits.

Integrated use of organic manure and bio-fertilizer along with inorganic fertilizers in banana *cv.* Jahaji (AAA) resulted in fruits with higher TSS, reducing sugar, non-reducing sugar, ascorbic acid and moisture contents except sugar -acid ratio and titrable acidity compared to control (Hazarika and Ansari, 2008). Mustaffa and Kumar (2008) reported that application of compost, vermi-compost, *neem* cake and poultry manure in combination recorded maximum TSS, acidity, total sugars and starch content in Rasthali and Karpuravalli cultivars.

Moniem *et al.* (2008) observed that fruit quality was on par when 100 % RDF was applied as FYM or banana compost. In cv. Grand Naine, application of vermicompost (3kg $plant^{-1}$) and castor cake (3kg $plant^{-1}$)

produced superior quality fruits with better shelf life (Patel *et al,* 2010).

Fertilizer dose consisting of 20 ton FYM, 5 kg *Azospirillum* and PSB/ha, 250g neem cake/plant +200: 35: 330 g NPK/plant with foliar application of micro nutrients improved quality characters of banana fruits (Thangaselvabai *et al*., 2009 b).

Thangaselvabai *et al.* (2009 a) reported that application of higher level of nitrogen and *Azospirillum* along with 100g inorganic N produced better yield (19 kg/plant) with enhanced quality fruits. Similarly, application of inorganic N (200 g/plant) in 4 splits also increased the fruit quality characters of banana.

Dinesh *et al*. (2012) observed that application of 50% RDF (150 :60 : 155 NPK/plant) + application of N: P: K in the ratio 3:2:1 at vegetative stage and 1:3:2 at shooting stage and 2:1:3 at fruit development stage resulted in higher pulp: peel ratio (2.68) in Monthan banana.

Dinesh and Pandey (2012) found that application of 150 % RDF of NPK (165: 55: 495 g/plant)in four splits *viz*., 2,4,6 and 8 month after planting was essential to increase the fruit quality characters of tissue cultured banana.

Kuttimani *et al.* (2013) revealed that quality parameters was also influenced by nutrient management practices *i.e*. combined application of 40% Wellgro soil or Cow based Farm Yard Manure @ 10 kg per plant with recommended dose of fertilizers to banana has been found to be an ideal option to improve yield and quality characters of banana.

Kuttimani *et al.* (2013) reported that quality was superior in terms of total soluble solid of fruits in banana plants treated with inorganic fertilizer and bunches treated with 2% of organic liquid spray.

Vanilarasu *et al.* (2014) reported that, banana *cv.* Grand Naine (AAA) plants treated with FYM @ 10 kg + Neem cake @ 1.25 kg + Vermicompost @ 5 kg and Wood ash @ 1.75 kg /plant + Triple green manuring with sunhemp + Double intercropping of Cow pea + biofertilizers *viz.*, VAM @ 25g, *Azospirillum* @ 50 g, PSB @ 50 g and *Trichoderma harzianum* @ 50 g/plant, recorded highest quality characters (TSS-23.23%, acidity-0.82 %, ascorbic acid-12.92 mg/100g, non reducing sugars and total sugars-6.06 and 14.92%), improved shelf life of banana fruits (14.03 days) and reduced physiological loss in weight (7.44%).

Hafiz *et al.* (2016) conducted an experiment and their results revealed that using the recommended dose of nitrogen (RDN) via 25 % as a mineral source and 25 to 50% as an organic one enriched with 50 or 25 % of EM or bio-mex significantly improved the fruit quality compared to use the RDN only as a mineral source.

Lenka *et al.* (2016) reported that 100% RDF + PSB + Azospirillum increased TSS (22.2 brix), reducing sugars (8.12 %), and non-reducing sugars (3.75 %) of banana cv. Grand Naine.

Ganapathi and Dharmatti (2018) reported maximum TSS (23.52 brix), total sugars (20.30%), reducing sugars (20.30%), non-reducing sugars (17.87%), pulp-to-peel ratio (3.81), shelf life (6.33 days), and titratable acidity (0.25) when treated with vermicompost @ 24.20 t/ha + urea @ 535.73 kg/ha + sunn hemp @ 8.88 t/ha + Azospirillum @ 30.86 kg/ha and PSB @ 30.86 kg/ha in banana cv. Grand Naine.

2.5. Nutrient sources affecting fruit qualities in other fruit crops

Barve (1992) noticed good results in growth of grape plants which were applied with vermicompost. Application of vermicompost improved the berry quality with respect to taste, firm attachment and attractive luster in grape. Sathyanarayana and Babu (1992) reported that i*n-situ* green manuring with sunnhemp and mulching with banana residues improved fruit quality in terms of TSS, sugars, acidity and sugar acid ratio. Application of vermicompost @ 5.0 t/ha in Thompson Seedless grapes, recorded significantly higher amount of sugars and lower per cent of total acidity and increased yield. Application of organic manures resulted in higher amount of ascorbic acid, total sugars and reduction in acidity of grapes than the inorganic fertilizer (Venkatesh, 1995).

Tiwari *et al.* (1999) examined that application of N: P_2O_5: K_2O @800:300:600 g/plant with 15 kg neem cake/tree/year in sweet orange resulted in higher yield.

Goramnagar *et al.* (2000) found that Nagpur orange plants produced maximum leaf area, plant height and plant spread, which were supplied with FYM (15 kg) + N (360 g) + P_2O_5 (180 g/plant). Application of poultry manure (30 kg) and 66 per cent mineral fertilizer in guava plants produced vigorous plant growth as well as good quality fruits.

Guava plants applied with poultry manure (30 kg) with 66 per cent

mineral fertilizer gave higher yield and improved nutrient content of plant (Corrales *et al.,* 2000). Application of chemical fertilizers along with neem cake significantly increased the yield with good quality fruits in acid lime (Ingle *et al.,* 2001).

Higher yields of (13.69 kg/plant) in Guava *cv.* Allahabad Safeda was registered when it was supplied with 200 kg FYM + 200 g *Azotobacter* (Ram and Nagar, 2003). Nagpur mandarin plants applied with of 800 g N, 300 g P_2O_5 and 600 g K_2O along with 7.5 kg neem cake per plant per year, results in increase in number and weight of fruits and total soluble sugars (Ingle *et al.,* 2003).

In situ application of vermiculture @ 50 worms/plant produced higher yield (29.10 kg/plant) in guava (Athani *et al.,* 2005) and also concluded that guava plants treated with 75 per cent RDF + vermicompost (10 kg /plant) produced significantly higher leaf area (78.55 cm^2) and total chlorophyll content (1.698 mg/g).

Medhi *et al.* (2007) also reported that the application of mustard oil cake (10 kg/plant), bio fertilizers (*Azotobacter* and PSB) and K_2O (600 g/plant) enhanced the fruit quality (juice, TSS, total sugars and ascorbic acid.

The use of biofertilizers and organic manures resulted in improvement in fruit quality over chemical fertilizers. Yadav *et al*. (2011) reported that application of NPK+ Vermicompost+ *Azotobacter*+ Zn+ Fe+ Paclobutrazol in the recommended dose resulted in higher TSS (23.72 and 23.91 °brix), TSS: acid ratio (191.60, 197.76), ascorbic acid (44.13, 45.63 mg/100g), reducing sugar (8.35 and 8.39%), non reducing sugars (9.94 and 9.95%), total sugars (18.29, 18.34%) in mango *cv.* Amrapalli.

Trivedi *et al*. (2012) investigated the response of Guava varieties with organic manures, inorganic fertilizers and biofertilizers. They found that Allahabad Safeda *cv.* of guava recorded higher TSS. Application of biofertilizer recorded increased yield and available phosphorus content in the soil.

Marathe *et al*. (2012) reported that the results of application of FYM, Vermi compost, wheat straw along with green manuring with Sunhemp as singly or in combination with inorganic fertilizers or biofertilizers like *Azotobacter* and PSB resulted in positive correlation with yield as well as fruit

quality and with leaf micronutrient contents in sweet orange. They also concluded that it saved 25 per cent organic manures or fertilizers applied for N and P nutrition by application of *Azotobacter* and PSB.

Ghosh *et al*. (2012) observed that highest yield (8.1kg/plant) was recorded in pomegranate when FYM 20 kg along with NPK (400:100:300g/year) was applied along with the foliar application of N/K in the ratio of 1:3.The treatment also recorded maximum fruit weight (200 g) with highest TSS (14°brix), reducing sugar (12%) and vitamin-C (12.5 mg/100 ml) content. The fruit from organic nutrition plants had maximum shelf life.

Kashyap *et al*. (2012) reported that maximum fruit set (28.85and27.37%), fruit yield (14.94 and 14.91kg), TSS (16.07and 16%), total sugar (11.46 and 11.44%), non-reducing sugars (2.80 and 2.68%) and reducing sugar (9.56 and9.58%) of pomegranate *cv*. Ganesh were recorded with the treatment of N and K 500g each per plant. The fruit with minimum yield, lowest TSS, total sugar, non-reducing and reducing sugar were obtained with higher doses of N and K (750: 600g) application.

Goswami *et al*. (2012) found that integrated application of biofertilizers along with FYM+ half dose of recommended fertilizer (225g N: 195g P: 150g K) enhanced the fruit quality of guava.

Nazir *et al*. (2012) observed that application of poultry manure + *Azotobacter* +wood ash + PSB + oil cake and also application of poultry manure + *Azospirillum* + wood ash + PSB + oil cake enhanced the yield and sustainability of crop. Plant growth and fruit yield (132.75 q/ha) was maximum from this method of application in strawberry.

Reddy *et al*. (2012) reported that combined application of 50 % recommended dose of fertilizer in the form of FYM + *Azospirillum* + PSB+ Mycorrhiza + vermicompost showed better fruit quality of papaya such as total carotenoids, lycopene, TSS and low ascorbic acid. Average fruit weight were not affected by various organic nutrient treatments.

Singh *et al*. (2012) observed that the application of standard dose of inorganic fertilizers along with organic nutrient sources like oil cake, FYM increased the fruit yield and fruit qualities like TSS, total sugar, vitamin C, total phenol content in aonla *cv.* NA-7.

Papaya *cv.* Surya plants when applied with farm yard manure,

biofertilizers like VAM along with 100% recommended dose of fertilizer, produced fruits with good quality parameters and yield attributes (Reddy *et al.,* 2013).

Khehra (2014) reported that application of FYM (75 kg/tree), inorganic nitrogen (350 g/tree) with *Azotobacter* (18 g/tree) was found to be the best treatment in minimizing fruit cracking and improving fruit quality of lemon *cv.* Baramasi.

Kumar *et al.* (2015) revealed that the use of organic manure (FYM, vermicompost and press mud) and biofertilizers (*Azotobacter*, PSB and *Azospirillum*) in combination produced the fruits with higher yield with good quality in strawberry *cv.* Chandler.

2.6. Effects of nutrient sources on available soil and plant nutrients

Data related to the nutrient uptake and distribution is used to calculate plant nutrient requirements. Element responsible for vegetative growth *i.e*. nitrogen is evenly distributed throughout the plant but highly deposited in leaves. Hewitt (1955) was the first scientist to determine the critical level of nutrients in the leaves of banana. It was concluded that the 3rd youngest leaf in the plant was most indicative of nutrition of plant since it had the highest N concentration. Best time of sampling of leaf suggested was at the time of shooting of flower bud. According to Murray (1962) phyllochron is under the influence of mineral nutrition. Number of functional leaves is a good index for the nutritional status in banana and the rate of production of leaves is influenced by mineral nutrition.

The study conducted by Walmsley and Twyford (1968) on the uptake and distribution pattern of micronutrients in banana revealed that uptake of Mn and Fe were high at the vegetative phase whereas Zn and Cu was at fruiting phase. Therefore, Mn was present mainly in the leaves and Fe in pseudostem. The rapidly growing tissues contain higher concentration of other elements.

Ramaswamy (1971) reported that calcium and magnesium uptake increased when higher level of nitrogen was applied. Leaves, pseudostem and rhizome were the main repositories of Ca and Mg in plants. Until shooting these two elements continued to enter every part of the plant. Uptake of these two elements was increased in all the stages of growth.

Martin (1973) noticed that magnesium and nitrogen are two elements which are further responsible for the phosphorus nutrition. Higher levels of nitrogen further increased the uptake of phosphorus. The phosphorus uptake was high at shooting and harvesting stages, as it occurred throughout the plants life (Twyford and Walmsley, 1974).

Shanmugavelu *et al.* (1987) reported that potassium is an important element in plant so it is present in higher amount than other elements at every stages of growth and development. Potassium in leaves, petioles and pseudostem dropped when there was shooting indicates that the organs supplied potassium for fruit development even though there was still substantial post shooting uptake from the soil. Mustaffa (1988) reported that leaf nitrogen content in banana increased both in main as well as in the ratoon crop with application of 300g N/plant. Ray *et al*. (1988) reported that the leaf content of N 2.8%, 6.25% and 3.8% K at shooting of banana was best indicator of productivity.

Hasan *et al*. (2001) investigated the nutrient uptake pattern in banana with the application of K fertilizer @100-600g K_2O/plant in four doses and found that N uptake increased from vegetative to shooting stage and declined thereafter. Low rates of K application resulted in low leaf K concentration. K uptake showed similar pattern in uptake and declined at shooting stage. Yield was increased with leaf K content.

Higher EC was recorded in plants which received inorganic fertilizers which might due to the increase in salt concentration; might be due to presence of various ions like nitrates (Atiyeh *et al*., 2000).

Majumdar *et al.* (2002) reported that application of 50 % RDF along with10t ha^{-1} vermicompost improved soil porosity and reduced bulk-density of the soil.

Hasan *et al*. (2002) studied the effects of different levels of N and K on leaf nutrient content of Dwarf Cavendish banana *cv.* Giant Governor at various growth stages along with their relationship to yield. Leaf N, P and K content was highest at vegetative stage when 300 g N /plant and 400 g K_2O /plant was applied. Yield of banana was positively correlated with leaf N content, leaf P at vegetative stage and leaf K at harvesting stage. Leaf P content at harvesting stage showed negative correlation with yield.

Mustaffa *et al.* (2004) observed that application of organic manures (2.5kg compost + 1kg vermicompost + 1kg *neem* cake + 2.5kg poultry manure plant-1 at 3rd, 5th and 7th month after planting) improved soil physical-properties. The effect of organic farming practices in banana on improvement of soil quality was due to increased cation exchange capacity, lesser bulk-density and, in turn, increased porosity (Mei *et al.,* 2007).

Leaves and pseudostem were the main repositories of phosphorus. There was a steady uptake of phosphorus in all organs except corm up to shooting. Uptake ceased at large stage. Higher content of nitrogen is present in the leaves in the vegetative phase followed by pseudostem and corm in the shooting phase, whereas during the fruiting phase the fruits contained more nitrogen than either the pseudostem or corm (Thangaselvabai *et al*., 2007).

Singh *et al.* (2000) found application of organic manures (FYM @ 330 qha^{-1} + pongamia oil cake @ 8.30 qha^{-1} + neem oil cake @ 8.30 qh^{-1} + Sterameal @ 8.30 qh^{-1} + rock phosphate @ 8.30 qh^{-1} + wood ash @ 8.30 qh^{-1}) increased the physical properties and water holding capacity of the soil. Phirke and Mahorkar (2010) concluded that fortification of soil with organic manures like nitrogen fixers, phosphate solubilizing microbes, Vesicular Arbuscular Mycorrhizae (VAM) and bio-fertilizers increased soil porosity also infiltration of water in banana fields.

The use of poultry manure with Azospirillum, Azotobacter and P-solublizing bacteria biofertilizer for a soil cultivated with banana (*Musa paradisiaca,* AAA Simmonds) had improved plant performance and soil physical and biological properties (Maria *et al*., 2008).

Ratan *et al* (2008) concluded that application of organic manures like vermicompost, FYM, poultry manure, neem cake and its combinations recorded equal leaf nutrient status compared to100 % inorganic fertilizers in cv. Grand Naine.

Gaikwad *et al*. (2009) observed that application of *Azospirillum* (50 g /plant) + PSB (50 g/plant) +VAM (250 g/ plant) + *Trichoderma hazianum* (50 g/plant) recorded highest yield of banana. However application of either *Azospirillum* @ 50 g/ plant or PSB @ 50 g/ plant at the time of planting with FYM 10 kg/plant and 100 % RDF found beneficial in terms of net profit of banana cultivation. Higher N uptake was observed with *Azospirillum* bio

inoculant. Phosphorous uptake was higher in the treatment where PSB and VAM were used.

Selvamani and Manivannan (2009) reported that combined application of organic manures (FYM, Vermicompost and neem cake), biofertilizers (VAM, *Azospirillum*, PSB, *Trichoderma hazianum*) with inorganic fertilizers enhanced the leaf nutrient contents in banana leaf. It was recorded significant high leaf N and K content during vegetative stage (3.24 %, 0.44 %), flowering stage (3.58 %) and harvesting stages (2.68 %) and highest leaf P (0.42, 0.43, 0.38 %) found indifferent stages of growth.

Trivedi *et al*. (2012) elucidated the response of Guava varieties to the application of organic manures, inorganic fertilizers and biofertilizers. Sardar variety of Guava recorded increased plant height, plant spread and nitrogen uptake than Allahabad Safeda; whereas Allahabad Safeda registered better availability of N, P_2O5 and K_2O contents in the soil. The maximum available, P_2O_5 and K_2O were observed with bio compost. The uptake of NPK was influenced significantly with incorporation of vermicompost. The result showed maximum nitrogen uptake in vermicompost and that of maximum P uptake in FYM.

Marathe *et al*. (2012) studied that effect of application of FYM along with 50 % dose of inorganic fertilizer and calcium and green manuring with Sunhemp along with 50 % dose of inorganic fertilizers and results showed highest concentration of N (2.19%), P (0.111%) K (1.38%) and micronutrients in the leaves of sweet orange.

The greater biological activity of nitrogenases coupled with stabilization of extracellular enzymes through complexation with humic substances through organic manures might be the reason for continuous availability of substrate for enzymes (Adak *et al.*, 2014).

The application of chemical fertilizers along with organic nutrient sources like vermicompost 30kg/tree, biofertilizer 60 g/tree, cow urine 12.5% as foliar application and 50% NPK improved the leaf nutrient status of apricot (Singh *et al*., 2012). Mayadevi (2016) revealed that the production of vermicompost in planting pits could manifest a 24 percent increase in MBC of soil. Mayadevi (2016) also reported that the highest microbial counts were recorded in the soils treated with vermicompost prepared using native earthworms. The sustained

supply of nutrients and organic matter in the rhizosphere of vermicompost treated soils provide energy sources to microbes and thereby encourage their proliferation (Khaddar and Yadav, 2006). Mayadevi (2016) studied that the cultivation of banana caused a reduction in electrical conductivity of rhizosphere soils.

Materials and Methods

3. MATERIALS AND METHODS

The study entitled “Response of banana *Musa* (AAB) 'Nendran' to nutrient sources” was conducted at Banana Research Station, Kannara, Thrissur, Kerala during 2017-2019. Two crops of banana was taken at ‘C’ block of BRS, Kannara. Soil and plant analysis was carried out at Regional Agriculture Research Station (RARS), Pattambi and Radio Tracer Laboratory (RTL), Vellanikkara. Biochemical analysis of fruits was done at Department of Fruit Science, and Fruit Crop Research Station, (FCRS), Vellanikkara, College of Horticulture, Vellanikkara, Thrissur. A survey was also done in different *Panchayats* of Thrissur districts in consultation with agricultural officers of respective areas. The Ph D research work was conducted as two different experiments.

Experiment 1

Effect of different sources of nutrients on quantitative and quality characters of banana *Musa* (AAB) 'Nendran'.

Experiment 2

Quality analysis fruits of banana *Musa* (AAB) 'Nendran' from farmers’ field.

3.1 Experimental site

The location of the first experiment is situated at 10.53° North latitude and 76.33° East longitude at an altitude of 55m MSL, is raised, levelled, and well drained garden land. The experiment site is located about 10 km away from KAU, head quarters, Vellanikkara, Thrissur. The predominant soil type is laterite.

3.2. Experimental Design and Layout

Experiment I

Effect of different sources of nutrients on quantitative and quality characters of banana Musa (AAB) 'Nendran'.

Clone – Nedunendran

Design of experiment: Randomized Block Design (RBD)

Number of Treatments: 9

Replications: 3

Plot size: 16 plants per treatment

Total number of plants: 432 (Four hundred thirty two)

Spacing: 2.0 m X 2.0 m

3.2.1. Experiment details

Experiment was formulated with nine treatments and three replications and laid out as Randomized Block Design. Treatments details are as given as below;

Treatment Details:

Treatments:

T_1. POP recommendation of KAU for TC banana (N: P_2O_5: K_2O @ 300g: 115g: 450g + Lime 1.0kg + FYM 15.0 kg per plant).

T_2. POP recommendation of KAU with organic manures
15kg FYM and 0.5 kg lime as basal + FYM @ 28kg/plant + ash @4kg/plant which was applied in two splits *i.e.* one as basal and one at 3 MAP) + *in situ* green manuring.

T_3. POP recommendation of KAU with organic manures 15kg FYM and 0.5 kg lime as basal + Poultry manure @ 14kg/plant + ash @4kg/plant which was applied in two splits *i.e*. one as basal and one 3 MAP + *in situ* green manuring .

T_4. Best treatment from AICRP trials at BRS, Kannara
(FYM10kg + Neem cake 1.25 kg + vermicompost 5 kg + wood ash 1.75kg + biofertilizers (AMF25g + Azospirillum50g + PSB 50g + *Trichoderma harzianum* 50g per pit) + 0.5 kg lime.)

T_5. Best treatment from AICRP trials at BRS, Kannara with native isolates of biofertilizers (FYM10kg + Neem cake 1.25 kg + vermicompost 5 kg + wood ash 1.75kg + biofertilizers (native isolates of AMF 25g + *Azospirillum* 50g +

PSB 50g + *Trichoderma viridae* 50g per pit) + 0.5 kg lime.

T_6. Modified POP recommendation of KAU including micro nutrients as per soil test.

T_7. Fertigation with inorganic manures (adhoc recommendation): FYM @ 15.0 kg/plant

Fertigation schedule for banana (TC Nendran)

Rate for 1000 TC plants (full dose of N: P_2O_5: K_2O @300:115:450 g/plant)

Fertiliser material kg per application

Period	No. of splits	Urea	MAP	MOP
1-60 days	15	8.0	4.4	10.0
61-120 days	15	14.2	6.6	17.5
121-180 days	15	13.0	0	15.0
181-280 days	25	3.6	0	4.7

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.

T_9. Control (without manures and fertilisers)

For treatments 6 and 7 lime was applied based on soil test.

The experiment was repeated for two seasons and the treatments were applied in the same location.

3.2.2. Location

The experiment was located at C block of Banana Research Station, Kannara (Plate 1.)

3.2.3. Land preparation

Field was thoroughly ploughed, levelled and laid out for the experiment.

3.2.4. Lay out

After laying out of the field, pits of 60 cm^3 were dug and well rotten FYM and Neem cake, Wood Ash and lime applied according to the treatments. After application of organic manures, all the pits were covered with the soil and then enough amount of water is applied by irrigating with hose and allowed as such for 20 days for well decomposition of organic manures (Plate 2).

3.2.5. Planting

45 days old tissue cultured banana plants of Nedundendran clone were planted on the top of the pit. Biofertilizers are applied in particular treatments. All the plants were watered and each plant was covered with coconut fronds for protection from heavy sunlight for 2-3 weeks (Plate 3).

3.2.6. Cultural operations

Irrigation

Initially irrigation basins were formed around each pit. Water is applied at every 3-4 days interval.

Drip irrigation

Irrigation applied through drip system which helps to maintain the proportion of soil air and water. Drip irrigation was given @15 litre/plant/day from planting to 4^{th} month, 20 litre/plant/day from 5^{th} month to shooting stage and 25 litre/plant/day from shooting to harvest. Drip system was installed in single line system where only one lateral line and 2 dripper per plant were used.

Fertigation

Application of water soluble fertilizers through drip irrigation (fertigation) is adopted in treatments T_7.

For treatment T_8, fertigation with organic sources once in four days applied with extract of 14 kg $plant^{-1}$ FYM through irrigation water till one month after bunch emergence. 14 kg of FYM divided by total number of splits required till one month after planting. The total quantity for all 3 replications for a split, weighed and mixed with water then filtered with cloth twice and applied through ventury in drip system.

Plate.1 Overview of field at C' block of BRS, Kannara

Plate. 2. Land preparation

Plate.3. Planting of *Musa* Nendran TC plants

Plat.4. *In situ* green manuring with cow pea and treatment application

Earthing up at 5 MAP

Insitu green manuring at 6 MAP

Propping with wooden stick

Covering of the bunches for protection

Plate.5 Intercultural operations in banana

Manures and Fertilizers

Manures and fertilizers were applied as per treatments. In T_1 and T_6 the dose of N: P_2O_5: K_2O @300:115:450 g per plant were applied in six split doses. In T_6, (Modified POP KAU as per soil test), additional dose of Borax (0.2%), Magnesium sulphate (2%) and Copper sulphate were applied as foliar spray at 5 months after planting.

Weed control

Hand weeding was done at monthly intervals till harvest of the crop. Harrow weeding combined with soil mounds around the plant trunk was done at 5^{th} month after planting. No chemicals were used for weed control.

Earthing up

Earthing up was followed in all the treatments by loosening and shifting of the soil around the plant. It is an important operation which provides support to the base of the plant and also gives chances for the formation of a better root system. It was done during rainy season for avoiding water logged conditions. It will also provide proper drainage facilities to the plant.

Mulching

Mulching was practiced in all the treatments during summer months in all the treatments.

***In situ* green manuring**

Cow pea seeds are sown manually in interspace left after planting. Before flowering stage, cow pea plants are uprooted and applied and covered with soil. Three time green manuring was practiced in all organic treatments till one month after bunch emergence (Plate 4).

Propping

Nendran is a tall variety which require propping. Due to heavy weight of bunch and high wind velocity, the plant goes out of balance and the bearing plant may lodge and production and quality are adversely affected. Therefore, plants were propped with the help of wooden poles.

Desuckering

Removal of unwanted suckers is a critical operation in banana for reducing internal competition with the main plant. Small suckers were removed on regular basis up to 6 months. Only 2-3 suckers were retained after emergence of bunch.

Denavelling

Male bud was removed in all the treatments around 25 days after shooting with long handle sickle.

Bunch Covering

Transparent white polythene sheets were used for covering bunches. It prevents bunch from direct exposure of sunlight, prevents the attack of birds and any kind of spots to the fruits (Plate 5).

3.2.7. Plant protection

Neem oil + Pseudumonas two sprays were done uniformly in all the plants at 5th month after planting to reduce the attack of Pseudostem weevil and Sigatoka leaf spot. Since the plants were grown under organic nutrition, no chemicals were used for plant protection measures.

3.2.8. Harvesting

Fruits were harvested manually when it attained around 80-85 per cent maturity.

3.3. Main items of observations

Experiment-1

Observation on various characters were recorded from central four plants in each replication from all the treatments.

3.3.1 Biometric characters

Observations on vegetative characters were taken each month after planting to days taken for emergence of bunch. Days to bunch emergence, incidence of pest and diseases were also noted. Days to harvest, bunch weight, number of hands, number of fingers per hand, finger weight, finger length, finger girth, days for ripening and shelf life were recorded at the time of harvesting.

3.3.1.1. Plant characters

Phyllochron

Phyllochron is the rate of leaf production. The number of days required for phyllochron was counted and expressed as number of days.

Plant height (cm)

The plant height was measured from the ground level to the marked point up to the angle between youngest first and second leaf axils in the pseudostem and was expressed in centimeter (cm).

Pseudostem girth (cm)

The circumference of pseudostem was measured at 20 cm above the ground level at monthly intervals up to shooting of the plants and expressed in cm.

Total biomass at the time of harvest

For total biomass production, fresh weight of all parts *i.e.* leaves, pesudostem, rhizome, peduncle and fruits of observation plant was taken after harvesting and expressed in kg per plant.

3.3.1.2. Leaf characters

Number of leaves per plant

The total number of fully opened green functional leaves capable of photosynthesis retained by the plant were recorded.

Leaf area index (LAI)

The LAI of functional leaves was calculated using the formula suggested by Watson (1952).

3.3.1.3. Flowering and fruiting characters

Mean number of days for shooting

Time taken for shooting was recorded from the date of planting to visual bunch emergence and expressed in days.

Mean number of days for harvesting

Time duration for harvesting was calculated from the date of planting to the date of harvest and expressed in days.

Bunch maturity period

It was calculated by the time duration required from the date of bunch emergence to the date of harvest and expressed in days.

3.3.1.4. Fruit characters

Bunches were harvested at full maturity when the fingers showed disappearance of angles or round full condition. The following observations were made on bunches and fruit.

Number of hands per bunch

The total number of hands per bunch was counted and recorded after harvest and expressed in number.

Number of fingers per bunch

Number of fingers in a bunch were counted and recorded after harvest.

Finger length

The middle fruit in the top row of the second hand was selected as representative finger or index finger. The finger length was measured from base of fruit to the tip where it is attached to the stalk by using a twine and expressed in centimetres (cm).

Finger girth

The finger girth was measured at the middle of the finger by using a thread and expressed in centimeters (cm).

Finger weight

Weight of fruit was taken by using a standard electronic balance and expressed in grams (g).

Bunch weight

The matured bunches were harvested and the peduncle was cut, leaving 22.50 cm above the first hand and 5 cm below the last hand. Mean weight of bunches was recorded and expressed in kg per plant.

Peduncle weight

Weight of peduncle was taken by using a standard electronic balance and expressed in gram (g).

Pulp to peel ratio

Pulp to peel weight of index finger was recorded separately on analytical balance in grams. Pulp and peel ratio was calculated by dividing the weight of pulp by weight of the peel.

Fruit peel thickness

Peel thickness of fruit was recorded at fruit maturity, i.*e*. at ready to eat ripe or full yellow stage with the help of Vernier calipers and expressed in millimeter (mm).

3.3.2. Soil and plant analysis

3.3.2.1. Soil health analysis

Soil Analysis was done at Radio Tracer Laboratory, Vellanikkara and Department of Soil Science and Agricultural Chemistry, RARS, Pattambi. Microbial biomass carbon and enzymatic activities of the soil was measured at KFRI, Peechi. Analysis of soil physical, chemical and biological properties was carried out before and after each crop. Soil samples before planting were

collected and randomly pooled and analyzed for each treatment. After harvest of the crop also, soil samples were collected from each treatment and analyzed.

Soil samples for laboratory analysis were collected at before and after each crop. Both wet and dry soil samples maintained separately till the completion of analysis of physical, chemical and biological properties of the soil. The physical properties analyzed include water holding capacity and bulk density and aggregate stability. The chemical properties estimated were soil pH, organic carbon, CEC, available P, available K, Ca, Mg, S and micronutrients like Iron, Copper, Zinc, B, and Mn content. Soil biological properties includes microbial biomass carbon, dehydrogenase enzyme activity, nitrogenase enzyme activity and total microbial population. Microbial population which includes total fungi, bacteria, and actinomycetes were estimated by serial dilution and plating method.

3.3.2.1. Physical properties of soil

Water holding capacity (WHC)

The water holding capacity of the soil were determined using Keen-Raczkowski brass cup method (Piper, 1966).

Bulk density (BD)

Bulk density of the soil were determined using Keen-Raczkowski brass cup method (Piper, 1966). From the readings, core bulk density was calculated using the given formula.

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of the soil (g)}}{\text{Volume of soil with pore space (cm}^3\text{)}}$$

Aggregate stability

Aggregate analysis was carried out by Yoder's wet sieving method (Yoder, 1936). Soil sample (50 g) was placed in the top of sieves having openings of 5.0, 2.0, 1.0, 0.5 and 0.25 mm diameter and wet sieved in Yoder's apparatus for 30 minutes. The fractions retained on each sieve were transferred and dried to a constant weight at 105°C and the mean weight diameter (MWD) was calculated by the formula (Bavel, 1950),

$$\text{Mean weight diameter} = \sum d_i \, X \, w_i$$

where d_i and w_i are the mean diameter in each size fraction and proportion of the total sample weight respectively.

3.3.2.2. Chemical properties of soil

Chemical analysis of the soil samples were done using 0.5 mm sieved soil. Chemical characteristics of the soil *viz.*, pH, organic carbon, available P, K, Ca and micronutrients like Fe and Mn were analyzed as per the protocols given in Table .

Table Methods used for estimation of chemical properties of soil

Sl No.	Chemical Properties	Methods		Reference
		Extraction	Estimation	
1.	pH	1:2.5 soil water suspension	Potentiometry	Jackson (1973)
2.	EC		Conductivity meter	Jackson (1973)
3.	Organic carbon	Wet digestion		Walkely and Black (1934)
4.	Available N	Alkaline permanganate method		Subbiah and Asija (1956)
5	Available P	Bray No.1	Colorimetry	Bray and Kurtz (1945)
6.	Available K	1N NH_4OAc	Flame Photometry	Jackson (1973)
7.	Available Ca	1N NH_4OAc	ICP OES (Model: Optima 8x00 series)	Jackson (1973)
8.	Available Mg	Atomic absorption spectroscopy		Jackson (1973)
9.	Available S	Photoelectric colorimetry		
10.	Available micronutrients (Fe, Zn, Cu, Mn)	0.1 N HCl	ICP OES (Model: Optima 8x00 series)	Sims and Johnson (1991)
11.	Available B	Photoelectric colorimetry		Bingham (1982)

Cation exchange capacity

The cation exchange capacity of the soil was determined by the method suggested by Hendershot and Duquette (1986).

3.3.2.3. Soil biological parameters

Wet samples kept separately in the refrigerator and analyzed freshly for testing different biological properties.

Sl. No.	Parameter	Method	Reference
1.	Microbial biomass carbon	Wet digestion (Chloroform fumigation)	Jenkinson and powlson, 1976
2.	Dehydroganse enzyme activity	TTC (mg TPF/day/kg of soil)	Casida *et al*., 1964
3.	Nitrogenase enzyme activity	Acetylene reduction technique (C_2H_4/g/hour n moles)	Hardy, *et al*., 1973

Microbial analysis

Microbial count in the soil were enumerated using serial dilution and plating as described by Johnson and Curl (1992). For this, 10 g of soil sample was added to 90 ml of sterile water taken in 250 ml conical flask and shaken for 30 min. in orbital shaker (150 rpm). Pipetted out one millilitre of soil suspension (10^{-1}) to nine millilitre of sterile water taken in test tube to get a dilution of 10^{-2}. Likewise, serial dilutions were prepared up to 10^{-7}. The dilutions and media used for the enumeration of different groups of microorganisms are given in the following table

Table. Details of dilutions and medias used for enumeration of rhizosphere microflora

Sl.No.	Organism	Dilution	Medium	Period of incubation
1.	Fungi	10^{-3}	Martin's Rose Bengal Agar	24 h.
2.	Bacteria	10^{-5}	Nutrient Agar	48 h.
3.	Actinomycetes	10^{-4}	Ken Knight's Agar	Seven days

3.3.2.2. Plant analysis

Plant nutrient analysis

Third fully opened leaf from the apex, which was considered as the index, was taken for the analysis in each season at 5th month after planting. Samples of leaf lamina from either side of the middle portion of the index leaf were collected before shooting and at harvesting. The samples were dried in hot air oven at 70^{o} C for 72 hrs. The dried plant samples *viz*. leaf, pseudostem,

rhizome, peduncle and fruit were also analyzed for major and minor nutrients after harvesting of each crop.

Table 6. Analytical methods followed for the plant analysis

S. No.	Parameter	Method	Reference
1.	Total N	Modified kjeldhal digestion method	Jackson, 1973
2.	Total P	Diacid extract estimated colorimetrically in Spectrophotometer	Jackson, 1973
3.	Total K	Diacid extract method using flame photometer	Jackson, 1973
4.	Total Ca	Atomic absorption spectroscopy	Issac and Kerber,1971
5.	Total Mg	Atomic absorption spectroscopy	Issac and Kerber,1971
6.	Total S	Turbidimetry method using spectronic 20	Bhargava and Raghupathy, 1995
7	Total Zn	Di acid method using Atomic absorption spectrophotometer	Emmel *et al*., 1977
8	Total B	Digestion by dry ashing and estimated by azomethine blue colour method	Kaira, 1998
9	Total Fe	Diacid method using Atomic Absorption Spectrophotometer	Piper, 1966 Emmel *et al*., 1977
10	Total Cu		
11	Total Mn		

Chlorophyll content

From third leaf of observation plants at different growth stages Chlorophyll ‘a’ and ‘b’ content and total chlorophyll was estimated by extracting in 80 per cent acetone and read at 663 nm and 645 nm in spectrophotometer. The amount of chlorophyll content was calculated using absorption coefficient (Witham *et al*., 1971).

Total dry matter

Dry matter content of the observation plant was determined with the method suggested by Piper (1966). Male bud, pseudostem, midrib petiole, lamina and rhizome were separated and fresh weight of each was recorded. Fresh sample of 500 g from each plant part was washed, air dried and then oven dried at 70°C to constant weight for calculating the moisture content. Total dry matter content was calculated using the values for percentage moisture and fresh weight of each part. Using the value for moisture per cent and fresh weight of each part, total dry matter content was computed.

Nutrient uptake

The total nutrient uptake of major and minor nutrients were determined by using dry matter accumulation and nutrient concentration at harvest. The uptake of each nutrient was calculated separately for leaves, pseudostem, rhizome, peduncle and fruit. The total uptake at harvest was calculated by summing the nutrient uptake by leaves, pseudostem, rhizome, peduncle and fruit.

3.3.2.3. Biochemical analysis of fruits

Mature stage

Biochemical analysis was done at Fruit Crops Research Station, Vellanikkara and Orchard Lab, Department of Fruit Science, Vellanikkara. Raw fruits of nendran banana were analyzed for the following constituents. The physiologically mature fruit samples were drawn from central four observation plants. The middle three fruits of third hand from the top were selected and cut in small slices. These fruit slices were air dried and oven dried at 70°C temperature till constant weight. The dried fruit sample were ground in mortar and pestle and used for their nutrient concentration.

Starch content

The starch content was estimated calorimetrically using anthorne reagent, as suggested by Sadasivam and Manickam (2008).

Protein content

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 acid tryosine and tryptophane present in the protein plus the colour developed by the biuret

reaction of the protein with alkaline cupric tartrate was measured in the lowry's method as suggested by Sadasivam and Manickam (2008).

Total dry matter

Determination of dry matter content of fruit was made according to the methods suggested by Piper (1966). 50g of fruit sample were kept in hot air oven at 70 degree centigrade to constant weight for calculating the moisture content. Using the value for moisture percentage and fresh weight of each part, total dry matter content was computed.

Tannin content

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

Estimation of Crude fibre was done by acid –alkali digestion method as suggested by Chopra and Kanwar (1978).

Moisture content

Moisture content was estimating using the method A.O.A.C. (1980).

Ripe stage

Ripe nendran banana fruits were used to estimate the quality parameters.

Total soluble solids (TSS)

Total soluble solids was estimated using a hand refractometer having a range of 0 to 32 ° Brix and expressed in degree brix (°Brix) (Ranganna, 1977).

Titrable acidity

Titrable acidity was determined by the procedure proposed by (Ranganna, 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

The ascorbic acid content of ripe banana fruit was estimated by the method of A.O.A.C. (1980) using 2, 6-dichlorophenol indophenol dye and expressed as milligram per hundred gram of fruit (mg/100g).

Total sugars

Total sugar content of the sample was estimated by the method described by A.O.A.C. (1980).

Reducing sugars

Reducing sugars was determined by following copper reduction method using Fehling's solution (A.O.A.C. (1980).

Sugar- acid ratio

Sugar- acid ratio was arrived at by dividing the value of total sugars and titrable acidity of the corresponding sample.

Tannin content

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 Sadasivam and Manickam (2008).

Moisture content

Moisture content was estimating using the A.O.A.C. (1980) method.

Shelf life

The number of days taken for ripening and days taken to the development of the black colour on the peel which is not suitable for consumption, was recorded to determine the shelf life of the fruits at room temperature.

Carotene content

Estimation of Total carotene of ripe fruits was done by using method suggested by A.O.A.C. (1980).

3.3.2.4. Characterization of organic manures

Organic manures *viz*. FYM, vermicompost, poultry manure, wood ash, neem cake, *etc*. were used for nutrient composition, total dry matter, C: N ratio and Microbial Analysis. Analysis was done along with soil analysis at RARS, Pattambi.

Organic manures analysis for heavy metals

DTPA extractable heavy metals

Ten gram of manures was mixed with 20 ml of DTPA - TEA solution (0.005 M) in plastic bottles and were shaken for two hours and filtered through Whatman No. 42 filter paper. Extractable heavy metals in the extract were measured in an atomic absorption spectrophotometer (Jackson, 1973).

3.3.2.5. Organoleptic evaluation

Preparation of banana chips

Chips from the mature Nendran banana were prepared after peeling and cutting the fruit into thin uniform slices. The slices were fried in the coconut oil and packed (100g) in polythene packets for 250 gauge thickness and labelled which was used for sensory evaluation.

Sensory evaluation

Organoleptic evaluation of ripe fruits and banana chips was carried out based on nine point hedonic scale for taste, flavor, colour, texture, appearance and overall acceptability which vary from dislike extremely (1) to like extremely (9) as proposed by Amerine *et al.* (2013). It was carried out by a five member panel of judges from FCRS, Vellanikkara and College of Horticulture, Vellanikkara.

3.3.2.6. Incidence of pest and diseases

Observation were recorded on pest infestation, diseases incidence and disorders was observed throughout the crop period and the severity of incidence was recorded using an index scale proposed by Mayee and Datar (1986).

$$\text{Incidence of pest and diseases (\%)} = \frac{\text{Number of plants affected}}{\text{Total number of plants}} \times 100$$

Organic measures like neem oil and nimbicidine spray was used for managing psuedostem weevil and pseudomonas spray for control of sigatoka disease.

3.3.2.7. Benefit/Cost ratio

The economics of the cultivation was worked out considering all the aspects of cost of cultivation and the income derived from the plants for all the treatments. Benefit cost ratio was calculated for all sixteen plants in each plot. Total cost incurred in each treatment in all three replications was calculated right from the beginning including planting cost, labour cost, manures and fertilizers, fixed cost (Drip Installation), other intercultural practices, other costs in the first year and second year. The price of banana was calculated @ Rs. 35/kg from integrated nutrient management and @ Rs. 50/kg from organic nutrient management. Benefit cost ratio was calculated by dividing total income generated banana from each treatment with total cost incurred**.**

B: C ratio = Gross income/ cost of cultivation

3.3.2.8. Statistical analysis

Data were subjected to analysis of variance using the statistical package 'OPSTAT (Sheoran, 1998). Data were analysed following ANOVA, and the means were compared based on the critical differences (least significant difference) at 0.05 level of significance. The statistical software 'OPSTAT' was used for pooled analysis of first and second year data. Correlation and T-test was worked in MS excel for various characters.

Results

4. RESULTS

The research project entitled “Response of banana *Musa* (AAB) 'Nendran' to nutrient sources” was undertaken to elucidate the response of banana *Musa* (AAB) 'Nendran' in terms of growth, yield and quality to nutrient sources and to compare the fruit quality of banana grown under organic and conventional systems in farmer’s field. Experiment-I was conducted in the laterite soil of Banana Research Station, Kannara, Thrissur. Two crops were taken in the same field during the period 2017-18 and 2018-2019. Climate of experimental site is humid tropical with a mean annual temperature of 29^{o} C and mean annual rainfall of 2500 mm. Soil belong to inceptisol order. For the experiment-II survey was conducted in different Panchayats in Thrissur district. Results of both experiments conducted as part of the study are detailed below.

Experiment- I

Effect of different sources of nutrients on quantitative and quality characters of banana *Musa* (AAB) ‘Nendran’

4.1 Biometric characters

4.1.1. Plant characters

Plant height

The effect of nutrient sources on plant height during first year and second year is given in table 4.1 and 4.2 respectively.

There was no significant difference in plant height up to 4 months after planting in the first year. Significant difference for plant height was observed at 150 and 180 days after planting. Maximum plant height was found in treatment T_3 at 150 DAP which was on par with treatments T_5, T_6 and T_8. At 180 DAP maximum plant height was observed from treatment T_8 on par with treatments T_3 and T_6. There was no significant difference after 180 days

Table. 4.1 Effect of nutrient sources on plant height in first year

Treatment	Plant height (cm)								
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**	**180 DAP**	**210 DAP**	**240 DAP**	**270 DAP**
T_1	19.58	35.08	78.50	100.50	113.75	140.17	184.58	216.08	269.75
T_2	21.83	43.83	89.58	108.58	122.83	139.33	181.25	223.67	283.25
T_3	20.67	45.17	77.42	103.50	128.92	146.50	182.00	230.58	293.00
T_4	18.58	41.42	78.67	102.75	117.17	135.83	177.17	225.08	275.33
T_5	20.42	38.50	79.50	96.17	115.58	136.50	183.58	226.67	281.92
T_6	22.25	44.08	74.08	102.58	123.83	144.42	186.50	223.58	277.08
T_7	21.08	34.00	61.08	88.42	105.67	124.42	165.67	214.58	269.17
T_8	18.67	42.17	86.58	105.83	127.58	148.75	195.58	226.92	286.33
T_9	19.92	33.83	68.50	90.33	108.92	115.00	164.92	199.33	255.50
SE(d)	**2.35**	**5.46**	**9.91**	**8.67**	**5.52**	**7.68**	**19.29**	**16.13**	**14.86**
C.D.	**NS**	**NS**	**NS**	**NS**	**11.81**	**16.41**	**NS**	**NS**	**NS**
C.V.	**14.14**	**16.79**	**15.75**	**10.63**	**5.72**	**6.87**	**13.11**	**8.95**	**6.57**

Table. 4.2 Effect of nutrient sources on plant height in second year

Treatment	Plant height (cm)								
	30 DAP	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**	**180 DAP**	**210 DAP**	**240 DAP**	**270 DAP**
T_1	21.25	39.67	79.42	104.83	129.00	159.25	200.75	230.67	270.42
T_2	24.00	36.17	68.58	104.58	128.08	158.83	200.17	242.83	283.75
T_3	23.08	35.92	78.33	109.92	135.75	165.75	207.67	250.33	291.58
T_4	20.88	37.83	73.33	105.17	129.67	160.75	201.33	244.50	285.58
T_5	22.42	38.67	74.75	105.67	134.58	164.92	202.58	242.42	283.17
T_6	24.38	40.33	79.83	110.50	143.17	173.00	211.75	254.17	293.33
T_7	22.42	40.75	77.58	103.50	128.42	159.50	200.33	243.50	283.42
T_8	22.00	39.25	70.83	103.67	130.67	161.25	204.50	244.50	285.58
T_9	22.50	34.00	58.83	86.58	114.58	143.17	182.33	213.00	254.25
SE(d)	**2.17**	**2.24**	**7.21**	**8.67**	**5.49**	**5.13**	**4.35**	**4.80**	**4.29**
C.D.	**NS**	**NS**	**NS**	**11.34**	**11.73**	**10.98**	**9.30**	**10.25**	**9.16**
C.V.	**11.80**	**7.12**	**12.01**	**6.25**	**5.15**	**3.91**	**2.65**	**2.44**	**1.87**

In the second year, significant difference in plant height was observed from 120 days after planting. Maximum plant height was recorded in treatment T_6 from 4 months to 9 months after planting. T6 was on par with T_3 and T_5, at 150 and 180 DAP with T_3, T_5 and T_8 at 210 DAP, with T_3, T_4 and T_8 at 240 and 270 DAP. Lowest plant height was recorded in control.

Pseudostem girth

Significant difference in pseudostem girth was noticed throughout the growing stages of Nendran banana in both years. (Table 4.3).

During first year, at 60DAP, maximum pseudostem girth was recorded from T5 and it was on par with T1, T_2, T_3, T_4 and T_8. At 90 DAP, maximum girth was recorded from T_3 and T_5 which were on par with T_2, T_4, T_6 and T_8. Similarly maximum pseudostem girth was recorded from T_3 on par with T_2, T_4, T_5, T_6 and T_8 at 120 DAP. At 150 and 180 DAP, T_3 recoded the maximum girth which were on par with all treatments other than control. Minimum value was recorded from control at all stages of growth.

During second year, pseudostem girth was maximum in treatment T_5 at 60 DAP, in T_6 at 90 DAP, in T_3 at 120 and 150 DAP and in T_6 at 180 DAP. T_5 was on par with T_3, T_4 and T_8 at 60 DAP, T_3 was on par with T_1, T_2, T_4, T_5 and T_8 at 120 DAP, T_3 was on par with T_1, T_2, T4, T_5 and T_6 at 150 DAP and T_6 was on par with T_1, T_2, T_3, T_4, T_5 and T_8 at 180 DAP. Lowest value was recorded from T_9 in all stages of growth.

Table. 4.3 Treatment effect on pseudostem girth

Treatment	Pseudostem girth (cm) of Nendran banana									
	60 DAP		90 DAP		120 DAP		150 DAP		180 DAP	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	13.58	12.05	20.08	22.64	27.25	29.00	38.67	41.74	47.58	51.29
T_2	13.25	13.52	21.42	22.64	29.83	32.08	37.42	40.03	47.17	50.98
T_3	14.58	14.68	24.33	23.36	31.75	33.07	40.50	43.73	48.42	52.02
T_4	13.08	14.07	22.00	26.22	31.58	32.56	38.42	41.23	46.50	50.06
T_5	16.33	17.46	24.33	23.81	29.17	31.37	37.50	40.23	47.17	51.01
T_6	12.42	13.35	20.08	26.37	28.08	29.76	38.25	41.38	48.17	52.13
T_7	11.17	11.95	16.96	21.41	20.08	21.41	31.92	34.60	41.50	44.49
T_8	14.08	14.42	22.00	18.46	27.75	28.64	36.67	39.40	46.42	49.88
T_9	9.71	10.44	17.83	22.89	22.08	23.54	30.67	33.19	38.08	39.11
SE(d)	**1.53**	**1.55**	**1.97**	**2.11**	**3.19**	**3.20**	**2.69**	**2.85**	**3.02**	**3.44**
C.D.	**3.27**	**3.32**	**4.21**	**NS**	**6.81**	**6.84**	**5.74**	**6.09**	**6.45**	**7.36**
C.V.	**14.26**	**14.02**	**11.47**	**11.19**	**14.19**	**13.49**	**8.97**	**8.83**	**8.10**	**8.60**

4.1.2. Leaf characters

Number of functional leaves

Number of functional leaves retained in the plant at different months after planting is presented in table 4.4.

Effect of nutrient sources on number of functional leaves was not significant in first year. In the second year, highest number of functional leaves was recorded from treatment T_8 at 120, 150, 180 and 210 DAP. T_8 was on par with all treatments other than control at 120, 150 and 180 DAP. However at 210 DAP, T_8 was on par with treatment T_1, T_2 and, T_4. T_9 (control) recorded lowest number of leaves.

Table. 4.4 Treatment effect on total number of leaves

Treatment	Total number of leaves of Nendran banana													
	30 DAP		60 DAP		90 DAP		120 DAP		150 DAP		180 DAP		210 DAP	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	4.08	4.42	5.92	6.42	8.75	8.75	11.58	12.25	13.00	15.17	14.67	16.25	15.75	18.08
T_2	4.25	4.33	7.00	6.25	9.83	8.58	12.50	12.33	13.17	14.83	14.83	15.67	16.25	17.33
T_3	4.08	4.00	7.08	6.92	10.25	8.83	11.92	11.67	13.25	15.17	15.00	16.08	16.50	17.25
T_4	4.42	4.42	6.75	6.75	9.75	9.17	12.67	12.75	13.83	15.17	15.17	15.83	16.58	17.67
T_5	4.08	4.00	7.08	6.25	10.25	8.58	11.92	12.33	13.25	15.17	15.00	16.08	16.50	17.25
T_6	5.17	4.33	8.25	6.67	10.50	9.08	11.92	12.58	12.75	14.75	14.67	15.67	16.00	17.58
T_7	3.92	3.92	5.42	6.33	8.58	8.50	10.08	11.92	11.83	14.75	13.67	15.50	14.92	17.33
T_8	5.00	4.50	6.67	6.50	9.42	9.00	11.75	12.83	13.08	15.33	14.42	16.25	15.75	18.25
T_9	5.08	4.08	6.42	6.08	8.58	8.00	11.33	9.92	12.58	12.08	13.25	13.50	14.08	14.42
SE(d)	**0.43**	**0.27**	**0.92**	**0.24**	**0.69**	**0.33**	**0.75**	**0.43**	**0.70**	**0.39**	**0.85**	**0.49**	**0.73**	**0.62**
C.D.	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.923**	**NS**	**0.84**	**NS**	**1.05**	**NS**	**1.33**
C.V.	**11.92**	**7.71**	**16.71**	**4.53**	**8.83**	**4.56**	**7.82**	**4.38**	**6.59**	**3.26**	**7.17**	**3.85**	**5.68**	**4.42**

Leaf area index (LAI)

The data of LAI is presented in table 4.5. In the first year, significant difference in leaf area index was noticed only on 30 days after planting. Maximum value was recorded from Treatment T_8 and T_9 and minimum from T_9. Leaf area index of banana plant was not significantly affected at later stages of plant growth. In the second year, significant difference was noticed at 4^{th}, 5^{th}, 6^{th} and 7^{th} MAP. Maximum values for LAI was recorded in T_8. All the treatments other than control were on par. Lowest LAI was recorded from control.T_8 value was 2.17 at 120 DAP, 2.59 at 150 DAP, 2.75 at 180 DAP and 3.09 at 210 DAP.

Table. 4.5 Treatment effect on Leaf Area Index

Treatment	Leaf Area Index of Nendran banana													
	30 DAP		60 DAP		90 DAP		120 DAP		150 DAP		180 DAP		210 DAP	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	0.69	0.75	1.00	1.09	1.48	1.48	1.96	2.08	2.20	2.55	2.48	2.75	2.66	3.06
T_2	0.72	0.73	1.18	1.05	1.66	1.45	2.11	2.08	2.23	2.51	2.51	2.65	2.75	2.93
T_3	0.69	0.68	1.20	1.17	1.73	1.49	2.01	1.97	2.24	2.56	2.54	2.72	2.79	2.92
T_4	0.75	0.75	1.14	1.14	1.65	1.55	2.14	2.16	2.34	2.56	2.56	2.68	2.81	2.99
T_5	0.69	0.68	1.20	1.06	1.73	1.45	2.01	2.09	2.24	2.56	2.54	2.72	2.79	2.92
T_6	0.87	0.73	1.40	1.13	1.78	1.53	2.01	2.13	2.16	2.49	2.48	2.65	2.71	2.97
T_7	0.66	0.66	0.92	1.07	1.45	1.44	1.70	2.01	2.00	2.49	2.31	2.62	2.52	2.93
T_8	0.80	0.76	1.13	1.10	1.59	1.52	1.99	2.17	2.21	2.59	2.44	2.75	2.66	3.09
T_9	0.80	0.69	1.09	1.03	1.45	1.36	1.91	1.68	2.13	2.04	2.24	2.28	2.38	2.44
SE(d)	**0.05**	**0.05**	**0.16**	**0.04**	**0.12**	**0.054**	**0.13**	**0.073**	**0.12**	**0.69**	**0.14**	**0.084**	**0.12**	**0.105**
C.D.	**0.12**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.156**	**NS**	**0.15**	**NS**	**0.179**	**NS**	**0.225**
C.V.	**8.97**	**7.70**	**16.67**	**4.57**	**8.86**	**4.52**	**7.81**	**4.38**	**6.61**	**3.40**	**7.15**	**3.88**	**5.68**	**4.416**

Phyllochron

There was no significant difference for phyllochron at 2 and 4 months after planting in first year (Table.4.6). However significant difference was observed at 6 months after planting. At 6 months after planting, highest phyllochron (10.38) was recorded in T_8 on par with T_2, T_3, and T_9 and lowest value was recorded for T_1 & T_7 (9.17). During second year, phyllocron was significantly different at 2, 4 and 6 months after planting. At 2 months after planting, lowest values for phyllocron (7.75) was recorded from T_2, T_5 and T_6. Maximum was from T_9 (10.25). 4 months after planting, observations recorded showed that phyllocron was minimum for T_8 (7.42) and maximum for control (10.17). At 6 months after planting, highest phyllochron (10.42) was recorded in T_8 on par with T_2, T_3 and the lowest in T_7 (9.17).

Table. 4.6 Treatment effect on Phyllochron

Treatment	60 DAP		120 DAP		180 DAP	
	First year	Second year	First year	Second year	First year	Second year
T_1	7.58	8.75	7.67	8.58	9.17	10.08
T_2	8.00	7.75	8.25	8.67	10.36	10.28
T_3	7.75	7.92	7.83	8.00	10.08	10.24
T_4	7.17	7.67	8.00	8.33	8.58	9.00
T_5	7.08	7.75	7.17	7.83	8.92	8.83
T_6	7.58	7.75	8.08	8.42	8.50	8.75
T_7	7.17	7.67	7.67	8.00	9.17	9.17
T_8	7.67	7.92	7.33	7.42	10.38	10.42
T_9	8.83	10.25	9.58	10.17	10.08	9.67
SE(d)	**0.51**	**0.41**	**0.66**	**0.49**	**0.67**	**0.58**
C.D.	**NS**	**0.89**	**NS**	**1.04**	**1.43**	**1.23**
C.V.	**8.23**	**6.25**	**10.12**	**7.12**	**9.47**	**7.95**

4.1.4. Flowering and fruiting characters

Days to flowering

Effect of nutrient sources for days to flowering is presented in the table 4.7. In first year, minimum number of days for shooting (187.00 days) was recorded in T_8 followed by T_3 (190.83 days). Maximum number days for shooting (230.08) was recorded from control. In the second year also minimum number of days for shooting (190.92 days) was recorded in T_8 followed T_3 (195.08 days). Maximum number days for shooting (233.25) was recorded in treatment with no manures and fertilizers (T_9).

Days to harvesting (Total crop duration)

Results presented in the table 4.7 indicates that total duration of the crop was significantly influenced by nutrient sources. During first year, early harvesting of bunches (307.17 days) was recorded in T_4 followed by (307.58 days) in T_3. In the second year early harvesting was noticed in T_5 (290.11 days) followed T_3 (295.31 days). Maximum number days for harvesting (335.60 days) was recorded in treatment with no manures and fertilizers (T_9).

Bunch maturity period

Data on bunch maturity period is presented in the table 4.7. Bunch maturity period was not significantly different in both the years. Days from flowering to bunch maturity varied from 112.08 to 127.42 in the first year and from 97.22 to 103.21 in second year.

Table. 4.7 Treatment effect on bunching characters

Treatment	Days for flowering		Days for harvesting		Bunch maturity period	
	First year	Second year	First year	Second year	First year	Second year
T_1	201.00	205.17	318.08	307.32	117.08	101.26
T_2	200.58	204.42	314.33	301.21	113.75	98.46
T_3	190.83	195.08	307.58	295.31	116.75	101.29
T_4	195.08	198.75	307.17	296.13	112.08	97.22
T_5	198.17	201.42	311.83	290.11	113.67	99.01
T_6	202.17	204.67	315.92	300.11	113.75	99.66
T_7	197.67	201.35	310.25	298.47	112.58	97.59
T_8	187.00	190.92	314.42	299.12	127.42	112.04
T_9	230.08	233.25	349.25	335.60	119.17	103.21
SE(d)	**3.04**	**3.41**	**4.26**	**5.615**	**4.65**	**4.68**
C.D.	**6.49**	**7.29**	**9.12**	**12.01**	**NS**	**NS**
C.V.	**1.86**	**2.05**	**1.65**	**2.27**	**4.90**	**5.67**

4.1.5. Yield and yield attributing characters

The bunch yield and associated characters observed during the first year and second year are furnished in table 4.8.

Bunch weight

Significant difference was observed in both years between the treatments for yield and yield attributing characters except for the number of hands and finger girth. Highest bunch weight was observed in T_8 (10.32 kg) in the first year and it was on par with T_2, T_3, T_4, T_5 and T_6. Lowest bunch weight (7.01 kg) was observed in control where no manures and fertilizers were used.

In the second year, highest bunch weight (11.14 kg) was obtained in T_8 followed by (10.49 kg) T_7 which was on par with T_2 and T_3. Lowest bunch weight (7.86 kg) was observed in treatment without manures and fertilizers.

Number of hands

There was no significant influence of nutrient sources in the number of hands per plant in both the seasons. Number of hands ranged from 5.42 to 5.83 in the first year and 5.56 to 6.29 in the second year.

Total number of fingers

In the first year, fertigation with organic manures (T_8) produced highest number of fingers (55.33) followed by T_3 (52.67) which were on par with treatments T_5 and T_6. Lowest number of fingers (44.33) was recorded in control.

In the second year, highest total number of fingers (64.28) per bunch was found in T_8 on par with T_3 and T_5. Total number of fingers was lowest (49.42) in T_9.

Yield per plot

Yield per plot (160.88 kg) was maximum in treatment in T_3 in the first year, found to be on par with T_2, T_4, T_5, T_6 and T_8. Lowest yield of banana (114.13 kg) was obtained in control (T_9). In second year, highest yield per plot was obtained in T_8 (169.2 kg) found to be on par with T_7. Lowest yield of banana fruits (116.56 kg) was obtained in control (T_9).

Finger characters

Finger weight and finger length were significantly different in both the year.

Finger weight

In the first year, highest finger weight (170.96 g) was observed in T_3 followed by T_5 (155.55 g). Lowest finger weight (133.16 g) was recorded from control. In the second year, maximum finger weight was recorded from T_3 (167.44g) and minimum from T_9 (128.98g)

Finger length

Finger length varied from 22.84 cm to 22.47 cm in the first year and from 24.01 cm to 26.44 cm in the second year. Maximum values was recorded in the first year from T_8 which was on par with T_2, T_3, T_4, T_5 and T_6 and in the second year maximum was from T_8 which was on par with T_3, T_4, T_5 and T_6.

Finger girth

Finger girth was `not significantly influenced by the treatments in both the years. Finger girth values ranged from 11.64 cm to 13.31 cm in first year and from 11.49 cm to 13.13 cm in second year.

Table. 4.8 Treatment effect on yield and yield attributing characters

Treatment	Weight of bunch (kg)		No. of hands		No. of fingers		Finger weight (g)		Finger length (cm)		Finger girth (cm)		Yield per plot	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T1	8.08	9.18	5.58	5.72	46.25	50.69	146.31	141.98	23.69	24.59	12.57	12.41	136.44	136.25
T2	9.54	10.07	5.58	6.11	48.67	56.89	154.34	150.38	25.01	25.44	13.31	13.13	159.19	149.44
T3	10.25	10.12	5.75	6.08	52.67	63.76	170.96	167.44	24.94	26.16	12.71	12.55	160.88	149.99
T4	9.04	9.50	5.58	5.87	49.00	59.18	153.11	149.06	24.39	25.55	12.72	12.58	144.67	140.67
T5	8.99	9.67	5.75	6.20	52.25	62.31	155.55	151.67	25.41	26.13	12.75	12.58	143.85	149.83
T6	9.46	8.51	5.58	6.30	52.33	60.16	152.59	148.63	24.68	25.97	13.04	12.88	153.37	133.00
T7	7.98	10.49	5.42	5.95	48.17	55.66	146.29	144.28	24.17	24.80	13.13	12.95	131.00	155.51
T8	10.32	11.14	5.83	5.91	55.33	64.28	154.82	150.90	25.47	26.44	12.52	12.35	160.22	169.20
T9	7.01	7.86	5.50	5.56	44.33	49.42	133.16	128.98	22.84	24.01	11.64	11.49	114.13	116.56
SE(d)	**0.88**	**0.55**	**0.21**	**0.29**	**2.46**	**1.88**	**6.90**	**7.23**	**0.51**	**0.43**	**4.41**	**4.14**	**8.73**	**7.06**
C.D.	**1.87**	**1.16**	**NS**	**NS**	**5.25**	**4.03**	**14.76**	**15.46**	**1.09**	**0.92**	**NS**	**NS**	**18.67**	**15.84**
C.V.	**11.97**	**6.94**	**4.56**	**5.92**	**6.03**	**3.98**	**5.57**	**5.98**	**2.55**	**2.07**	**39.24**	**37.50**	**7.38**	**5.98**

Fruit characters

Fruit characters of *Musa* Nendran observed in first year and second year are presented in table 4.9.

Pulp to peel ratio

Pulp to peel ratio of fruits was significantly different between the treatments in both the years. In the first year highest pulp peel ratio (3.02) was obtained in T_8 on par with T_2, T_3, T_4, T_5, T_6 and T_7. Lowest pulp peel ratio (2.52) was recorded in T_1. In the second year highest pulp to peel ratio (3.13) was recorded in T_5 which was on par with T_3, T_4, T_6, T_7 and T_8. Lowest pulp to peel ratio (2.29) was recorded in T_9.

Peel thickness

Peel thickness of fruits was not significantly influenced by the nutrient sources in both the years. Peel thickness varied from 2.97 mm to 3.19 mm in the first year and from 2.47 mm to 2.86 mm in the second year.

Days to ripening

Days to ripening was significantly different in first year but not in the second year. In the first year, early ripening was recorded from T_1 followed by T_2 and T_6. In the second year number of days taken for ripening varied from 5.67 to 6.25 days.

Shelf life of fruits

In first year, no significant difference was observed for shelf life of fruits. The values varied from 5.5 to 7.17 days. In second year however significant difference was observed in the shelf life of fruits. Highest shelf life of fruits (7.68 days) was obtained in T_6 and it was on par with T_3, T_4, T_5, T_7 and T_8. Lowest shelf life (5.58 days) of fruits was observed in T_9.

Table. 4.9 Treatment effect on fruit characters of Nendran banana

Treatment	Pulp to peel ratio		Peel thickness (mm)		No. of days to ripening		Shelf life of fruits	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	2.52	2.56	3.01	2.47	5.08	5.92	5.50	5.75
T_2	2.93	2.81	3.05	2.71	5.17	5.67	6.00	5.75
T_3	3.00	2.95	3.13	2.75	6.08	6.25	6.25	6.67
T_4	2.90	3.05	2.97	2.80	5.58	5.58	7.17	7.42
T_5	2.97	3.13	3.05	2.86	5.75	5.75	6.83	7.33
T_6	3.01	3.09	3.14	2.83	5.17	5.58	7.00	7.67
T_7	2.96	2.94	3.05	2.55	5.92	6.00	6.42	6.83
T_8	3.02	3.11	3.15	2.68	5.75	6.25	7.00	7.42
T_9	2.61	2.29	3.19	2.68	5.67	6.17	6.67	5.58
SE(d)	**0.02**	**0.14**	**0.22**	**0.21**	**0.29**	**0.33**	**0.73**	**0.61**
C.D.	**0.23**	**0.30**	**NS**	**NS**	**0.62**	**NS**	**NS**	**1.30**
C.V.	**4.64**	**5.99**	**8.77**	**9.69**	**6.40**	**6.92**	**13.68**	**11.10**

Total biomass production

Total biomass accumulation by each part and the whole plant in the first year and second year are furnished in table 4.10.

In both the years, total biomass production of Nendran banana plants was influenced by the nutrient sources. In the first year, highest total biomass (66.63 kg plant^{-1}) was recorded in T_3 which was on par with T_5, T_6 and T_8. Lowest biomass (51.79 kg plant^{-1}) was produced in control. In the second year, highest total biomass (64.45 kg plant^{-1}) was observed in T_8 which was on par with T_3 and T_7. Total biomass was lowest (52.09 kg plant^{-1}) in T_9.

Biomass production of leaf was highest in first year in T_2 and T_6 (1.93kg) which was on par with T_4, T_5, T_7, T_8 and lowest in T_9 (1.35kg). In the second year, highest was in T_6 (2.08 kg) and lowest in T_9 (1.46 kg).

Biomass production of bunch in the first years was maximum recorded from T_8 (10.32 kg) and it was on par with T_2.T_3, T_4, T_5 and T_6 and minimum from T_9. During the second year maximum value for pseudostem was obtained from T_8 (21.60 kg) which was on par with T_2, T_3 and T_7 and minimum for T_9 (16.44 g). Biomass of male bud, peduncle and rhizome was not affected significantly by nutrient sources. The values ranged from 532 to 663.43 g in Ist year and 564.92 to 730.93g in IInd year for male bud, 745.90 to 1093.58 g in first year and 792.16 to 1083.72 g for second year for peduncle and 24.68 to 30.03 kg in first year and 22.86 to 28.45 kg in second year for rhizome.

Table. 4.10 Treatment effect on total biomass production

Treatment	Male Bud (g)		Leaves (kg)		Pseudostem (kg)		Bunch (kg)		Peduncle (g)		Rhizome (kg)		Total Biomass (kg/plant)	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	630.42	730.93	1.48	1.58	17.77	17.36	8.08	9.18	1093.58	934.25	24.68	22.86	54.31	52.64
T_2	613.17	699.58	1.93	2.04	19.18	18.64	9.54	10.07	961.33	1035.16	26.63	24.97	58.87	57.46
T_3	593.92	695.52	1.80	1.94	21.93	21.41	10.25	10.12	1060.92	1090.92	30.03	25.87	66.63	61.12
T_4	663.42	857.58	1.80	1.94	20.45	20.02	9.04	9.50	1011.92	1076.28	25.85	25.53	59.24	58.92
T_5	593.33	674.33	1.67	1.80	20.36	19.90	8.99	9.67	1012.92	1080.60	28.13	26.42	60.73	59.55
T_6	571.17	632.78	1.93	2.08	21.49	21.02	9.46	8.51	995.08	1073.64	27.85	26.48	62.29	59.79
T_7	532.00	724.45	1.79	1.94	19.49	18.96	7.98	10.49	993.25	1058.32	27.59	28.45	58.45	61.62
T_8	656.17	673.49	1.72	1.85	22.16	21.60	10.32	11.14	1022.00	1083.72	29.26	28.11	65.05	64.45
T_9	623.83	564.92	1.35	1.46	16.88	16.44	7.01	7.86	745.92	792.16	25.28	24.96	51.79	52.09
SE(d)	**41.95**	**77.25**	**0.12**	**0.132**	**0.81**	**0.86**	**0.88**	**0.55**	**163.10**	**95.14**	**2.71**	**1.94**	**2.88**	**1.77**
C.D.	**NS**	**NS**	**0.26**	**0.28**	**1.72**	**1.83**	**1.87**	**1.17**	**NS**	**NS**	**NS**	**NS**	**6.16**	**3.78**
C.V.	**8.44**	**13.61**	**8.70**	**8.76**	**4.94**	**5.37**	**11.97**	**6.94**	**20.21**	**11.37**	**12.19**	**9.13**	**5.91**	**3.69**

4.3. Effect of treatments on physical properties of experimental soil

4.3.1. Initial physical properties of experimental soil

Representative nine composite soil samples from the plots where each treatment is imposed were drawn from experimental field and samples were analysed for physical properties (Table 4.12). Bulk density (BD) of initial experimental soil varied from 1.31 to 1.52 g^1 cm^3 and the initial water holding capacity (WHC) of rhizosphere soil from 41.97 to 47.97 per cent. The aggregate stability of the experimental soil was measured by mean weight diameter. Mean weight diameter of initial soil ranged from 47.12 to 50.03 mm.

4.3.2. Physical properties of experimental soil in first and second year

Soil samples from 0-30 cm depth were collected after the harvest of banana from each plot and tested for the physical properties. The results are presented below.

Bulk Density (BD)

The BD of the banana rhizosphere soils before and after harvest of crop in both the years is given in Table 4.11. Organic and inorganic sources of nutrients did not have significant influence on the rhizosphere BD of the experimental soil. During the first year, BD of the experimental soil collected after harvest varied from 1.28 to 1.39 g^1 cm^3. After the second crop, BD of soil ranged from 1.27 to 1.38 g^1 cm^3 between the treatments.

Water Holding Capacity (WHC)

During the first year, water holding capacity of the experimental soil measured after harvest of the crop did not show any significant difference between the treatments (Table 4.11). WHC of soil ranged from 42.64 to 46.83 per cent. But the different organic and inorganic sources of nutrients had a significant influence on the water holding capacity of the soil after the harvest of second crop. Highest WHC (47.30 %) was recorded in T_3 followed by T_5 (45.95 %) and it was on par with T_7, T_4 and T_8.

Aggregate stability

The aggregate stability of experimental soil was measured by estimating the mean weight diameter (Table.4.11). Mean weight diameter varied significantly in various treatments. In the first year, highest value for mean diameter (52.85 mm) was observed in T_8 which was on par with T_3 and T_7. Lowest mean weight diameter was recorded in T_1 (46.62 mm).

Similarly in the second year also different nutrient sources influenced the mean weight diameter between the treatments. Highest value (55.83 mm) was observed in T_8 which was on par with T_3 and T_7. Lowest value was recorded in T_1 (45.92 mm).

Table.4.11 Treatment effect on physical properties of soil

Treatments	Bulk Density (g/cm^3)		WHC (%)		Aggregate stability (mm)	
	First year	Second year	First year	Second year	First year	Second year
T_1	1.30	1.31	43.69	44.08	46.62	45.92
T_2	1.32	1.33	43.27	43.66	49.33	52.11
T_3	1.39	1.36	44.55	47.30	50.38	53.23
T_4	1.38	1.35	44.85	45.30	48.98	51.74
T_5	1.38	1.33	45.99	46.43	49.12	51.89
T_6	1.35	1.37	46.83	44.96	45.27	48.30
T_7	1.35	1.38	45.51	45.95	50.09	52.95
T_8	1.28	1.27	44.82	45.30	52.85	55.83
T_9	1.33	1.34	42.64	43.06	47.68	47.80
SE(d)	**0.08**	**0.08**	**1.68**	**1.71**	**1.35**	**1.37**
C.D.	**NS**	**NS**	**NS**	**3.22**	**2.89**	**2.93**
C.V.	**7.15**	**7.174**	**4.61**	**4.65**	**3.38**	**3.28**

4.4. Effect of treatments on chemical properties of experimental soil

4.4.1. Initial characterization of experimental soil

Representative nine composite soil samples (0-30 cm) from each treatment were drawn from experimental field and were analysed for chemical properties (Table 4.12). Initially experimental soil recorded a pH of 4.7 to 5.0 and electrical conductivity 0.15 to 0.23 dS m^{-1}. Organic carbon of rhizosphere soil ranged from 0.71 to 0.84 % and CEC of experimental soil ranged from 12.01 to 15.24 c mol kg^{-1} soil. The available of N in the experimental field (before start of the experiment) ranged from 143.43 to 167.63 kg ha^{1}, P ranged from 53.28 to 56.95 kg ha^{1}, and K ranged from 177.60 to 213.32 kg ha^{1}. The exchangeable Ca ranged from 236.93 to 390.03 mg kg^{1}, available Mg varied from 70.65 to 93.60 mg kg^{1} and S content varied from 10.28 to 20.08 mg kg^{1}.

Analysis of the micronutrients of the soil samples was also done before and after each season. In the first year before the crop, available iron content ranged from 17.29 to 30.50 mg kg^{1}, Cu ranged from 3.18 to 4.87 mg kg^{1} and Mn ranged from 37.51 to 48.80 mg kg^{1}. Available boron content ranged from 0.28 to 0.45 mg kg^{1} and Zn varied from 37.40 to 51.12 mg kg^{1}.

Table.4.12 Initial Physico-chemical and biological characteristics of the experimental soil

Parameters	**Range**
1. Physical properties	
Bulk density (g/cm3)	1.31- 1.52
Water holding capacity (%)	41.97- 46.64
Aggregate stability (mm)	45.63-50.03
2. Soil chemical properties	
Soil pH	4.8- 5.0
EC (dS/m^{-1})	0.15- 0.0.23
Organic carbon (%)	0.71- 0.84

CEC (c mol/kg)	12.01- 15.24
N (kg/ha)	143.43- 167.63
P (kg/ha)	53.28- 56.95
K (kg/ha)	177.60- 213.32
Calcium (mg/kg)	239.93- 390.03
Magnesium (mg/kg)	66.61- 93.60
Sulphur (mg/kg)	10.28- 20.08
Iron (mg/kg)	17.29-30.50
Copper (mg/kg)	3.18- 4.85
Manganese (mg/kg)	37.51- 47.74
Boron (mg/kg)	0.28-0.45
3. Biological properties	
MBC (µg/g of soil)	122.11- 167.68
Dehydrogenase Enzyme Activity (mg TPF/day/kg of soil)	15.23-19.85
Nitrogenase Enzyme Activity (C_2H_4/g/hour n moles)	26.77-38.11
Viable counts of total fungi (10^3 cfu/g)	26.00- 33.00
Viable counts of total bacteria (10^5 cfu/g)	25.00-33.33
Viable counts of actinomycetes (10^4 cfu/g)	29.00- 41.67

4.4.2. Chemical properties of experimental soil

The soil samples from 0-30 cm depth were collected after the harvest of each crop of banana and tested for the residual fertility in terms of chemical and biological properties. The results are presented in table 4.13.

Soil pH

The pH of the banana rhizosphere soils before and after harvest of crop varied significantly in both years. After the first crop, highest pH 5.4 was recorded in the rhizosphere soils which received organic manures with native isolates of biocontrol agents (T_5) and was on par with T_4 and T_8. Minimum value for pH was recorded from T_1.

In the second year, pH value was high in treatment T_5, and T_8 (5.5). pH value was minimum in treatment T_1 (4.6)

Electrical Conductivity (EC)

Electrical conductivity of the experimental soil did not vary significantly between the treatments in both years. EC values varied between 0.14 to 0.25 dSm^{-1} in first year and 0.18 to 0.34 dSm^{-1} in second year.

Organic carbon

Organic carbon content of rhizosphere soil was affected significantly by nutrient sources. In the first year after crop, highest organic carbon content of 0.96 per cent was recorded in rhizosphere soils that received fertigation with organic manures along with *in situ* green manuring (T_8) and it was on par with treatments T_2, T_3, T_4 and T_5. Lowest value of 0.6% was recorded from T_9.

During the second year, organic carbon content of the soil was significantly affected by nutrient sources. Among all the treatments the highest organic carbon (1.04 %) of experimental soil was observed in T_8 and the lowest from T_9 (0.62 %). The treatments T_2, T_3 and T_5 were on par with T_8.

Cation Exchange Capacity

Nutrient sources did not influence the CEC of the soil during both the years (table 4.13.). After the first crop, CEC content varied from to 12.07 to 15.98 c mol kg^1 and after the second crop, CEC of experimental soil ranged from 11.51 to 15.02 c mol kg^1.

Table. 4.13 Treatment effect on chemical analysis of experimental soil

Treatments	Soil pH		EC (dS/m^{1})		Organic carbon (%)		CEC (c mol kg^{1} of soil)	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	4.7	4.6	0.17	0.21	0.72	0.73	12.35	12.08
T_2	5.0	5.2	0.15	0.19	0.86	0.91	12.07	11.51
T_3	5.0	5.0	0.16	0.21	0.89	0.93	14.33	14.38
T_4	5.1	5.2	0.18	0.23	0.85	0.88	13.63	13.85
T_5	5.4	5.5	0.21	0.26	0.94	0.99	14.42	14.23
T_6	4.9	4.8	0.23	0.30	0.70	0.70	15.98	15.20
T_7	4.9	4.8	0.25	0.34	0.68	0.69	13.72	13.45
T_8	5.3	5.5	0.14	0.18	0.96	1.04	14.03	1448
T_9	4.9	5.1	0.19	0.24	0.60	0.62	13.52	12.28
SE(d)	**0.15**	**0.12**	**0.05**	**0.06**	**0.06**	**0.06**	**1.58**	**1.39**
C.D.	**0.32**	**0.25**	**NS**	**NS**	**0.13**	**0.13**	**NS**	**NS**
C.V.	**3.65**	**2.76**	**33.13**	**30.72**	**9.00**	**8.87**	**14.07**	**13.37**

Available nitrogen

Results of the mineralizable N content of soil collected from 0-30 cm depth are presented in table 4.14. Available N content varied between the treatments significantly in the first year. Among all the treatments, the highest content of N (319.92 kg ha^{-1}) was recorded in T_4 whereas lowest N content (216.51 kg ha^{-1}) was observed in control (T_9). T_4 was on par with T_2 and T_8.

During the second year also, available N content of soil was influenced significantly by nutrient sources. Highest N content (349.87 kg ha^{-1}) was observed in T_8 which was on par with T_2 and T_4. Lowest N content (227.59 kg ha^{-1}) was recorded in control.

Available phosphorus

During first year, effect of treatments on the available P content (kg ha^{-1}) of rhizosphere soils was significant (Table 4.14). The highest available P content of 58.25 kg ha^{-1} was recorded in T_8 which was on par with T_4 (58.49 kg ha^{-1}). Lowest P content (48.34 kg ha^{-1}) was found in T_9.

During the second year, P content was not significantly different between the treatments. P content varied between 45.95 kg $ha^{-1}$and 64.40 kg ha^{-1}.

Available potassium

Available K content of soil was not significantly different between the treatments in both years. The values ranged from 192.02 kg ha^{-1} to 227.17 kg ha^{-1} in the first year and from 199.08 to 230.79 kg ha^{-1} in the second year.

Available calcium

Available Ca content of the rhizosphere soils was not significantly different between the treatments in first year and second year after crop harvest. Data revealed that the available Ca content of the rhizosphere soils ranged from 344.25 to 489.24 mg kg^{-1} of soil in the first year and from 338.74 to 508.64 mg kg^{-1} of soil in the second year.

Available magnesium

Application of different nutrient sources did not have a significant effect on available Mg of soil after harvest of the first crop (Table 4.14). Available Mg

content of rhizosphere soils ranged from 64.29 mg kg^{-1} to 81.27 mg kg^{-1} between the treatments.

During the second year, available Mg content of experimental soils was found to be significantly influenced by nutrient sources. Highest Mg content (95.29 mg kg^{-1}) was obtained in T_8 wherein plants received fertigation with organic manures along with *in situ* green manuring. T_8 was on par with T_2, T_3, T_4 and T_7. Lowest Mg content (62.90 mg kg^{-1}) was observed in T_9.

Table.4.14 Treatment effect on major nutrients of experimental soil

Treatments	N (kg/ha)		P (kg/ha)		K (kg/ha)		Calcium (mg/kg)		Magnesium (mg/kg)		Sulphur (mg/kg)	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	227.70	231.05	49.97	49.82	201.09	209.23	426.66	428.98	73.98	69.58	20.78	22.80
T_2	283.99	310.41	52.78	54.84	215.93	224.71	418.60	435.79	66.61	89.39	20.91	24.38
T_3	281.53	307.06	54.32	56.87	203.46	211.42	380.04	396.67	74.01	88.66	13.37	16.71
T_4	319.92	348.96	55.49	58.28	200.69	208.72	414.21	428.85	76.41	91.68	16.64	20.13
T_5	271.44	295.88	55.09	58.16	227.16	236.52	409.42	424.51	81.27	76.11	17.35	21.22
T_6	264.73	269.97	55.20	58.60	222.01	230.79	471.49	475.78	78.74	66.36	16.74	17.81
T_7	276.37	280.04	54.54	56.62	197.79	205.80	432.25	450.18	73.03	82.74	18.53	20.63
T_8	319.29	349.87	58.25	64.40	219.14	227.50	489.24	508.64	76.48	95.29	18.83	21.65
T_9	216.51	227.59	48.34	45.95	192.02	199.08	344.25	338.74	64.29	62.90	14.69	15.03
SE(d)	**17.66**	**19.619**	**1.31**	**2.405**	**13.16**	**13.87**	**45.58**	**45.34**	**7.02**	**8.70**	**2.93**	**2.721**
C.D.	**37.76**	**41.95**	**2.80**	**5.142**	**NS**	**NS**	**NS**	**NS**	**NS**	**18.60**	**5.05**	**NS**
C.V.	**7.91**	**8.251**	**2.99**	**5.264**	**7.72**	**7.825**	**13.27**	**12.85**	**11.64**	**13.27**	**20.43**	**16.63**

Available Sulphur

During the first year, significant difference was observed for available S content between the treatments (Table 4.14). Highest S content (20.91 mg kg^{-1} of soil) was recorded in T_2 which was on par with T_4, T_5, T_6, T_7 and T_8. Lowest S content (14.69 mg kg^{-1} of soil) was obtained in control (T_9).

However, during the second year, available S content of experimental soils was not influenced significantly by nutrient sources. S content varied from 15.03 mg kg^{-1} to 24.38 mg kg^{-1} between the treatments.

Available Iron

During the first year, significant difference was recorded in available Fe content between the treatments (Table 4.15). Available Fe content of rhizosphere soils revealed that the highest content (40.19 mg kg^{-1} of soil) was recorded in T_8 which was on par with T_2, T_3, T4 and T5. Lowest Fe content (22.59 mg kg^{-1} of soil) was obtained in control (T_9).

During the second year also, available Fe content of experimental soils were influenced significantly by the treatments. The highest Fe content (41.56 mg kg^{-1}) was obtained in T_8 wherein plants received fertigation with organic manures and *in situ* green manuring and it was on par with T_2. Lowest Fe content (22.11 mg kg^{-1}) was obtained in T_9.

Available Copper

During the first year, significant difference was observed for available Cu content between the treatments (Table 4.15). Data on available Cu content of rhizosphere soils revealed that the highest available Cu content (1.80 mg kg^{-1} of soil) was recorded in T_2 on par with T_3 and T_8. Lowest Cu content (0.84 mg kg^{-1} of soil) was obtained in control (T_9).

Similarly, during the second year also, available Cu content of experimental soils was significantly influenced by nutrient sources. Highest Cu content (2.13 mg kg^{-1}) was obtained in T_8 which was on par with T_2 and T_3. Lowest Cu content (1.10 mg kg^{-1}) was observed in T_9.

Available Manganese

During the first year, significant difference was observed for Mn content between the treatments (Table 4.15). Data on available Mn content of rhizosphere soils revealed that the highest content (51.32 mg kg^{-1} of soil) of available Mn was recorded in T_8 which was on par with T_3, T_4, T_5 and T_7. Lowest Mn content (34.38 mg kg^{-1} of soil) was obtained in control (T_9).

During the second year also, available Mn content of experimental soils was significantly influenced by nutrient sources. Highest Mn content (60.81 mg kg^{-1}) was obtained in T_8 which was on par with T_3 and T_5. Lowest Mn content (35.31 mg kg^{-1}) was observed in T_9.

Available Boron

During the first year, significant difference was observed for available Mg content between the treatments (Table 4.15). Data on available B content of rhizosphere soils revealed that the highest content (0.52 mg kg^{-1} of soil) of available B was recorded in T_8 which was on par with T_3, T_4, T_5 and T_7. Lowest B content (64.29 mg kg^{-1} of soil) was obtained in control (T_9).

During the second year, available B content of experimental soils was influenced by nutrient sources significantly. Highest B content (0.60 mg kg^{-1}) was obtained in T_8 and T_5 which was on par with T_2, T_3, T_4 and T_7. Lowest B content (0.37 mg kg^{-1}) was obtained in T_9.

Available Zinc

Significant difference was observed for available Zn content between the various treatments (Table 4.15) in the first year. Data on available Zn content of rhizosphere soils revealed that the highest content (44.93 mg kg^{-1} of soil) of available Zn was in T_3 which was on par with T_4 and T_5. Lowest Zn content (22.73 mg kg^{-1} of soil) was obtained in control (T_9).

Table. 4.15 Treatment effect on chemical properties (micro nutrients) of soil

Treatment	Iron (mg/kg)		Copper (mg/kg)		Manganese (mg/kg)		Boron (mg/kg)		Zinc (mg/kg)	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	23.59	22.83	1.21	1.36	34.41	40.73	0.35	0.36	25.16	28.13
T_2	37.90	38.83	1.80	2.10	41.77	51.55	0.41	0.51	32.86	36.86
T_3	35.71	36.11	1.49	1.74	47.45	55.65	0.47	0.57	44.93	48.29
T_4	35.56	36.22	1.05	1.26	45.00	52.25	0.43	0.52	40.37	46.22
T_5	35.68	36.00	1.09	1.27	45.18	54.47	0.50	0.60	43.66	49.14
T_6	28.33	27.52	1.09	1.35	38.62	40.34	0.34	0.33	30.04	32.28
T_7	34.02	32.69	1.13	1.45	44.68	50.83	0.50	0.56	35.78	38.16
T_8	40.19	41.56	1.78	2.13	51.32	60.81	0.52	0.60	35.99	43.52
T_9	22.59	22.11	0.84	1.10	34.38	35.31	0.34	0.37	22.73	24.69
SE(d)	**2.31**	**2.29**	**0.27**	**0.26**	**3.53**	**3.64**	**0.05**	**0.058**	**4.99**	**3.99**
C.D.	**4.94**	**4.90**	**0.58**	**0.56**	**7.54**	**7.79**	**0.10**	**0.124**	**10.66**	**8.54**
C.V.	**8.67**	**8.596**	**25.79**	**20.83**	**10.16**	**9.09**	**13.69**	**14.43**	**17.64**	**12.67**

During the second year, available Zn content of experimental soils was found to be influenced significantly by the treatments. Highest Zn content (49.14 mg kg^{-1}) was obtained in T_5 which was on par with T_3, T_4 and T_8. Lowest Zn content (24.69 mg kg^{-1}) was observed in T_9.

4.5. Effect of treatments on biological properties of experimental soil

Representative nine composite soil samples of the treatment plots were drawn from experimental field at a depth of 0-30 cm and fresh wet soil samples were analysed for biological properties (Table 4.16).

The activity of enzymes like dehydrogenase varied from 15.23 to 19.85 mg TPF day^{-1} kg^{-1} and nitrogenase activity ranged from 26.77 to 38.11 n moles C_2H_4 g^{-1} hr^{-1}. Microbial biomass carbon ranged from 122.11 to 167.68 µg C g^{-1}.

4.5.1. Microbial biomass carbon (MBC) (µg/g of soil)

Data on MBC of rhizosphere soils are shown in Table 4.16. Microbial biomass carbon content varied with the treatments significantly after the crop in first year. Content of MBC ranged from 105.62 to 151.21 µg g^{-1} of soil. In the first year, after the crop the highest MBC of 151.21 µg g^{-1} of soil was recorded in plots that received fertigation with organic manures (T_8) and the lowest was from T_1. T_8 was found to on par with T_2, T_3, and T_5.

In the second year after crop, among the different treatments, significantly higher MBC (173.89 µg g^{-1} of soil) was recorded in plots supplied with organic manures with *in situ* green manuring (T_8) which was found to be on par with T_4. Lowest value was recorded from T_1 (107.72 µg g^{-1} of soil).

4.5.2. Dehydrogenase activity

In the first year after the crop, highest activity of dehydrogenase (24.21 mg TPF day^{-1} g^{-1} of soil) was recorded in T_5 (rhizosphere soils receiving native isolates of bio control agents with organic manures and *in situ* green manuring) which was on par with T3, T4, T_6 and T_8. Lowest value was recorded fromT1 (3.25 mg TPF day^{-1} g^{-1} of soil).

In the second year after crop, the highest activity of dehydrogenase (45.91 mg TPF day^{-1} g^{-1} of soil) was recorded in T_8 (fertigation with organic manures

and *in situ* green manuring) which was on par with T_4 and T_5. Lowest value was recorded from T_1 (20.22 mg TPF day^{-1} g^{-1} of soil).

4.5.3. Nitrogenase activity

The results of the nitrogenase activity of rhizosphere soils are shown on Table 4.16. In the first year after crop, the activity of nitrogenase in the rhizosphere soil was significantly higher in T_8 (fertigation with organic manures with *in situ* green manuring) (61.09 n moles C_2H_4 hr^{-1} g^{-1} of soil) which was on par with T_3 and T_5. Minimum value was recorded from T9 (28.11 n moles C_2H_4 hr^{-1} g^{-1} of soil).

Similar trend was noticed in the second year on the activity of nitrogenase in the rhizosphere soil. The activity was highest in T_8 (fertigation with organic manures with *in situ* green manuring) (63.52 n moles C_2H_4 hr^{-1} g^{-1} of soil) and lowest in T_9 (25.25n moles C_2H_4 hr^{-1} g^{-1} of soil). Organic and inorganic nutrient sources significantly influenced nitrogenase activity in rhizosphere soils.

Table. 4.16 Treatment effect on biological properties of experimental soil

Treatments	Micro biomass carbon (µg/g of soil)		Dehydrogenase enzyme activity (mg TPF/day/kg of soil)		Nitrogenase enzyme activity (C_2H_4/g/hr n moles)	
	First year	Second year	First year	Second year	First year	Second year
T_1	105.62	107.72	13.25	20.22	28.11	25.25
T_2	138.28	159.02	16.86	32.30	42.84	42.45
T_3	139.09	159.96	20.20	29.76	49.26	51.20
T_4	142.14	163.46	23.07	43.01	47.07	50.64
T_5	135.51	155.84	24.21	44.51	49.49	50.51
T_6	126.19	119.78	18.48	21.79	37.24	31.12
T_7	118.73	120.81	15.59	18.88	32.29	31.46
T_8	151.21	173.89	23.20	45.91	61.09	63.52
T_9	118.98	127.18	14.74	21.52	32.35	35.88
SE(d)	**7.00**	**5.56**	**2.78**	**5.64**	**6.02**	**3.97**
C.D.	**14.97**	**11.90**	**5.96**	**12.05**	**12.87**	**8.49**
C.V.	**6.57**	**4.76**	**18.04**	**22.37**	**17.47**	**11.46**

4.5.4. Total microbial count

4.5.4.1. Total fungi (10^3 cfu/g)

The results of the viable microbial cell counts of the rhizosphere soil before and after crop are shown in Table 4.17. In the first year after the crop, significant difference was observed between the treatments, the highest fungal count of 40 x 10^3 cfu g^1 was recorded in fertigation with organic manures with *in situ* green manuring (T_8) which was on par with T_2, T_3, T_4 and T_5. The lowest count was recorded from T_1 (24.33 x 10^3 cfu $g^{1)}$.

In the second year after crop, significant difference were observed between treatments and the highest fungal count of 41 x 10^3 cfu g^1 was recorded in fertigation with organic manures with *in situ* green manuring (T_8) which was on par with T_2, T_3, T_4 and T_5 as in the first year. Lowest count was from T_1 (24. x10^3 cfu g^1).

4.5.4.2. Total Bacteria (10^5 cfu/g)

Viable counts of bacterial cells varied from 25.00 to 33.33 x10^5 cfu g^1initially. After crop, among the treatments, the highest bacterial count of 37.33 x10^5 cfu g^1 was observed in treatment T_4 (organic manures with bio control agent) in first year and 39.0 x10^5 cfu g^1 in second year which were on par with T_2, T_3, T_5 and T_8 in both years. Lowest counts were recorded from T_7 in first year and T_6 in second year and the value was 27.33 x10^5 cfu g^1 in both years (table 4.17).

Table. 4.17 Treatment effect on total microbial counts

Treatment	Total fungi (10^3 cfu/g)		Total Bacteria (10^5 cfu/g)		Actinomycetes (10^4 cfu/g)	
	First year	Second year	First year	Second year	First year	Second year
T_1	24.33	24.00	30.33	31.00	29.00	28.00
T_2	34.00	37.00	35.33	37.33	41.33	41.67
T_3	36.00	37.67	37.00	36.67	46.67	45.67

T_4	36.67	38.67	37.33	39.00	36.67	40.00
T_5	33.00	36.67	36.00	37.33	36.00	37.67
T_6	27.67	25.00	27.67	27.33	31.40	29.33
T_7	31.33	30.00	27.33	30.33	31.00	30.00
T_8	40.00	41.00	35.33	36.00	46.33	45.33
T_9	31.67	33.67	29.33	30.33	36.33	35.33
SE(d)	**3.70**	**2.61**	**3.21**	**2.75**	**3.37**	**2.84**
C.D.	**7.91**	**5.59**	**6.87**	**5.89**	**7.22**	**6.07**
C.V.	**13.85**	**9.49**	**11.97**	**9.94**	**11.13**	**9.39**

4.5.4.3. Total Actinomycetes (10^4 cfu/g)

In the first year before the crop no significant difference was observed for total actinomycetes (table 4.17). Viable counts of total actinomycetes varied from 29 to 41.67 x 10^4 cfu g^{-1}. After the first crop, viable count of actinomycetes cell was significantly high (46.67 x 10^4 cfu g^{-1}) in treatment (T_3) that received POP recommendation of KAU with organic manures (15 kg FYM and 0.5 kg lime as basal + 14 kg Poultry manure + 4 kg wood ash, plant1). The lowest actinomycetes count (29 x 10^4 cfu g^{-1}) was recorded in T_1. T_3 was on par with T_2 and T_8.

During the second year after crop, the results of the total microbial count revealed the significant influence of treatments. Highest actenomycetes count (45.67 x 10^4 cfu g^1 of soil) was recorded in T_3 which was on par with T_2, T_4 and T_8. Minimum count was from T_1 (28.0 x 10^4 cfu g^1 of soil)

4.6. Plant analysis

4.6.1 Nitrogen content in the index leaf at 4 MAP

Nitrogen content in the index leaf of banana at vegetative growth stages and in different plant parts at harvest during the first year and second year are furnished in Tables 4.18.

In the first year, nitrogen content in the index leaf was not significantly different between the treatments. N content varied from 2.44 to 3.60 per cent between the treatments.

During the second year, N content varied significantly. Highest nitrogen content (3.64 %) was observed in plots that received fertigation with chemical fertilizers (T_7) which was on par with T_6, T_1, T_2, T_4, T_5 and T_8. Lowest N content (2.42 %) was recorded from control plots.

N content of different plant parts at harvest

The N content of various plant parts at harvest during first and second year are given in Tables 4.18 and 4.19 respectively.

Leaf

Organic and inorganic sources of nutrients influenced the nitrogen content in leaf at the time of harvest in both the years. In the first year, fertigation with organic manures (T_8) recorded the maximum (1.50 %) which was on par with T_4 (1.47 %). Minimum was recorded from T_9 (1.05%).

During the second year, N content in index leaf after harvest was maximum from T_8 (1.48%) and minimum from T_9 (1.07 %). T_8 was on par with T_4 and T_5.

Pseudostem

N content of pseudostem was significantly influenced by the nutrient sources in both the years. In first year maximum value was recorded from treatment T_8 (0.96%) and minimum from T_9 (0.67%). In the second year T_8 recorded maximum N content in pseudostem (1.0%) which was on par with T_4. Minimum N content was recorded from control (0.67%)

Fruit

There was no significant difference between the treatments in N content of fruits in both years. N content ranged from 0.55 (T_9) to 0.86 (T_8) per cent in the first year and from 0.67 (T_9) to 1.05 (T_8) per cent in the second year.

Peduncle

Significant difference was obtained in N content of peduncle in both the years. Highest N content (2.00 %) in peduncle was obtained in T_8 which was

on par with treatments T_5 and T_7 in first year. Lowest value was recorded from T_1 (1.27%). In the second year, treatment T_8 recorded the maximum N content (2.24%) which was on par with T_5 and T_7. Lowest value was recorded from T_1 and T_9 (1.43%).

Rhizome

Nitrogen content in the rhizome was influenced significantly by nutrient sources in both the years. T_8 recorded the maximum values of 1.54 and 1.82 percent in year I and II respectively. It was on par with T7. Minimum values were recorded from T_9 (0.98 % and 1.16 %).

Table. 4.18 Treatment effect on Nitrogen (%) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	3.58	3.61	1.15	1.14	0.68	0.72	0.56	0.69	1.27	1.43	1.01	1.19
T_2	3.22	3.24	1.31	1.31	0.77	0.81	0.69	0.85	1.59	1.79	1.18	1.39
T_3	2.79	2.82	1.29	1.28	0.75	0.80	0.72	0.89	1.67	1.88	1.19	1.41
T_4	3.54	3.43	1.47	1.46	0.85	0.90	0.76	0.94	1.73	1.94	1.21	1.44
T_5	3.18	3.15	1.36	1.35	0.81	0.85	0.79	0.97	1.89	2.12	1.27	1.51
T_6	3.57	3.56	1.28	1.27	0.82	0.86	0.62	0.76	1.48	1.66	1.05	1.24
T_7	3.60	3.64	1.28	1.28	0.82	0.86	0.81	1.00	1.90	2.13	1.44	1.71
T_8	3.32	3.29	1.50	1.48	0.96	1.00	0.86	1.05	2.00	2.24	1.54	1.82
T_9	2.44	2.42	1.05	1.07	0.64	0.67	0.55	0.67	1.28	1.43	0.98	1.16
SE(d)	**0.39**	**0.32**	**0.06**	**0.06**	**0.05**	**0.05**	**0.03**	**0.042**	**0.09**	**0.11**	**0.06**	**0.076**
C.D.	**NS**	**0.69**	**0.13**	**0.14**	**0.10**	**0.11**	**NS**	**NS**	**0.20**	**0.23**	**0.13**	**0.16**
C.V.	**14.76**	**12.16**	**5.61**	**6.08**	**7.40**	**7.37**	**5.98**	**5.98**	**6.83**	**7.04**	**6.36**	**6.47**

4.6.2 Phosphorus

P content in the index leaf at 4 MAP

The P content in the index leaf was significantly different between the treatments in both the years (Table 4.19).

P content was highest for treatment T_8 in first year and second year (0.31 % and 0.35% respectively) which was on par with T_2, T_3 and T_7 in both years. Minimum was recorded from T_9 in both years (0.22% and 0.23% respectively).

P content in different plant parts at harvest

P content of the various plant parts at harvest are presented in Table 4.19 for the first year and second year.

Leaf

P content in index leaf at the time of harvest varied from 0.11 per cent to 0.14 per cent in the first year and from 0.25 to 0.32 per cent in the second year. In both the years, highest P content was recorded with fertigation with organic manures (T_8) and minimum from control. T_8 was on par with T_5 in first year.

Pseudostem

Fertigation with organic manures (T_8) resulted in the highest P content (1.11%) in first year. Minimum value was recorded from control. In the second year it was not significant.

Fruit

In both the years, phosphorous content in fruit was significantly influenced by the treatments. P value was highest in T_8 (0.79 and 0.41 respectively) in first year and second year and it was on par with T_6 and T_7. The lowest P content was recorded from T_9 (0.41% and 0.21% respectively).

Peduncle

Significant difference was recorded for P content in peduncle in both years. P content in the peduncle ranged from 0.l6 per cent (T_9) to 0.32 per cent (T_6) in the first year and from 0.33 per cent (T_9) to 0.66 per cent (T_6) in the second year. In the first year and second year T_6 was on par with T_3, T_4, T_5, T_7 and T_8.

Rhizome

Significant difference was recorded for P content in rhizome in both years. P content in rhizome varied from 0.09 (T_9) to 0.18 (T_6) per cent during the first year and from 0.50 (T_9) to 1.01(T_6) during the second year. T_6 was on par with T_3, T_4, T_5, T_7 and T_8 in both years.

Table. 4.19 Treatment effect on Phosphorous (%) in the index leaf at 4 months after planting and in different plant parts

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	0.24	0.26	0.12	0.26	0.92	0.64	0.44	0.23	0.19	0.39	0.11	0.60
T_2	0.30	0.33	0.12	0.26	0.88	0.46	0.54	0.28	0.23	0.47	0.13	0.75
T_3	0.27	0.31	0.13	0.28	0.90	0.63	0.62	0.32	0.27	0.56	0.16	0.91
T_4	0.23	0.28	0.12	0.27	0.87	0.56	0.64	0.33	0.28	0.57	0.16	0.92
T_5	0.23	0.28	0.12	0.27	0.88	0.59	0.63	0.33	0.28	0.57	0.16	0.87
T_6	0.25	0.28	0.12	0.27	0.86	0.54	0.72	0.37	0.32	0.66	0.18	1.01
T_7	0.30	0.33	0.12	0.28	0.95	0.65	0.72	0.38	0.30	0.62	0.17	0.97
T_8	0.31	0.35	0.14	0.32	1.11	0.68	0.79	0.41	0.29	0.58	0.17	0.92
T_9	0.22	0.23	0.11	0.25	0.85	0.54	0.41	0.21	0.16	0.33	0.09	0.50
SE(d)	**0.22**	**0.020**	**0.01**	**0.015**	**0.06**	**0.024**	**0.04**	**0.022**	**0.024**	**0.05**	**0.02**	**0.10**
C.D.	**0.05**	**0.043**	**NS**	**NS**	**0.13**	**NS**	**0.09**	**0.05**	**0.51**	**0.11**	**0.04**	**0.22**
C.V.	**10.27**	**8.37**	**6.86**	**6.88**	**8.46**	**18.93**	**8.56**	**8.66**	**11.48**	**11.87**	**15.35**	**15.04**

4.6.3 Potassium

K content in the index leaf at 4 MAP

Concentration of potassium in various plant parts as influenced by the treatments are presented in Table 4.20 for the first year and second year. K content in leaf varied from 2.33 percent (T_9) to 4.22 (T_8) percent in the first year and from 2.24 (T_9) to 4.37 (T_8) per cent at in the second year.

K content in different plant parts at harvest

Significant difference was recorded for K content in different plant parts in both years. (Table 4.20)

Leaf

The effect of different treatments was highest (2.07 %) and (1.89 %) respectively in first and second year in leaves of plants fertigated with organic manures (T_8).

Pseudostem

K content was highest in T_8 and lowest in T_9 in the both years. Values ranged from 8.97 to 12.27 in first year and 6.55 to 9.33 in second year. T_8 was on par with T_7.

Fruit

The K content in fruit ranged from 1.1 to 1.8 per cent and 1.3 to 2.2 percent in the first year and second year respectively. Highest K content was obtained in T_8 in both years and lowest in T_9.

Table. 4.20 Treatment effect on Potassium (%) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	2.41	2.48	1.12	1.02	9.07	6.67	1.28	1.51	8.66	6.70	6.68	5.81
T_2	3.05	3.05	1.45	1.32	10.28	7.54	1.50	1.77	10.11	7.85	7.63	6.63
T_3	2.59	2.67	1.29	1.18	9.97	7.41	1.56	1.84	10.47	8.14	8.23	7.16
T_4	2.69	2.78	1.27	1.16	9.55	7.09	1.66	1.96	10.48	8.14	6.82	5.93
T_5	3.07	3.10	1.46	1.34	10.55	7.73	1.66	1.96	10.52	8.16	7.66	6.66
T_6	3.79	3.85	1.74	1.59	10.86	7.94	1.36	1.61	9.03	6.97	9.49	8.25
T_7	3.49	3.77	1.78	1.64	11.75	8.64	1.58	1.87	10.67	8.12	8.73	7.60
T_8	4.22	4.37	2.07	1.89	12.70	9.33	1.87	2.21	12.50	9.62	10.56	9.19
T_9	2.23	2.24	1.03	0.94	8.97	6.55	1.10	1.29	7.66	5.90	6.02	5.24
SE(d)	**0.19**	**0.114**	**0.12**	**0.116**	**0.70**	**0.50**	**0.06**	**0.071**	**0.70**	**0.540**	**0.48**	**0.419**
C.D.	**0.41**	**0.24**	**0.27**	**0.25**	**1.50**	**1.06**	**0.13**	**0.157**	**1.51**	**1.15**	**1.03**	**0.90**
C.V.	**7.58**	**4.45**	**10.35**	**10.58**	**8.27**	**7.94**	**4.88**	**4.86**	**8.61**	**8.53**	**7.39**	**7.39**

Peduncle

In peduncle also K content was highest in treatment T_8 and lowest in T_9 in both years. Values ranged from 7.66 to 12.5 in first year and 5.92 to 9.62 in second year.

Rhizome

The content of potassium in rhizome ranged from 6.02 to 10.56 per cent in the first year and from 5.24 to 9.18 per cent in the second year. Highest values were obtained for T_8 and lowest for T_9.

4.6.4 Calcium

Significant difference was observed between the treatments in Calcium content in all plant parts. Results are presented for year I and II in Table 4.21.

Ca content in the index leaf at 4 MAP

Ca content was maximum in T_8 both in I^{st} year and II^{nd} year which was on par with T_7. T_9 recorded the lowest values. Ca. content ranged from 0.51 to 0.92 in first year and 0.51 to 0.97 in second year.

Ca content in different plant parts at harvest

Leaf

Highest Ca content (1.80 % and 2.21%) was observed in T_8 and lowest in T_9 in both first year and second year. T_8 was on par with T_4 and T_5 in second year.

Pseudostem

Calcium content of pseudostem ranged from 0.56 to 0.93 per cent and 0.62 to 1.03 per cent in the first year and second year respectively. In the first year, highest Ca content (0.93 %) in pseudostem was recorded in T_8 which was on par with T_7 while lowest Ca content (0.54 %) in pseudostem was observed in control.

Similarly, in the second year highest Ca content (1.03 %) in pseudostem was obtained in T_8 which was on par with T_7 (0.92 %) while lowest Ca content (0.62 %) in pseudostem was observed in control.

Fruit

Calcium content in the fruit was influenced by nutrient sources in both the years. Calcium content of fruits ranged from 0.21 to 0.35 per cent in the first year and 0.26 to 0.43 per cent in the second year. In the first year, highest Ca content (0.35 %) in the fruit was observed in T_8 which was on par with T_7. In the second year also, highest Ca content (0.43 %) was recorded in T_8. Lowest Ca content in fruit was observed in control in both the years.

Peduncle

Calcium content of peduncle ranged from 0.57 to 0.88 per cent and 0.61 to 0.95 per cent in the first year and second year respectively. T_8 recorded the highest and T_9 recorded the lowest content of calcium in both the years.

Rhizome

In the first year, highest Ca content (1.03 %) in rhizome was obtained in T_8 which was on par with T_4 and T_5. Lowest Ca content (0.65 %) in rhizome was observed in control. In the second year T_8 recorded highest Ca content and T_9 recorded the lowest values. T_8 was on par with T_3 and T_5 in first year and with T_3, T_4 and T_5 in second year.

Table. 4.21 Treatment effect on Calcium (%) in the index leaf at 4 months after planting and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	0.61	0.65	1.29	1.57	0.54	0.60	0.25	0.31	0.62	0.66	0.77	0.65
T_2	0.64	0.69	1.44	1.77	0.66	0.74	0.28	0.34	0.69	0.74	0.89	0.75
T_3	0.63	0.67	1.49	1.84	0.62	0.69	0.28	0.34	0.71	0.77	0.92	0.78
T_4	0.64	0.67	1.62	1.99	0.63	0.71	0.29	0.36	0.79	0.86	0.99	0.84
T_5	0.62	0.65	1.59	1.97	0.69	0.76	0.30	0.37	0.78	0.85	0.95	0.81
T_6	0.75	0.71	1.49	1.86	0.80	0.89	0.27	0.33	0.73	0.78	0.87	0.73
T_7	0.91	0.89	1.51	1.85	0.83	0.93	0.29	0.36	0.74	0.79	0.89	0.75
T_8	0.92	0.97	1.80	2.21	0.93	1.04	0.35	0.43	0.88	0.95	1.03	0.87
T_9	0.51	0.51	1.17	1.41	0.56	0.62	0.21	0.26	0.57	0.61	0.65	0.55
SE(d)	**0.06**	**0.043**	**0.06**	**0.123**	**0.05**	**0.056**	**0.02**	**0.021**	**0.03**	**0.043**	**0.04**	**0.041**
C.D.	**0.12**	**0.092**	**0.12**	**0.262**	**0.10**	**0.119**	**0.04**	**0.044**	**0.06**	**0.091**	**0.10**	**0.088**
C.V.	**10.27**	**7.38**	**4.78**	**8.21**	**8.58**	**8.81**	**7.35**	**7.32**	**5.06**	**6.73**	**6.16**	**6.78**

4.6.5 Magnesium

Mg content in the index leaf at 4 MAP

Magnesium content at 4 MAP was significantly influenced by nutrient sources (Table4.22). Highest Mg content was observed in T_8 in the first year and second year. T_8 was on par with T_3 and T_7. Lowest values were recorded from control.

Mg content in different plant parts at harvest

Leaf

Highest Mg content (0.30 %) was obtained in first year in T_5 which was on par with T_4 and T_7. In second year highest Mg content was recorded from T_8 and lowest Mg content from control. T_8 was on par with T_4 and T_7 in second year.

Pseudostem

In the first year, Mg content of pseudostem was significantly influenced by the treatments. Highest Mg content (0.23 %) was obtained in T_7 and lowest Mg (0.13 %) content in leaf was recorded in T_9 in first year. Treatments T_7 and T_9 recorded the highest and lowest values in the second year also.

Fruit

Mg content of fruits was not influenced by the treatments in both the years. Mg content varied from 0.11 % to 0.19 % in first year and 0.18% to 0.40 % in second year.

Peduncle

Mg content of peduncle was also not significantly different between the treatments in both the years. Mg content varied from 0.13 % to 0.30 % in first year and 0.17% to 0.4% in second year.

Rhizome

Mg content of rhizome was significantly influenced by the treatments in both years. Maximum Mg content of rhizome was recorded in T_6 (0.30% and 1.0% respectively) and minimum from T_9 (0 .13% and 0.52%) in first year and second year. T_6 was on par with T_4, T_5 and T_8 in both years.

Table.4.22 Treatment effect on Magnesium content (%) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	0.125	0.15	0.209	0.49	0.160	0.25	0.129	0.20	0.161	0.21	0.260	0.69
T_2	0.144	0.17	0.246	0.57	0.191	0.30	0.136	0.21	0.170	0.23	0.307	0.81
T_3	0.189	0.22	0.235	0.55	0.182	0.28	0.146	0.23	0.181	0.24	0.293	0.77
T_4	0.159	0.18	0.265	0.62	0.204	0.32	0.152	0.24	0.185	0.24	0.331	0.88
T_5	0.132	0.15	0.297	0.68	0.203	0.31	0.155	0.25	0.189	0.25	0.342	0.92
T_6	0.135	0.16	0.185	0.43	0.154	0.24	0.252	0.40	0.303	0.40	0.232	1.00
T_7	0.180	0.21	0.281	0.65	0.225	0.35	0.162	0.26	0.192	0.25	0.351	0. 61
T_8	0.198	0.23	0.256	0.60	0.200	0.31	0.192	0.30	0.221	0.29	0.369	0. 93
T_9	0.077	0.09	0.158	0.37	0.127	0.20	0.113	0.18	0.132	0.17	0.199	0.52
SE(d)	**0.009**	**0.012**	**0.017**	**0.036**	**0.009**	**0.014**	**0.047**	**0.074**	**0.056**	**0.073**	**0.011**	**0.059**
C.D.	**0.020**	**0.025**	**0.037**	**0.077**	**0.018**	**0.029**	**NS**	**NS**	**NS**	**NS**	**0.024**	**0.126**
C.V.	**7.08**	**8.18**	**8.90**	**7.99**	**5.751**	**5.88**	**35.97**	**36.05**	**35.87**	**35.40**	**4.51**	**9.09**

4.6.6 Sulphur

Sulphur content in the index leaf at 4 MAP

Sulphur content in leaf was significantly influenced by the different nutrient sources. Results are presented in table 4.23.

S content in leaf was significantly higher in T_5 than other treatments in first year (0.23 %) and lowest in T_9 (0.08%). T_5 was on par with T_4 and T_8. In the second year highest values for S in leaf was recorded from T_8, T_4 and T_5 (0.23%). Lowest value of 0.1% was recorded from T_9.

S content in different plant parts at harvest

Leaf

Sulphur content of leaf after harvest was significantly influenced by nutrient sources in both the years. Highest S content (0.56 %) was obtained in T_8 and lowest S content (0.16 %) was recorded in T_9 in the first year. In the second year T_8 had the maximum S content (0.66%) and T_9 the minimum (0.2%)

Pseudostem

In the first year highest S content (0.56 %) was obtained in T_8 and lowest S (0.17 %) was recorded in T_9. S content varied from 0.19 to 0.66 per cent in the second year. Lowest values were recorded from T_9 and highest from T_8.

Fruit

S content in fruit was highest in treatment T_8 and lowest in treatment T_9 in both the years. It varied from 0.14 to 0.51 per cent in first year and 0.14 to 0.52 percent in second year.

Peduncle

S content of peduncle varied from 0.38 to 0.0.71 percent in first year and 0.41 to 0.80 percent in second year. Highest values were recorded from T_7 which was on par with T_3, T_4, T_5 and T_8 in first year and T_2, T_3, T_4, T_5 and T_8 in second year.

Rhizome

In the first year, S content of rhizome after harvest was significantly influenced by nutrient sources. Among all the treatments, maximum S content of rhizome was recorded in T_5 (0.78 %) which was on par with T_2, T_3, T_4, T_7 and T_8 and the lowest from T_9 (0.45%)

S content in rhizome was influenced significantly in the second year also. The values varied from 0.53 (T_9) to 0.9 (T_7) per cent in the second year. T_7 was on par with T_2, T_3, T_4, T_5 and T_8.

Table. 4.23 Treatment effect on Sulphur (%) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	0.106	0.12	0.179	0.50	0.182	0.21	0.153	0.15	0.405	0.44	0.485	0.58
T_2	0.130	0.14	0.257	0.76	0.252	0.29	0.221	0.22	0.584	0.66	0.703	0.85
T_3	0.153	0.16	0.318	0.92	0.299	0.35	0.265	0.26	0.612	0.69	0.692	0.84
T_4	0.225	0.23	0.283	0.80	0.281	0.32	0.248	0.24	0.602	0.67	0.663	0.80
T_5	0.230	0.23	0.378	1.10	0.378	0.44	0.343	0.35	0.688	0.79	0.774	0.94
T_6	0.162	0.17	0.207	0.62	0.207	0.24	0.172	0.17	0.491	0.56	0.557	0.67
T_7	0.192	0.20	0.403	1.22	0.408	0.48	0.371	0.37	0.712	0.80	0.792	0.95
T_8	0.221	0.23	0.556	1.68	0.565	0.66	0.514	0.52	0.694	0.79	0.758	0.91
T_9	0.086	0.10	0.166	0.47	0.169	0.20	0.143	0.14	0.376	0.41	0.445	0.54
SE(d)	**0.011**	**0.010**	**0.032**	**0.163**	**0.036**	**0.046**	**0.030**	**0.041**	**0.052**	**0.067**	**0.065**	**0.079**
C.D.	**0.024**	**0.021**	**0.069**	**0.348**	**0.078**	**0.098**	**0.064**	**0.087**	**0.112**	**0.144**	**0.139**	**0.168**
C.V.	**8.080**	**6.80**	**12.99**	**22.22**	**14.64**	**15.93**	**13.62**	**18.54**	**11.138**	**12.81**	**12.169**	**12.25**

4.6.7 Iron

Fe content of the plant parts for both years are presented in table 4.24.

Fe content in the index leaf at 4 MAP

Fe content in the leaf 4 MAP was observed to be significantly influenced by the nutrient sources in both the years. Highest Fe content (483.42 ppm) in index leaf was observed in T_8 and lowest Fe content (199.92 ppm) was obtained in control. Fe content varied from 203.32 (T_9) to 490.66 ppm (T_8) in the second year.

Fe content in different plant parts at harvest

Leaf

Fertigation with organic manures (T_8) resulted in the highest Fe content in the leaf at harvest in both the years. In the first year highest Fe content in index leaf was observed in T_8 (706.0 ppm) which was on par with T_5 and T_8. In the second year also treatment T8 had maximum Fe content (1803.63 ppm) which was statistically on par with T_3 and T_5. Lowest Fe content in the leaves was recorded in the second year from control (847.03ppm) which was also on par with T_3 and T_5.

Pseudostem

Influence of nutrient sources on the Fe content in pseudostem was similar in both the years. Highest Fe content was recorded in fertigation with organic manures (T_8) (736.18 and 714.82ppm) respectively for first year and second year and lowest value was recorded from T_9 (343.92 and 350.88ppm). T_8 was on par with T_5 in both years.

Fruit

Fe content in the fruit was high in T_8 in first year and second year. The values recorded from T8 are 227.74 ppm in first year and 183.19ppm in second year. Lowest content (103.77 ppm) in first year and 83.86 ppm in second year was found in control.

Peduncle

In peduncle, Fe content was highest (516.58 ppm) in T_8 which was on par with T_5 in the first year. In the second year T_4 resulted in the higher Fe content in peduncle (595.48 ppm). Treatment T_4 was on par with T_5 and T_8 in second year. Lowest Fe content (191.5 and 215.66 ppm) in peduncle was obtained in T_9 in both years..

Rhizome

Fe content of rhizome ranged from 1320 to 2782 ppm in the first year and from 946.85 to 2023.73 ppm in the second year. In the first year highest Fe content (2782.89 ppm) was obtained in T_8 which was on par with T_3, T_4, T_5 and T_7 and in second year T_8 was on par with T_3, T_5 and T_7. Least Fe content was recorded in control both in first year (1320.89 ppm) and in second year (946.86 ppm).

Table. 4.24 Treatment effect on Iron content (ppm) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	204.67	208.14	395.25	1002.80	398.01	410.27	120.28	96.67	210.75	235.77	1498.80	1077.88
T_2	281.25	285.86	527.58	1301.05	528.94	540.28	160.56	129.60	339.42	379.62	2084.55	1479.28
T_3	288.08	292.92	598.50	1482.20	600.15	614.05	181.29	146.21	401.33	448.36	2409.72	1712.13
T_4	332.58	337.97	560.17	1375.67	562.60	572.91	167.41	135.37	369.50	420.31	2233.42	1581.68
T_5	328.42	331.89	650.25	1630.25	653.06	670.99	187.83	151.18	447.17	595.48	2516.92	1816.33
T_6	224.92	228.41	497.00	1296.12	504.73	523.40	128.76	103.22	308.33	355.00	2043.81	1499.83
T_7	252.50	256.87	539.42	1407.03	547.22	567.95	139.75	111.97	346.42	395.43	2242.58	1644.60
T_8	483.42	490.66	706.00	1803.63	714.82	736.18	227.74	183.19	516.58	502.15	2782.89	2023.73
T_9	199.92	203.32	341.00	847.03	343.92	350.88	103.77	83.86	191.50	215.66	1320.89	946.86
SE(d)	**17.72**	**17.38**	**46.33**	**157.48**	**48.53**	**53.05**	**13.48**	**11.20**	**44.33**	**61.98**	**240.89**	**195.09**
C.D.	**37.88**	**37.16**	**99.06**	**336.72**	**103.32**	**113.44**	**28.83**	**23.95**	**94.78**	**132.53**	**515.07**	**417.13**
C.V.	**7.52**	**7.27**	**10.61**	**14.29**	**11.02**	**11.73**	**10.49**	**10.82**	**15.61**	**19.26**	**13.88**	**15.60**

4.6.8 Zinc

Zn content in different plant parts was significantly different in both years (Table 4.25).

Zinc content in the index leaf at 4 MAP

In the first year at 4 MAP highest leaf Zn content (39.00 ppm) was observed in treatment T_8 which was on par with T_7 (35.02 ppm). Lowest Zn content (12.53) in the index leaf was recorded in T_9. In the second year Zn content was highest in T_8 (37.6) and lowest in T_6 (17.03).

Zinc content in different plant parts at harvest

Leaf

Zn content varied from 11.12 (T_9) to 17.35 (T_2) ppm during first year and from 12.27 (T_9) to 19.48 ppm (T_2) during second year. T_2 was on par with T_6 and T_8 in first year and T_3, T_4, T_6 and T_8 in second year.

Pseudostem

Significant difference was observed for Zn content in pseudostem between the treatments in both years. Highest Zn content (37.04 ppm) was recorded in fertigation with organic manures (T_8) and lowest in control (24.80ppm) in first year. T_8 was on par with T_2 and T_6. In second year Zn content was maximum in treatment T_8 (53.41ppm) which was on par with T_2 and T_6. Lowest value was recorded from T_9 (35.61ppm).

Fruit

Highest Zn content (9.94 ppm) in fruit was observed in T_4 which was on par with T_2 and T_8 in the first year. Lowest was recorded from T_9 (6.54). Similarly in second year also the highest content (79.35 ppm) in fruit was observed in T_8 which was on par with T_4, T_5 and T_6. Control recorded the lowest value of 52.43.

Table. 4.25 Treatment effect on Zinc content (ppm) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	19.11	17.64	12.76	13.94	27.32	39.43	7.51	54.13	18.43	22.12	21.20	17.00
T_2	23.26	27.91	17.45	19.48	35.71	51.53	9.38	61.79	22.03	26.44	28.68	23.16
T_3	23.19	27.83	15.12	16.52	30.25	43.63	8.68	59.72	22.96	27.55	31.58	20.46
T_4	20.68	24.27	14.54	16.10	30.08	43.45	9.94	68.53	25.58	28.30	24.65	19.84
T_5	20.52	24.21	14.36	15.95	30.10	43.63	9.20	71.16	19.70	23.64	24.85	20.06
T_6	22.14	17.03	14.81	16.57	32.98	47.37	8.74	75.88	20.77	24.93	26.98	21.66
T_7	35.02	32.01	14.23	15.98	31.03	44.67	8.17	66.43	21.16	25.39	25.86	20.82
T_8	39.00	37.60	17.35	19.28	37.04	53.41	9.90	79.35	25.19	30.23	25.52	25.37
T_9	12.53	20.01	11.12	12.27	24.80	35.61	6.54	52.43	15.59	18.71	20.67	16.51
SE(d)	**2.36**	**1.58**	**1.29**	**1.61**	**2.41**	**3.52**	**0.80**	**5.12**	**1.69**	**2.024**	**2.15**	**1.80**
C.D.	**5.04**	**3.37**	**2.76**	**3.44**	**5.15**	**7.54**	**1.72**	**10.94**	**3.61**	**4.33**	**4.60**	**3.86**
C.V.	**12.05**	**7.60**	**10.80**	**12.15**	**9.50**	**9.65**	**11.35**	**9.58**	**9.82**	**9.82**	**10.31**	**10.76**

Peduncle

Organic manures with bio control agents (T_4) resulted in a highest Zn content (25.58 ppm) which was on par with T_2, T_3, T_7 and T_8 in the first year, while fertigation with organic manures (T_8) resulted in highest Zn content (30.23 ppm) in second year. T_8 was on par with T_2, T_3, T_4 and T_7. Lowest values of 15.59 and 18.71 was recorded from control in both years.

Rhizome

Zn content varied from 20.67 (T_9) to 31.58 ppm (T_3) in the first year and from 16.51 (T_9) to 25.37 ppm (T_8) in the second year. T_8 was on par with T_2 and T_3 in first year and T_4 in second year.

4.6.9 Copper

Copper content in plant parts during the first year and second year are given in Tables 4.26. There was significant difference between the treatments in both years in all plant parts.

Cu content in the index leaf at 4 MAP

Fertigation with organic manures resulted in a higher Cu content (14.45 ppm) in the index leaf which was on par with T_3, T_4 and T_5. In the second year also highest Cu content (27.78 ppm) was obtained in T_8. Lowest Cu content (10.75 and 13.03 ppm respectively) was recorded in T_9.

Cu content in different plant parts at harvest

Leaves

During the first year maximum Cu content (8.57 ppm) was found in T_8 which was on par with T_4. Lowest Cu content in leaves was obtained in T_9. During the second year it ranged from 5.39 (T_9) to 8.32 ppm (T_8). T_8 was on par with T_4.

Pseudostem

Fertigation with organic manures (T_8) resulted in higher Cu content in the first year (11.65 ppm) which was on par with T_4. In the second year T_8 recorded the maximum value of 13.69 ppm which as on par with T_3 and T_4. Lowest values were recorded from T_9 in both the years.

Fruit

Cu content of fruit ranged from 5.69 (T_9) to 8.79 ppm (T_8) in the first year and it was 5.69 (T_9) to 11.33 ppm (T_8) during second year. T_8 was on par with T_4 in both years.

Peduncle

Cu content of peduncle ranged from 6.40 to 10.13 ppm in the first year and 8.19 to 12.97 ppm during second year. Lowest values were recorded from T_9 and highest from T_8. T_8 was on par with T_4 in both years.

Table. 4.26 Treatment effect on Copper content (ppm) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	11.85	14.23	6.12	5.99	8.70	10.01	6.58	8.68	7.53	9.63	9.52	10.66
T_2	13.74	16.49	6.98	6.78	9.87	11.55	7.30	9.64	8.40	10.75	10.80	12.09
T_3	14.34	17.21	7.39	7.18	10.29	12.09	7.70	10.17	8.85	11.33	11.41	12.78
T_4	14.42	19.77	7.83	7.62	10.65	12.56	8.05	10.63	9.35	11.97	11.94	13.37
T_5	14.14	18.61	6.98	6.75	9.76	11.56	6.87	9.06	8.05	10.31	10.53	11.79
T_6	12.58	14.11	6.79	6.63	9.35	10.89	7.33	9.69	8.61	11.02	10.47	11.72
T_7	12.73	23.09	6.81	6.60	9.43	11.07	7.37	9.73	8.54	10.93	10.52	11.79
T_8	14.45	27.78	8.57	8.32	11.65	13.69	8.79	11.60	10.13	12.97	12.93	14.48
T_9	10.75	13.03	5.49	5.39	7.81	9.06	5.69	7.50	6.40	8.19	8.27	9.26
SE(d)	**0.32**	**0.54**	**0.44**	**0.38**	**0.56**	**0.82**	**0.38**	**0.497**	**0.41**	**0.530**	**0.64**	**0.713**
C.D.	**0.68**	**1.15**	**0.93**	**0.81**	**1.19**	**1.76**	**0.81**	**1.064**	**0.88**	**1.132**	**1.36**	**1.525**
C.V.	**2.95**	**3.61**	**7.63**	**6.82**	**7.03**	**8.86**	**6.33**	**6.32**	**6.01**	**6.01**	**7.29**	**7.283**

Rhizome

In the first year fertigation with organic manures (T_8) recorded the highest Cu content in the rhizome (12.93 ppm). In the second year, highest Cu content (14.48 ppm) was observed in T_8. T_8 was on par with T_4. Least Cu content (8.27 ppm and 9.26 ppm) was recorded in control in first and second year respectively.

4.6.10 Manganese

Manganese content in different plant parts was significantly different in both years and the results are presented in table 4.27.

Mn content in the index leaf at 4 MAP

During the first year highest Mn content (4297.83 ppm) was obtained in T_8 and least content (1720.83 ppm) was recorded in control. Similarly in the second year, fertigation with organic manures (T_8) resulted in highest Mn content (1641.30 ppm) in the index leaf and control (655.73 ppm) recorded the minimum.

Mn content in different plant parts at harvest

Distribution of manganese in different plant parts was determined at harvest.

Leaf

Mn content in the leaf at harvest varied from 4152 (T_9) to 7780 ppm (T_8) in the first year and from 2288.07 (T_9) to 4268.48 ppm (T_8) in the second year. T_8 was on par with T_4 in both years.

Pseudostem

Mn content in pseudostem varied from 835.08 (T_9.) to 1281.09 ppm (T_8) in the first year. In the second year highest Mn content in pseudostem (1039.31 ppm) was recorded in T_8 while lowest Mn content (678.66 ppm) in peduncle was recorded in control. T8 was on par with T_4, T_5 and T_7 in both years.

Fruit

Mn content in fruit varied from 772 to 1188.75 ppm in the first year and from 817.75 to 1242.30 ppm in the second year. In both years maximum values were recorded from T_8 which was on par with T_4, T_5 and T_6 in first year and with T_4 in the second year. Lowest Mn content was recorded from control in both years.

Peduncle

Maximum Mn content (1358.93) was obtained in T_8 and minimum content (913.37 ppm) was observed in control in the first year. Similarly in the second year highest Mn content (924.07 ppm) was recorded in T_8 and lowest Mn content (621.08 ppm) in peduncle was recorded in T_9. T_8 was on par with T_6 in both years.

Rhizome

In the rhizome integrated use of organic and inorganic sources of nutrients (T_6) resulted in higher Mn content in the first year, while in the second year T_8 (fertigation with organic manures) had the highest content (1284.64 ppm). In the first year, T_6 was on par with T_2, T_4, T_5, T_7 and T_8. In the second year T_8 was on par with T_2, T_4, T_5, T_7 and T_8. Lowest Mn content 1343.10 ppm in first year and 873.02 ppm in second year was observed in T_9.

Table. 4.27 Treatment effect on Manganese content (ppm) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	2,286.83	872.40	4,608.83	2550.64	943.93	764.46	811.17	938.02	947.33	644.19	1,482.32	963.51
T_2	1,817.50	689.83	4,942.58	2743.18	973.66	788.36	919.92	1172.70	1,110.90	755.41	1,663.12	1081.03
T_3	2,433.00	928.81	6,060.67	3241.23	1,047.55	855.16	887.58	1085.05	1,143.00	777.24	1,589.57	1033.22
T_4	2,862.33	1089.72	6,813.42	3728.34	1,176.66	955.34	1,022.50	1237.01	1,138.75	774.35	1,826.58	1187.28
T_5	2,850.08	1149.13	6,080.08	3356.77	1,166.75	947.32	1,075.17	1150.70	1,178.90	801.65	1,891.25	1229.31
T_6	2,612.42	999.89	5,720.33	3106.95	1,119.26	913.51	1,138.00	1092.33	1,311.47	891.80	1,919.52	1247.69
T_7	2,558.08	978.45	5,937.50	3244.29	1,138.22	926.68	998.08	1020.72	1,166.37	793.13	1,659.78	1078.86
T_8	4,297.83	1641.30	7,780.42	4268.48	1,281.09	1039.31	1,188.75	1242.30	1,358.93	924.08	1,906.37	1284.64
T_9	1,720.83	655.73	4,152.92	2288.07	835.08	678.66	772.08	817.75	913.37	621.09	1,343.10	873.02
SE(d)	**350.13**	**122.36**	**608.73**	**319.29**	**66.98**	**54.97**	**81.09**	**100.48**	**79.41**	**54.005**	**152.17**	**98.91**
C.D.	**748.63**	**261.62**	**1,301.68**	**682.69**	**143.22**	**117.53**	**173.39**	**215.60**	**169.80**	**115.47**	**325.37**	**211.49**
C.V.	**16.47**	**14.98**	**12.88**	**12.34**	**7.63**	**7.70**	**10.14**	**11.34**	**8.52**	**8.53**	**10.93**	**10.93**

4.6.11 Boron

The influence of nutrient sources in banana with regard to B content is presented in Table 4.28. There was significant difference between the treatments in all plant parts in both years.

Boron content in the index leaf at 4 MAP

In the first year at 4 MAP the effect was significant and higher leaf B content was observed in the T_8 (53.67 ppm) and lowest in T_1 and T_9 (21.58 ppm). T_8 was on par with T_6 and T_7.

During the second year highest B content (45.66 ppm) was recorded in T_7 which was on par with T_6 and T_8. Lowest content (20.73 ppm) was observed in control.

Boron content in different plant parts at harvest

Leaf

In the first year, highest B content (59.33 ppm) in leaf at harvest was observed in T_8 which was on par with T_6, T_7 and T_8. Lowest value was observed in T_9. In the second year integrated use of organic manures (T_6) resulted in highest B content (38.21 ppm) and lowest value was recorded from T_1. Treatment T_6 was on par with T_4, T_5, T_7 and T_8.

Pseudostem

Integrated use of organic manures with chemical fertilizers (T_6) resulted in highest B content (43.26 ppm and 47.48 ppm) in pseudostem in first and second year respectively. In the first year, B content in pseudostem ranged from 26.70 (T_1) to 43.26 ppm (T_6). In the second year, B content varied from 28.81 (T1) to 29.56 ppm (T_6). However T_6 was on par with T_2, T_4, T_5, T_7 and T_8 in both years.

Fruit

B content in fruits varied from 10.68 to 23.55 ppm in the first year. Maximum value was recorded from T_6 and minimum from T_9. T_6 was on par with T_5, T_7 and T_8. In the second year B content varied from 14.09 to 31.09

ppm between the treatments. Highest B content (31.09 ppm) in fruit was recorded in T_6 which was on par with T_5, T_7 and T_8 while lowest B content was observed in T_9 (14.09 ppm).

Peduncle

In the first year, integrated use of organic manures with fertilizers (T_6) resulted in highest B content in peduncle in both the years and the lowest value from T_9. Boron content in peduncle varied from 16.23 to 37.08 ppm in the first year and from 17.85 to 40.79 ppm in the second year. T_6 was on par with T_5, T_7 and T_8.

Rhizome

Boron content in rhizome varied from 26.15 (T_9) to 54.08 ppm (T_6) in the first year and from 22.02 (T_9) to 44.05 ppm (T_8) in the second year. T_6 was on par with T_2, T_5 and T_8 in first year. T_8 was on par with T_2, T_5, T_6 and T_7 in the second year.

Table. 4.28 Treatment effect on Boron content (ppm) in the index leaf at 4 MAP and in different plant parts at harvest

Treatment	4 MAP		Leaf		Pseudostem		Fruit		Peduncle		Rhizome	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	21.58	21.94	28.42	17.51	26.70	28.81	11.39	15.04	18.84	20.73	32.98	27.70
T_2	36.25	35.42	42.08	25.56	38.57	41.76	15.93	21.03	26.53	29.19	43.50	36.29
T_3	34.75	33.81	38.42	23.74	34.07	36.90	14.98	19.78	24.37	26.80	38.25	31.81
T_4	40.92	36.40	45.42	29.72	38.72	41.90	17.67	23.32	28.18	31.00	38.57	32.33
T_5	40.08	39.08	46.00	27.90	38.78	42.40	19.82	26.17	32.68	35.95	46.83	39.26
T_6	52.17	43.72	57.08	38.21	43.26	47.48	23.55	31.09	37.08	40.79	54.80	42.83
T_7	51.42	45.66	56.42	37.42	41.88	46.15	21.92	28.93	33.26	36.59	48.68	41.30
T_8	53.67	43.03	59.33	37.40	42.58	46.31	23.37	30.85	35.55	39.10	54.08	44.05
T_9	21.58	20.73	27.75	17.69	27.27	29.56	10.68	14.09	16.23	17.85	26.15	22.03
SE(d)	**3.68**	**2.55**	**4.19**	**5.47**	**3.26**	**3.96**	**1.75**	**2.31**	**3.49**	**3.84**	**7.42**	**5.29**
C.D.	**7.86**	**5.46**	**8.95**	**11.69**	**6.96**	**8.46**	**3.74**	**4.94**	**7.46**	**8.203**	**15.87**	**11.32**
C.V.	**11.49**	**8.80**	**11.51**	**23.62**	**10.82**	**12.08**	**12.11**	**12.11**	**15.21**	**15.21**	**21.32**	**18.37**

4.7 Total Nutrient uptake at harvest

Response on total nutrient uptake by banana plant after harvest as influenced by nutrient sources are furnished in table 4.29 for the first year and table 4.30 for second year.

4.7.1 Nitrogen

The total uptake of N by the plant was affected significantly by sources of nutrients in both the years. In the first year T_8 was significantly superior to all other treatments with respect to total nitrogen uptake. Highest N uptake (134.15 g plant^{-1}) was recorded in T_8 and lowest uptake (71.13 g plant^{-1}) was observed in T_9.

Similar pattern was observed for N uptake by the plants in the second year also. The highest N uptake (147.87 g plant^{-1}) was observed in T_8 which was on par with T_7 (134.24 g plant^{-1}). Lowest N uptake (79.83 g plant^{-1}) by plants was recorded by the plants which received no manures and fertilizers.

4.7.2 Phosphorus (g plant^{-1})

Total phosphorus uptake by the plants differed significantly with respect to various treatments. The plants which received fertigation with organic manures (T_8) exhibited highest P uptake (14.71 g plant^{-1}) in the first year, which was on par with T_3, T_4, T_5, T_6, and T_7 while the least uptake (7.02 g plant^{-1}) of P was obtained in control.

In the second year highest P uptake (61.80 g plant^{-1}) was recorded in T_7 which was on par with T_3, T_4, T_5, T_6 and T_8. Least uptake (28.86 g plant^{-1}) of P was obtained in control in the second year.

4.7.3 Potassium

The uptake of K was significantly different between the treatments. In the first year, maximum uptake of K (946.26 g plant^{-1}) was recorded in T_8 and least uptake (476.21 g plant^{-1}) was observed in control.

Table. 4.29 Treatment effect on total nutrients uptake of nutrients by plants during first year

Treatment	Major nutrients (g/plant)						Micronutrients (mg/plant)				
	N	P	K	Calcium	Magnesium	Sulphur	Iron	Copper	Manganese	Boron	Zinc
T_1	75.96	8.30	524.87	58.55	18.59	29.87	83.08	0.75	130.53	2.45	1.76
T_2	97.00	10.45	642.73	74.43	23.54	46.02	122.14	0.92	160.57	3.65	2.49
T_3	110.15	13.48	761.93	84.58	25.73	54.75	163.29	1.10	179.29	3.68	2.52
T_4	103.61	12.05	598.96	80.03	25.21	44.63	131.69	1.02	188.14	3.43	2.20
T_5	107.76	12.23	686.58	81.66	26.91	57.46	154.39	0.93	186.20	3.99	2.28
T_6	94.83	13.66	790.09	81.32	20.94	38.12	123.01	0.94	192.32	4.69	2.45
T_7	112.92	12.98	749.91	79.27	27.07	57.23	131.65	0.90	170.08	4.09	2.23
T_8	134.15	14.71	946.26	98.89	29.98	68.10	176.82	1.20	217.70	4.78	2.96
T_9	71.13	7.02	476.21	50.30	13.82	26.26	71.78	0.63	111.29	2.00	1.58
SE(d)	**7.24**	**1.45**	**41.14**	**4.91**	**1.86**	**5.31**	**18.13**	**0.10**	**14.37**	**0.56**	**0.24**
C.D.	**15.49**	**3.10**	**87.96**	**10.50**	**3.97**	**11.34**	**38.77**	**NS**	**30.72**	**NS**	**NS**
C.V.	**8.80**	**15.22**	**7.33**	**7.86**	**9.66**	**13.84**	**17.26**	**10.19**	**10.31**	**18.85**	**13.03**

In the second year also, highest K uptake (776.31 g plant^{-1}) was recorded in T_8 (plants which received the fertigation with organic manures). Lowest K uptake (396.26 g plant^{-1}) was recorded in control.

4.7.4 Calcium

Total uptake of Ca by banana plants was significantly different between the treatments. Fertigation with organic manures (T_8) resulted in a higher uptake of calcium (98.89 g plant^{-1}). Lowest Ca uptake (50.30 g plant^{-1}) by the plants was noticed in T_9.

Similarly in the second year also maximum Ca uptake (91.31 g plant^{-1}) was recorded in T_8 while minimum Ca uptake was recorded in control (46.78 g plant^{-1}).

4.7.5 Magnesium

Significant difference was noticed in Mg uptake in both years. In both the years, fertigation with organic manures resulted in maximum uptake of Mg (table.4.30). In the first year maximum uptake (29.98 mg plant^{-1}) was obtained in T_8 which was on par with T_5 (26.91 g plant^{-1}) and minimum uptake (13.82 g plant^{-1}) was recorded in control.

Likewise in the second year maximum Mg uptake (66.58 mg plant^{-1}) was obtained from plants which were given fertigation with organic manures (T_8). It was on par with T_7 (64.00 g plant^{-1}) and minimum (31.24 g plant^{-1}) was recorded in control.

Table. 4.30 Treatment effect on total nutrients uptake of nutrients by plants during second year

Treatment	Major nutrients (g/plant)						Micronutrients (mg/plant)				
	N	P	K	Calcium	Magnesium	Sulphur	Iron	Copper	Manganese	Boron	Zinc
T_1	81.40	32.11	416.11	51.55	39.37	33.04	58.65	0.82	75.26	2.09	1.78
T_2	104.55	43.93	520.39	66.91	49.99	53.90	90.09	1.02	93.51	3.14	2.58
T_3	110.51	53.25	573.70	70.72	50.51	58.24	107.16	1.13	97.67	2.94	2.44
T_4	112.80	53.55	492.43	72.44	55.17	53.58	97.34	1.15	109.45	3.07	2.32
T_5	116.66	53.14	555.79	73.25	57.86	67.17	115.60	1.03	109.48	3.54	2.34
T_6	100.90	59.91	640.07	74.14	43.65	45.45	94.18	1.04	112.51	3.93	2.55
T_7	134.24	61.80	650.19	76.75	64.00	73.84	106.35	1.08	128.21	3.89	2.43
T_8	147.87	60.84	776.31	91.31	66.58	82.47	135.55	1.37	106.15	4.21	3.09
T_9	79.83	28.86	396.26	46.78	31.24	32.46	54.48	0.74	69.52	1.85	1.65
SE(d)	**7.21**	**5.02**	**37.27**	**3.59**	**2.88**	**6.04**	**11.38**	**0.08**	**6.88**	**0.35**	**0.20**
C.D.	**15.43**	**10.74**	**79.68**	**7.67**	**6.16**	**12.91**	**24.34**	**0.17**	**14.72**	**0.75**	**0.44**
C.V.	**8.04**	**12.37**	**8.18**	**6.34**	**6.93**	**13.30**	**14.60**	**9.24**	**8.41**	**13.50**	**10.58**

4.7.6 Sulphur

Total S uptake by the plant also exhibited a similar trend as that of calcium uptake (table.4.30). In both the years, fertigation with organic manures resulted in maximum uptake of sulphur by the plants. In the first year maximum S uptake (68.10 g plant^{-1}) was obtained in T_8 which was on par with T_5 and T_7 (57.46 g plant^{-1}). Lowest S uptake (26.26 g plant^{-1}) was recorded in plants raised without manures and fertilizers (T_9).

Similarly in the second year also T_8 registered highest uptake (82.47 g plant^{-1}) of sulphur which was on par with T_7 (73.84 g plant^{-1}) and lowest uptake was recorded in control (32.46 g plant^{-1}).

4.7.7 Iron

The effect of sources of nutrients on the uptake of Fe by plants was significant in both the years. The highest Fe uptake (176 mg plant^{-1}) was recorded in T_8 which was on par with T_3 and T_5 whereas lowest uptake (71.78 mg plant^{-1}) was registered in control in the first year.

Similar pattern was followed in the second year also. Fe uptake was highest in T_8 (135.55 mg plant^{-1}) on par with T_5 (115.60 mg plant^{-1}). Least value was recorded from control (54.48).

4.7.8 Copper

The different nutrient sources did not significantly affect total Cu uptake by the plant in the first year. Cu uptake by the plants ranged from 0.63 to 1.20 mg plant^{-1}.

But in the second year uptake of Cu was significantly different between the treatments. Highest Cu uptake (1.37 mg plant^{-1}) was observed in T_8 and lowest (0.74 mg plant^{-1}) in T_9.

4.7.9 Manganese

Total Manganese uptake by banana plants was influenced significantly by the nutrient sources in both the years (table.4.30). In the first year highest Mn uptake (217.70 mg plant^{-1}) was recorded in T_8 which was on par with T_4, T_6 and T_8. Lowest Mn uptake (11.29 mg plant^{-1}) was noticed in control.

In the second year, highest uptake of Mn (128.21 mg plant^{-1}) was recorded in T_8 and the lowest (69.52 mg plant^{-1}) in T_9.

4.7.10 Boron

Uptake of boron was not significantly different in the first year. The total uptake of B by the plants varied from (2.00 mg plant^{-1}) to (4.78 mg plant^{-1}). In the second year B uptake was significant and highest uptake of B (4.21 mg plant^{-1}) was recorded in T_8 which were on par with T_5, T_6 andT_7. Lowest uptake (1.85 mg plant^{-1}) was registered in control.

4.7.11 Zinc

In the first year Zn uptake by the banana plants was not influenced significantly by the treatments (table.4.30). Uptake of Zn ranged from 1.58 mg plant^{-1} to 2.96 mg plant^{-1}.

Unlike in the first year Zn uptake was influenced significantly by the different nutrient sources in the second year and highest uptake of Zn (3.09 mg plant^{-1}) was recorded in T_8 and lowest uptake (1.65 mg plant^{-1}) was recorded in control.

4.8 Analysis of organic manures

Manures used in the experiment was analysed both in the first year and second year and the values obtained are presented in appendix-I.

Total NPK content in FYM recorded was 0.68- 0.72%, 0.35-0.40%, and 0.75-0.78% respectively. Secondary and micronutrients are found in medium range. The heavy metals like Cd and Ni content was 13.25-15.75 and 18.50-23.25 mg kg^{-1} respectively in first year and second year. The organic carbon and CN ratio was recorded were 23.52-23.82 % and 33.08-34.59% respectively in first year and second year.

The total NPK content of 3.12-3.68 %, 0.42-0.56%, 1.52-1.73% respectively was recorded in vermicompost. Vermicompost was rich in secondary and micronutrients. The Cd and Ni was in trace range (13.17-23.29 & 12.35-17.22 mg kg^{-1}) respectively in first year and second year.

Wood ash which was applied in all the organic treatments, was medium in nutrients. The total NPK content varied from 0.66-0.82%, 0.42-0.56%, and

0.80-0.85% respectively in first year and second year. The wood ash was also found rich in micronutrients.

Poultry manure was found rich in nutrients. The NPK content of poultry manure recorded was 3.47-3.56%, 1.33-1.52%, and 1.12-1.25% respectively. The poultry manure was also higher in organic carbon of 52.35% and 50.05% respectively in first year and second year. The heavy metals like Cd and Ni was more in poultry manure. The Cd content of 121.28-123.26 mg kg^{-1} and Ni of 36.87-42.50 mg kg^{-1} were recorded.

Neem cake was found rich in NPK (3.40-3.43, 0.30-0.38, 0.98-1.25%). The total Ca and Mg content was also found higher in neem cake compare to other organic manures. The heavy metals like Ni and Cd were higher in neem cake. Cd content was 105.52-112.17 mg kg^{-1} and Ni 39.28-48.50 mg kg^{-1}.

4.9. Plant physiological characters

4.9.1 Chlorophyll content

Chlorophyll 'a' content

In the first year, there was significant difference in Chlorophyll 'a' content among the treatments (table 4.31). The highest chlorophyll 'a' content (0.87 mg) was obtained in T_8, which was on par with T_3, and T_5 90 DAP. Lowest chlorophyll 'a' content (0.59 mg) was obtained in control (T_9). At 150 days after planting, highest chlorophyll a content (1.20 mg) was obtained in T_8, which was on par with T_3. Lowest chlorophyll 'a' (0.91 mg) was obtained in control (T_9).

During the second year, the highest chlorophyll 'a' content (0.90 mg) and (1.27 mg) was obtained in T_8 respectively at 90 and 150 DAP. Lowest chlorophyll 'a' content (0.61 mg) and (0.89 mg) was obtained in control (T_9) at 90 and 150 DAP in both years. During the first year, Chlorophyll a content of leaves from treatment T_8 at 90 DAP was on par with T_5 and T_3 and at 150 DAP T8 was on par with T_3.

Chlorophyll 'b' content:

In the first year, chlorophyll 'b' content of the leaf was significantly influenced by nutrient sources (table 4.31). Among the different treatments, at

90 DAP maximum chlorophyll 'b' (1.31 mg) content was recorded in T_8 which was statistically on par with T_3, T_4 and T_5. Minimum chlorophyll 'b' content (1.05 mg) was recorded in T_9 which was given no manures and fertilisers (control). At 150 days after planting, maximum chlorophyll 'b' was recorded in T_3 (1.67 mg) which was statistically on par with T_8 (1.62 mg) and T_5 (1.58 mg). Minimum chlorophyll 'b' content (1.31) was recorded in control (T_9).

During the second year, the highest chlorophyll 'b' content (1.46 mg) and (1.54mg) was obtained in T_8 at 90 DAP and 150 DAP. At 150 DAP T_8 was on par with all treatments other than control. Lowest chlorophyll 'b' content (1.09 mg) was obtained in control (T_9) at 90 and 150 DAP.

Total chlorophyll content:

In the first year, among the different treatments, maximum total chlorophyll content (2.18 mg) was recorded in T_8 which was on par with T_3 (2.15 mg), 90 DAP. Minimum total chlorophyll content (1.65 mg) was recorded in T_9 (control). At 150 days after planting, maximum total chlorophyll (2.81 mg) was recorded in T_8 which was on par with T_3 and T_5. Minimum total chlorophyll content (2.22 mg) was recorded in T_9 (Control).

During the second year, the highest total chlorophyll content (2.36 mg) and (2.81 mg) was obtained in T_8 respectively at 90 and 150 DAP. Lowest total chlorophyll (1.70 mg) and (2.14 mg) was recorded in control (T_9) at 90 and 150 DAP. T_8 was on par with T_3.

Partitioning of dry matter

Results of the analysis on partitioning of dry matter between the plant parts are presented in table 4.32. Between the different plant parts, partitioning of dry matter was maximum in rhizome, followed by pseudostem, fruit, leaf, peduncle and male bud. There was no significant difference in dry matter content in male bud, fruit and peduncle between the treatments in both years Results for leaf was significant in second year. Maximum dry matter in rhizome was recorded from control in both years. Dry matter partitioning to pseudostem was high in treatment T8 in first year and treatment T_6 in second year.

Table. 4.31 Treatment effect on leaf chlorophyll production

Treatment	Chlorophyll content (mg/g of leaf) at 90 DAP						Chlorophyll content (mg/g of leaf) at 150 DAP					
	Chlorophyll a		Chlorophyll b		Total chlorophyll		Chlorophyll a		Chlorophyll b		Total chlorophyll	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	0.61	0.64	1.13	1.13	1.74	1.76	0.97	0.93	1.38	1.44	2.35	2.37
T_2	0.74	0.76	1.12	1.29	1.87	2.05	1.06	1.04	1.39	1.43	2.45	2.47
T_3	0.83	0.85	1.31	1.24	2.15	2.09	1.14	1.08	1.67	1.64	2.81	2.72
T_4	0.75	0.77	1.21	1.24	1.95	2.01	1.05	1.09	1.49	1.46	2.54	2.55
T_5	0.77	0.79	1.23	1.27	2.00	2.06	1.05	1.11	1.58	1.54	2.62	2.65
T_6	0.68	0.71	1.17	1.17	1.85	1.88	0.98	1.04	1.44	1.41	2.41	2.44
T_7	0.73	0.75	1.16	1.19	1.88	1.94	1.03	1.13	1.44	1.41	2.47	2.54
T_8	0.87	0.90	1.31	1.46	2.18	2.36	1.20	1.27	1.62	1.54	2.81	2.81
T_9	0.59	0.62	1.05	1.09	1.65	1.71	0.91	0.90	1.31	1.25	2.22	2.14
SE(d)	**0.05**	**0.05**	**0.06**	**0.035**	**0.08**	**0.08**	**0.05**	**0.051**	**0.07**	**0.072**	**0.10**	**0.10**
C.D.	**0.11**	**0.10**	**0.12**	**0.074**	**0.17**	**0.17**	**0.12**	**0.11**	**0.16**	**0.154**	**0.22**	**0.21**
C.V.	**8.31**	**7.97**	**5.73**	**3.45**	**5.00**	**5.01**	**6.32**	**5.86**	**6.15**	**6.05**	**4.97**	**4.83**

Table. 4.32 Total Dry matter (%) partitioning in different plant parts

Treatment	Male bud (%)		Leaves (%)		Pseudostem (%)		Peduncle (%)		Rhizome (%)		Fruit (%)	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T1	0.77	0.96	5.97	4.93	22.49	25.99	2.05	1.21	52.42	49.00	12.03	17.91
T2	0.73	0.95	7.03	5.79	22.64	25.40	2.13	1.23	51.13	49.00	13.22	17.62
T3	0.62	0.87	6.06	5.23	23.39	27.74	2.00	1.23	54.28	48.36	12.78	16.57
T4	0.83	1.07	6.99	5.41	24.95	26.66	2.25	1.25	53.44	49.24	12.99	16.36
T5	0.69	0.82	6.27	4.96	24.21	26.27	2.18	1.24	55.05	50.38	12.40	16.33
T6	0.61	0.86	7.01	5.70	24.68	27.54	2.10	1.22	51.55	50.20	12.80	14.48
T7	0.76	0.87	6.94	5.10	23.92	23.95	2.20	1.16	54.64	51.66	11.46	17.28
T8	0.66	0.86	6.16	4.75	25.11	26.57	2.09	1.16	53.75	49.94	13.68	16.71
T9	0.77	0.77	6.04	4.53	23.96	24.56	1.91	1.03	58.27	53.69	11.71	15.41
CD	**NS**	**NS**	**NS**	**0.60**	**2.52**	**3.04**	**NS**	**NS**	**5.28**	**4.73**	**NS**	**NS**
SE(d)	**0.08**	**0.09**	**0.47**	**0.28**	**1.21**	**1.49**	**0.20**	**0.11**	**2.37**	**2.29**	**1.27**	**1.22**
C.V.	**13.20**	**11.88**	**8.84**	**6.67**	**6.18**	**7.01**	**11.40**	**11.35**	**13.11**	**5.59**	**12.37**	**9.07**

4.10. Biochemical analysis of mature and ripe banana fruit of Nendran

Data on effect of nutrient sources on biochemical parameters of mature and ripe banana fruits of *Musa* (AAB) Nendran is presented in the Table.4.33, 4.34 for first year and Table.4.35, 4.36 for second year respectively.

Starch content

The results showed that during the first year, there was significant difference for starch content of mature banana fruits between the treatments. Highest starch content (99.61 mg) was found in T_8 and the lowest starch content (59.98 mg) was obtained in T_1. During the second year, starch content of the Nendran banana fruits was not influenced significantly by nutrient sources. The values ranged from 68.20 mg g^{-1} to 102.99 mg g^{-1}.

Protein content

Significant difference between the treatments was observed with regard to protein content of mature green banana fruits in both first year and second year. Highest protein content (9.60 mg g^{-1}) was observed in T_5, which was on par with T_2, T_3, T_4 and T_8. Lowest protein content (7.21 mg) was obtained in control (T_9).

In second year, highest protein content (11.56 mg g^{-1}) was observed in T_2 whereas lowest protein content (7.77 mg g^{-1}) was obtained in control (T_9).

Tannin content

During both the years, no significant difference was observed between the treatments for tannin content of mature green banana fruits. In the first year, tannin content ranged from 0.62 g/100g to 0.81 g/100g while in the second year, tannin content varied from 0.72 g/100g to 0.90 g/100g.

Tannin content of ripe fruits was also not significantly different in both years between the treatments. In the first year, the observations varied from 1.74 g/100g to 2.47 g/100g while in the second year it varied from 1.41 g/100g to 1.91 g/100g.

Total dry matter

Total dry matter content was not significantly different in both the years. It varied from 28.48% to 32.05% in first year and 29.76 to 32.88% in second year.

Moisture content

No significant difference was observed in the moisture content of mature fruits in both years. It varied from 67.95% to 71.53% in first year and from 70.47% to 73.72% in second year. Similarly, moisture content of ripe fruits was also not significantly different which varied from 70.69% to 73.99% in first year and 67.12% to 70.24% in second year.

Total soluble solids (TSS) content

In the first year, significant differences were observed in TSS content of ripe fruits. Highest TSS content (26.23 ° brix) was observed in T_6 which was on par with T_2, T_3, T_4, T_5 and T_8. Lowest TSS content (23.66 ° brix) was recorded in control (T_9).

During second year, significant difference was recorded in TSS of ripe banana fruits between the treatments. Highest TSS (27.54 ° brix) was obtained in T_6 which was on par with T_2, T_5 and T_8. Lowest TSS (22.95 ° brix) of ripe fruits was obtained in control (T_9).

Titrable acidity

No significant differences were observed for titrable acidity of ripe banana fruits between the treatments in both the years. In the first year minimum titrable acidity was 0.38 % and maximum was 0.45%. During second year, titrable acidity of banana fruits ranged from 0.37 % to 0.47 %.

Total sugars

In the first year, significant difference was recorded in total sugars of ripe banana fruits between the treatments. Highest total sugars (17.5 %) was obtained in T_3 which was on par with T_2, T_4, T_5, T_6 and T_8. Lowest total sugars (14.66 %) was obtained in control (T_9).

During the second year also significant difference was recorded in total sugars of ripe banana fruits. Highest value for total sugars (17.58 %) was obtained in T_4, which was on par with T_3 and T_6. Lowest total sugars (14.36 %) was obtained in control (T_9).

Reducing sugars

During first year, there was no significant difference in reducing sugars. Highest reducing sugars content recorded was 11.38% and lowest was 9.18 %.

In the second year, significant difference in reducing sugars was observed between the treatments. Highest reducing sugars (11.60 %) in banana was recorded in T_3 (11.6%) which was on par with T_2, T_4, T_5, T_6 and T_8. Lowest value for reducing sugars (9.25 %) was recorded in control (T_9).

Ascorbic acid

Ascorbic acid content of ripe banana fruits was not-significantly different between the treatments in both the years. Ascorbic acid content values varied from 28.32 mg to 36.67 mg in the first year and 29.79 mg to 39.39 mg in second year.

Sugar acid ratio

Sugar: acid ratio was also not significantly different in first year but was significantly different in second year. Sugar/acid ratio varied from 34.38 to 45.07 in first year.

In the second year highest sugar acid ratio (45.22) was found in T_3 which was on par with T_4, T_7 and T_8. Lowest sugar acid ratio (30.52) of ripe banana fruits was recorded in control (T_9).

Crude fibre

Significant difference in crude fibre content of mature fruits of Nendran banana was observed between the treatments in both years. In the first year, highest crude fibre (3.97 %) was obtained in T_8, which was on par with T_4 (3.56 %). Lowest crude fibre content of mature green fruits (2.77 %) was observed in control. In second year, highest value was recorded from T_4 which was on par with T_2, T_3, T_5, T_6, T_7 and T_8. Lowest value was recorded from T_9 (2.78%)

Crude fibre content of ripe fruits was not significantly different in both years. The values ranged from 1.12 to 1.86 percent in first year and 1.63 to 2.16 percent in second year.

β-carotene content

In first year, the results indicated that there were significant difference in β-carotene content. The highest β-carotene content (595.67 µg) was obtained in T_8 where manures were given in organic form as fertigation. Lowest β-carotene content (430.08 µg) was recorded in T_1.

During second year also β-carotene content of Nendran banana was significantly influenced by nutrient sources. Among the treatments, the highest β-carotene content (603.33µg) was obtained in T_8 which was on par with T_2, T_3, T_4 and T_5. Lowest β-carotene content (439.75µg) was found in T_1.

Table. 4.33 Effect of nutrient sources on biochemical attributes of mature fruits in first year

Treatment	Starch content (mg/g)	Protein (mg/g)	Total Dry Matter (%)	Crude fibre (%)	Tannin content (g/100g)	Moisture content (%)
T_1	59.98	7.66	30.99	2.88	0.62	69.01
T_2	70.84	9.27	31.92	3.31	0.69	68.08
T_3	80.92	9.21	30.24	3.19	0.75	69.77
T_4	71.80	9.57	32.00	3.56	0.70	68.00
T_5	77.32	9.60	32.05	3.42	0.70	67.95
T_6	67.37	8.12	31.58	3.38	0.68	68.43
T_7	79.47	8.38	31.26	3.36	0.78	68.74
T_8	99.61	9.53	31.11	3.95	0.81	68.89
T_9	68.83	7.21	28.48	2.77	0.64	71.53
SE(d)	**8.54**	**0.40**	**1.20**	**0.24**	**0.06**	**1.20**
C.D.	**18.25**	**0.84**	**NS**	**0.52**	**NS**	**NS**
C.V.	**13.91**	**5.54**	**4.74**	**9.00**	**10.01**	**2.14**

Table. 4.34 Effect of nutrient sources on biochemical attributes of mature fruits in second year

Treatment	Starch content (mg/g)	Protein (mg/g)	Total Dry Matter (%)	Crude fibre (%)	Tannin content (g/100g)	Moisture content (%)
T_1	68.20	8.05	31.30	**2.76**	0.83	72.11
T_2	70.35	11.56	32.22	3.20	0.79	71.15
T_3	85.33	9.94	30.63	3.19	0.84	72.80
T_4	77.59	9.58	32.26	3.50	0.79	71.10
T_5	80.61	9.63	32.34	3.30	0.79	71.02
T_6	72.18	8.96	32.88	3.38	0.77	70.47
T_7	87.42	9.27	32.68	3.37	0.88	70.68
T_8	102.99	10.46	32.24	3.65	0.90	71.12
T_9	70.71	7.77	29.76	2.78	0.72	73.72
SE(d)	**9.92**	**0.37**	**1.37**	**0.22**	**0.06**	**1.44**
C.D.	**NS**	**0.78**	**NS**	**0.48**	**NS**	**NS**
C.V.	**15.28**	**4.74**	**5.29**	**8.46**	**9.47**	**2.46**

Table. 4.35 Effect of nutrient sources on biochemical characters of ripe fruits in first season

Treatment	TSS (°brix)	Acidity (%)	Total Sugars (%)	Reducing Sugars (%)	Ascorbic Acid (mg/100g)	Sugar/Acid ratio	Tannin content (g/100g)	Crude fibre (%)	β Carotene (µg/100g)	Moisture content (%)
T_1	23.79	0.43	15.19	9.49	28.46	36.16	1.97	1.12	430.08	72.03
T_2	25.51	0.46	16.34	10.70	35.80	36.41	2.09	1.30	532.67	70.75
T_3	24.95	0.39	17.55	11.38	36.58	45.07	2.04	1.35	537.42	72.31
T_4	24.82	0.42	17.42	11.25	33.31	41.84	2.14	1.37	563.25	70.73
T_5	25.61	0.43	16.33	11.45	32.44	38.80	2.10	1.50	551.75	70.69
T_6	26.23	0.43	16.76	11.33	35.39	39.24	2.41	1.52	512.17	70.79
T_7	23.95	0.40	15.90	10.02	36.67	40.48	2.47	1.74	514.75	71.95
T_8	25.31	0.38	16.23	11.11	35.72	43.19	2.42	1.86	595.67	71.92
T_9	23.66	0.45	14.66	9.18	28.32	34.38	1.74	1.30	445.58	73.99
SE(d)	**0.75**	**0.04**	**0.65**	**0.65**	**3.67**	**3.56**	**0.26**	**0.22**	**34.77**	**1.32**
C.D.	**1.59**	**NS**	**1.39**	**1.39**	**NS**	**NS**	**NS**	**NS**	**7.34**	**NS**

Table. 4.36 Effect of nutrient sources on biochemical characters of ripe fruits in second season

Treatment	TSS (°brix)	Acidity (%)	Total Sugars (%)	Reducing Sugars (%)	Ascorbic Acid (mg/100g)	Sugar/Acid ratio	Tannin content (g/100g)	Crude fibre (%)	β Carotene (µg/100g)	Moisture content (%)
T_1	23.31	0.42	14.96	9.57	29.79	36.34	1.74	1.74	439.75	68.70
T_2	26.69	0.45	16.01	10.63	37.59	35.77	1.64	1.69	540.42	67.78
T_3	26.19	0.39	17.54	11.60	39.39	45.22	1.59	1.82	551.00	69.37
T_4	26.06	0.42	17.58	11.23	34.54	42.61	1.78	2.01	565.42	67.74
T_5	26.89	0.42	16.00	11.00	37.04	38.17	1.72	1.86	552.58	67.66
T_6	27.54	0.43	16.59	11.22	35.97	38.53	1.90	2.16	519.83	67.12
T_7	25.15	0.39	15.76	10.25	37.78	41.09	1.91	2.04	522.42	67.32
T_8	26.70	0.37	16.22	11.11	36.29	44.05	1.89	2.08	603.33	67.76
T_9	22.95	0.47	14.37	9.25	35.25	30.52	1.41	1.63	453.25	70.24
SE(d)	**0.503**	**0.030**	**0.538**	**0.604**	**2.909**	**2.720**	**0.196**	**0.191**	**32.355**	**1.374**
C.D.	**1.077**	**NS**	**1.15**	**1.29**	**NS**	**5.816**	**NS**	**NS**	**69.181**	**NS**
C.V.	**2.398**	**8.774**	**4.09**	**6.93**	**9.91**	**8.511**	**13.896**	**12.356**	**7.511**	**2.468**

4.11. Organoleptic evaluation of ripe fruit and chips of Nendran banana

Sensory characteristics like appearance, colour, texture, taste, flavour and overall acceptability of ripe fruits and mature fruit chips of Nendran banana were evaluated.

4.11.1 Sensory parameters of *Musa* Nendran ripe fruits

Data on sensory characteristics of ripe banana fruits for first and second year are illustrated in Table 4.37. The sensory score for appearance of banana fruits was not influenced significantly in the first year. Score for appearance of fruits ranged from 6.67 to 7.58. Appearance of ripe fruits was significantly influenced in the second year. Highest score of 7.17 was recorded from T_2 and T_8 which were on par with T_1, T_4, T_5 and T_7 and lowest score (6.08) for appearance was obtained in control.

The colour score for ripe banana fruits was not influenced significantly by nutrient sources in the first year. Score varied from 6.00 to 7.08 between the treatments. However in the second year the scores for colour of ripe fruits varied from 6.42 to 7.58. The highest score for colour was obtained in T_8 and T_2 (7.58) and was on par with T_1, T_3, T_4, T_5 and T_7. Lowest score (6.42) for colour of fruits was recorded from control.

Sensory scores for texture of ripe fruits grown under different treatments were non significant in both the years. In the first year, sensory score of Nendran banana fruits for texture varied from 6.25 to 7.50 and in the second year from 5.83 to 7.25.

Sensory characteristics for taste was influenced significantly in both the years. The highest score (7.75) was obtained in T_6 which was on par with T_7 and T_8 in the first year. Lowest taste score (6.50) was obtained in T_9. In the second year, the scores for taste of fruits ranged from 6.33 to 7.92. The highest score of 7.92 for taste of fruits was recorded for plants gown under fertigation with organic manures (T_8) and was on par T_5 and T_7. Lowest score was recorded in control (6.33).

Table. 4.37 Effect of nutrient sources on sensory characters of Nendran ripe fruits

Treatment	Appearance		Colour		Texture		Taste		Flavour		Overall Acceptability	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	7.17	6.92	6.33	7.17	6.75	6.58	6.83	7.08	6.58	7.25	6.67	6.83
T_2	7.58	7.17	6.83	7.58	6.42	6.83	7.00	6.75	6.58	7.75	7.08	6.92
T_3	7.33	6.25	7.08	7.25	6.33	7.08	6.92	6.83	5.83	7.42	7.08	6.83
T_4	7.42	7.00	6.92	7.42	6.83	7.25	6.58	6.75	7.00	7.50	7.00	7.00
T_5	7.25	6.92	6.58	7.33	6.75	7.00	6.92	7.17	7.00	7.25	7.75	7.25
T_6	6.83	6.25	6.67	6.83	6.92	6.67	7.75	6.83	5.75	6.83	6.92	7.08
T_7	7.25	7.00	6.67	7.42	6.92	6.75	7.58	7.25	6.83	7.42	7.33	6.92
T_8	7.50	7.17	6.50	7.58	7.50	6.92	7.33	7.92	6.83	7.52	7.08	7.50
T_9	6.67	6.08	6.00	6.42	6.25	5.83	6.50	6.33	5.92	6.67	7.17	6.08
SE(d)	**0.35**	**0.36**	**0.43**	**0.33**	**0.47**	**0.44**	**0.27**	**0.39**	**0.58**	**0.32**	**0.52**	**0.46**
C.D.	**NS**	**0.76**	**NS**	**0.70**	**NS**	**NS**	**0.57**	**0.83**	**NS**	**NS**	**NS**	**NS**
C.V.	**5.94**	**6.49**	**7.93**	**7.97**	**8.48**	**8.02**	**4.67**	**6.79**	**10.94**	**5.33**	**8.85**	**8.18**

Flavour scores were non-significant between the treatments in both the years. Flavour score ranged from 5.92 to 7.00 in first year and from 6.67 to 7.in second year.

Similarly, overall acceptability of the fruits was not significantly different between the treatments in both years. In the first year, score for overall acceptability of ripe fruits ranged from 6.67 to 7.33 and from 6.08 to 7.50 in the second year.

4.11.2 Sensory parameters of mature fruit chips of *Musa* Nendran

Data on sensory characteristics of chips prepared from mature green fruits for first and second year are illustrated in Table 4.38. The sensory score for appearance of Nendran fruit chips was influenced significantly in first year and second year. In first year, highest score (7.67) for appearance of chips was obtained in T_8 and T_2 which was on par T_4, T_6 and T_7 whereas the lowest score (5.33) was recorded from T_9.

The colour score for mature banana fruit chips was not influenced significantly by nutrient sources in both the year. The colour score of chips varied from 6.17 to 7.33 in the first year and from 5.42 to 7.67 in second year.

The sensory scores for texture of fruit chips was also non significant in both years. In the first year, sensory score of chips for texture varied from 6.17 to 7.67and from 6.25 to 7.50 in the second year.

Among the sensory parameters score for taste was significantly different between the treatments in both years. The highest taste score (7.92) of fruit chips was obtained in T_8 which was on par with T_2 in the first year. Lowest taste score of chips (5.50) was obtained in T_9.

In the second year, highest score for taste of chips (7.5) was recorded from plants grown under fertigation with organic manures (T_8) which was on par with T_1, T_2, T_4, T_5, T_6 and T_7. However lowest score of taste of chips was recorded in control (T_3).

Scores for flavour of chips was not influenced significantly in first year. Score values ranged from 5.92 to 7.17 in first year. In the second year however, sensory score of flavour of fruit chips varied significantly. Highest score for flavour was obtained from T_8 (7.5) which was on par with T_1, T_5 and T_7. Lowest score (5.92) for flavour was recorded from treatment T_9 (control.

In both the years, overall acceptability of mature banana fruit chips was not influenced significantly by nutrient sources. In the first year, score of overall acceptability of chips ranged from 6.25 to 7.58 and from 5.75 to 7.58 in the second year.

Table.4.38 Effect of nutrient sources on sensory characters of Nendran fruit chips

Treatment	Appearance		Colour		Texture		Taste		Flavour		Overall Acceptability	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T_1	6.25	6.92	6.42	6.92	6.58	6.25	6.58	7.17	6.58	6.83	6.58	6.92
T_2	7.67	7.08	6.83	7.08	7.00	7.17	7.00	7.25	6.67	6.42	7.08	6.83
T_3	6.50	6.67	6.17	6.67	6.75	6.50	6.42	6.08	6.08	6.08	7.00	5.75
T_4	7.00	6.83	6.50	6.83	6.58	6.67	6.58	6.75	6.67	6.00	6.92	6.50
T_5	6.67	7.08	6.83	7.08	6.67	6.25	6.17	7.25	6.67	7.67	6.75	6.58
T_6	7.08	7.42	7.08	7.42	6.50	7.33	6.50	7.42	7.00	6.17	7.08	7.00
T_7	7.00	6.67	6.67	6.67	6.92	6.83	6.33	6.75	6.17	7.00	7.25	5.92
T_8	7.67	7.67	7.33	7.67	7.67	7.42	7.92	7.50	7.17	7.50	7.58	7.58
T_9	5.33	5.42	6.42	5.42	6.17	6.50	5.50	6.25	5.92	5.92	6.25	6.25
SE(d)	**0.45**	**0.42**	**0.60**	**0.58**	**0.53**	**0.50**	**0.53**	**0.45**	**0.52**	**0.50**	**0.40**	**0.41**
C.D.	**0.96**	**0.90**	**NS**	**NS**	**NS**	**NS**	**1.13**	**0.96**	**NS**	**1.06**	**NS**	**NS**
C.V.	**8.11**	**7.50**	**10.91**	**10.47**	**9.66**	**8.92**	**9.88**	**8.29**	**9.64**	**9.23**	**7.11**	**7.08**

4.12 Pest and disease incidence

The infestation of major pests like Bihar hairy caterpillar, pseudostem weevil, rhinoceros beetle and rhizome weevil was recorded throughout the life cycle of crop (Table 4.39). For the control of Pseudostem weevil, *Menma*, a botanical, was applied. Bar soap was also applied on leaf axils as a preventive measure. Neem oil emulsion was sprayed at the rate of 1 per cent in all the treatments. No chemical plant protection measure was adopted.

Table 4.39 Major pest infestation recorded during the period of experiment

Treatment	Pseudostem weevil		Banana Rhizome weevil		Rhinoceros beetle	
	First year	Second year	First year	Second year	First year	Second year
T_1	2.69	2.80	2.33	2.68	2.85	2.56
T_2	2.69	2.79	3.16	2.19	3.12	2.16
T_3	2.21	3.41	2.95	3.32	2.65	2.65
T_4	3.07	3.72	2.32	2.01	2.30	2.56
T_5	3.93	2.13	2.33	2.08	2.72	3.20
T_6	1.95	3.02	2.95	3.02	2.95	2.10
T_7	2.08	2.15	2.59	3.41	2.84	3.25
T_8	1.80	3.12	2.71	2.74	3.20	2.20
T_9	1.57	3.18	3.05	2.13	2.56	3.10

Sigatoka leaf spot disease was the major problem in the rainy season. Later the infestation reduced. The incidence and symptoms have been recorded in all the plants but the disease severity was less. Significant difference was recorded between the treatments as given below (table 4.40).

Table 4.40 Percent Disease Severity (PDS) of Sigatoka Leaf spot during first year and second year

Treatment	PDS (%) in First year	PDS (%) in Second year
T_1	8.96	8.33
T_2	9.71	8.25
T_3	10.08	7.86
T_4	11.57	10.49
T_5	8.59	9.27
T_6	11.20	9.54
T_7	11.20	10.98
T_8	9.71	8.74
T_9	11.57	10.18
CD	**1.20**	**1.35**

4.13 Benefit cost ratio

Benefit cost ratio was calculated for sixteen plants per plot (table.4.41). The BC ratio was high in organic system to integrated system. BC ratio was maximum in T_8 in both the years. It was minimum in control followed by T_1.

Table. 4.41 Benefit cost ratio during first and second crop

Treatment	First Year	Second Year
T_1	2.63	2.72
T_2	2.90	2.96
T_3	2.85	3.04
T_4	2.82	3.05
T_5	2.86	2.95
T_6	2.75	2.80
T_7	2.95	3.10
T_8	3.05	3.16
T_9	2.42	2.50

4.15. Pooled results

Pooled analysis of the observations were conducted and the results are presented.

4.15.1 Growth parameters

Plant height

The pooled result showed that there was no significant difference for plant height up to 60 DAP, whereas significant difference were observed at 90, 120, 150, 180, 210 days after planting (Table.4.42). At 90 DAP, maximum plant height was recorded from T_2 which was on par with T_1, T_5 and T_8. At 120 DAP, maximum values was obtained from T_3 which was on par with T_1, T_2, T_5, T_6 and T_8. Plant height was maximum in T_6 at 150 and 180 DAP which was on par with T_2, T_3, T_4, T_5 and T_8. At 180 DAP it was on par with T_1 also. 210 DAP, plant height was maximum in T_8 on par with T_1 to T_6. Minimum value for plant height was recorded from control (table 4.42) (Fig.1).

Table.4.42 Pooled data for Plant height of *Musa* Nendran

Treatment	30 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP
T_1	20.42	37.38	78.96	102.67	121.38	149.71	192.67
T_2	22.92	40.00	79.08	106.58	125.46	149.08	190.71
T_3	21.88	40.54	77.88	106.71	132.33	156.13	194.83
T_4	19.73	39.63	76.00	103.96	123.42	148.29	189.25
T_5	21.42	38.58	77.13	100.92	125.08	150.71	193.08
T_6	23.31	42.21	76.96	106.54	133.50	158.71	199.13
T_7	21.75	37.38	69.33	95.96	117.04	141.96	183.00
T_8	20.33	40.71	78.71	104.75	129.13	155.00	200.04
T_9	21.21	33.92	63.67	88.46	111.75	129.08	173.63
CD	**NS**	**NS**	**6.76**	**4.89**	**10.64**	**12.63**	**17.03**

Pseudostem girth

Pseudostem girth was significantly influenced by the nutrient sources at 90, 120 and 180 DAP (Table.4.43). At 90 DAP maximum pseudostem girth was recorded from T_5 which was on par with T_3 and minimum from T_9. At 120 DAP, maximum girth was in T_3 (32.41 cm) on par with T_4 and minimum value was recorded in T_7. At 180 DAP maximum value was recorded from T_3 on par with T_1, T_2, T_4, T_5, and T_8 and minimum from T_9 (Fig.2).

Table.4.43 Pooled data for Pseudostem girth of *Musa* Nendran

Treatment	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP
T_1	12.82	21.36	28.13	40.21	49.437
T_2	13.38	22.39	30.96	38.72	49.073
T_3	14.63	25.28	32.41	42.11	50.218
T_4	13.58	22.91	32.07	39.82	48.278
T_5	16.90	25.35	30.27	38.86	49.09
T_6	12.89	20.75	28.92	39.82	50.15
T_7	12.15	17.71	20.75	33.26	42.995
T_8	14.36	22.45	28.19	38.03	48.147
T_9	10.07	17.22	22.81	31.93	38.597
CD	**NS**	**2.12**	**0.93**	**NS**	**6.25**

Total number of leaves

Pooled analysis of results showed that total number of leaves was significantly influenced by nutrients sources at 90, 120, 150 and 210 DAP. (Table 4.44). Maximum number of leaves (9.79) were recorded in T_6 at 90 DAP which was on par with T_1, T_2, T_3, T_4, T_5 and T_8. At 150 DAP, T_4 recorded

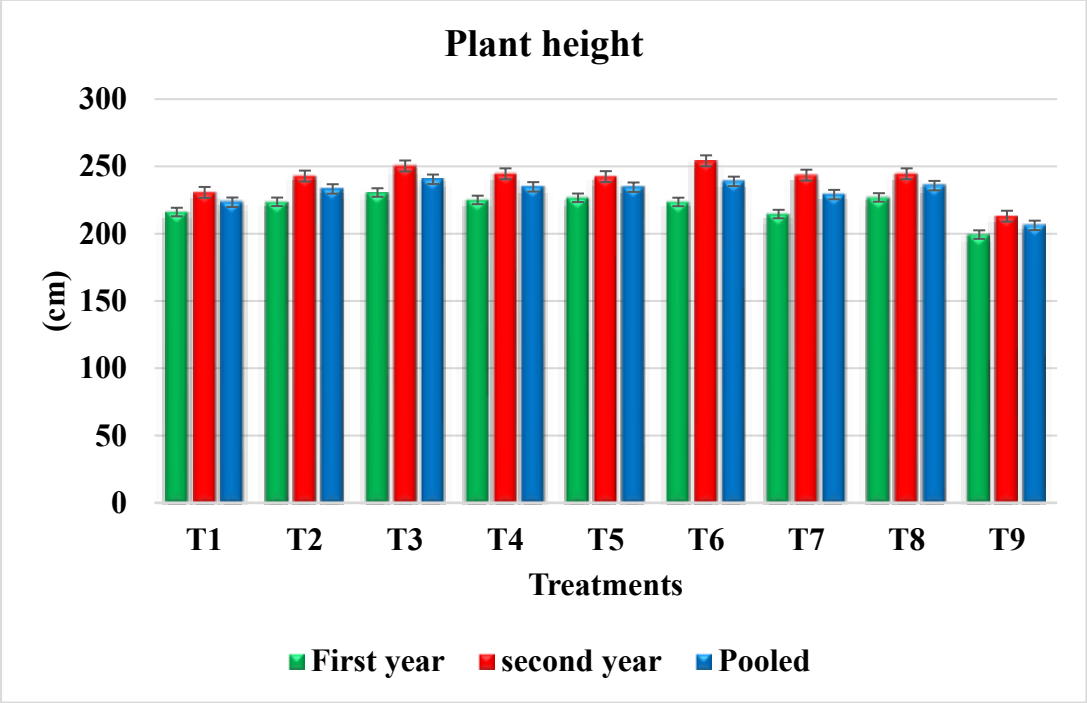

Fig.1 Plant height of *Musa* Nendran banana at 180 DAP

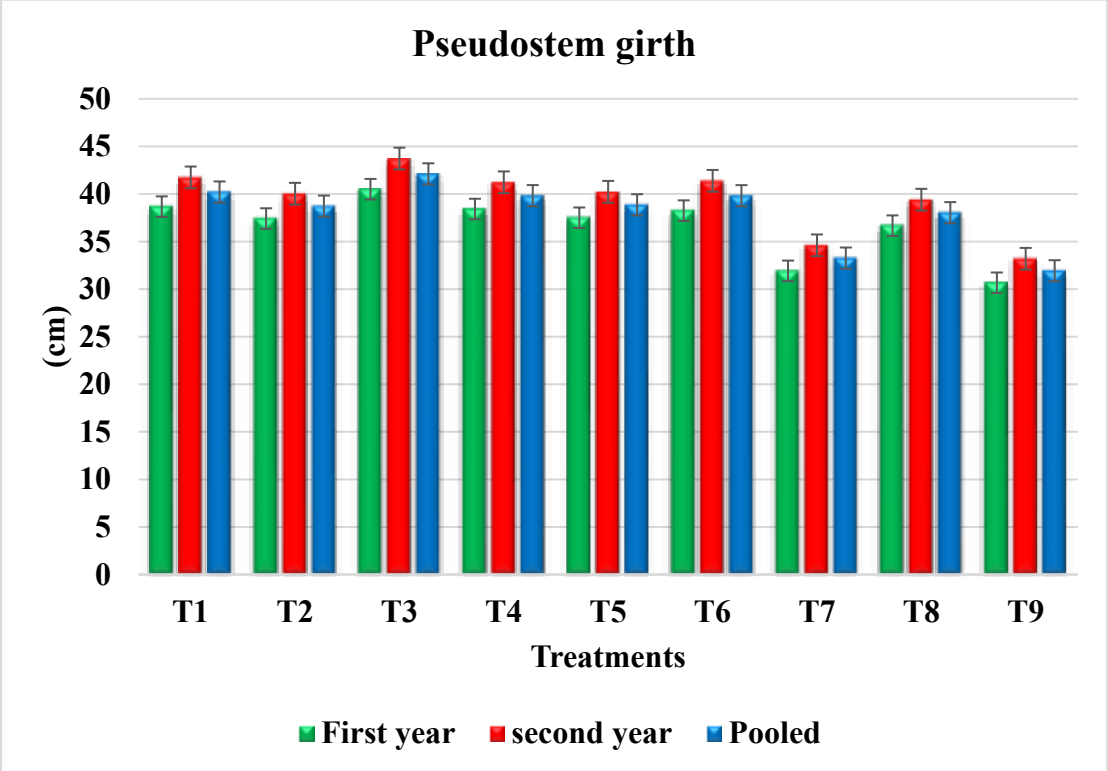

Fig. 2 Pseudostem girth of *Musa* Nendran banana at 180 DAP

maximum number of leaves (14.5) on par with T_1, T_2, T_3, T_5 and T_8. At 210 DAP also maximum number of leaves were recorded from T_4 which was on par with all treatments other than control.

Table. 4.44 Pooled data for total number of leaves of *Musa* Nendran

Treatment	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	210 DAP
T_1	6.17	8.75	11.92	14.08	15.46	16.92
T_2	6.63	9.21	12.42	14.00	15.25	16.79
T_3	7.00	9.54	11.79	14.21	15.54	16.88
T_4	6.75	9.46	12.71	14.50	15.50	17.13
T_5	6.67	9.42	12.13	14.21	15.54	16.88
T_6	7.46	9.79	12.25	13.75	15.17	16.79
T_7	5.88	8.54	11.00	13.29	14.58	16.13
T_8	6.58	9.21	12.29	14.21	15.33	17.00
T_9	6.25	8.29	10.63	12.33	13.38	14.25
CD	**NS**	**1.20**	**0.85**	**0.71**	**NS**	**1.02**

Leaf area index

Results of pooled analysis showed that the leaf area index was not influenced significantly by nutrient sources (Table.4.45). At flowering stage, LAI ranged from 2.26 to 2.63.

Table.4.45 Pooled data for LAI of *Musa* Nendran

Treatment	90 DAP	120 DAP	180 DAP
T_1	1.48	2.02	2.62
T_2	1.56	2.10	2.58
T_3	1.61	1.99	2.63
T_4	1.60	2.15	2.62
T_5	1.59	2.05	2.63
T_6	1.66	2.07	2.57
T_7	1.45	1.86	2.47
T_8	1.56	2.08	2.59
T_9	1.40	1.80	2.26
CD	**NS**	**NS**	**NS**

Phyllochron

Phyllochron was significantly influenced by the treatments at 120 and 180 DAP. At 120 DAP, minimum phyllochron was observed in T_8 which was on par with all treatments other than control. (Table.4.46). However at 180 DAP, maximum phyllochron (10.40) was recorded in T_8 which was on par T_1, T_2 , T_3 and T_9 while lowest (8.63) was in T_6 which was on par with T_4, T_5, T_7.

Table.4.46 Pooled data for phyllocron of *Musa* Nendran

Treatment	60 DAP	120 DAP	180 DAP
T 1	8.17	8.13	9.63
T 2	7.88	8.46	10.32
T 3	7.83	7.92	10.17
T 4	7.42	8.17	8.79
T 5	7.42	7.50	8.88
T 6	7.67	8.25	8.63
T 7	7.42	7.83	9.17
T 8	7.79	7.38	10.40
T 9	9.54	9.88	9.80
CD	**NS**	**1.12**	**1.01**

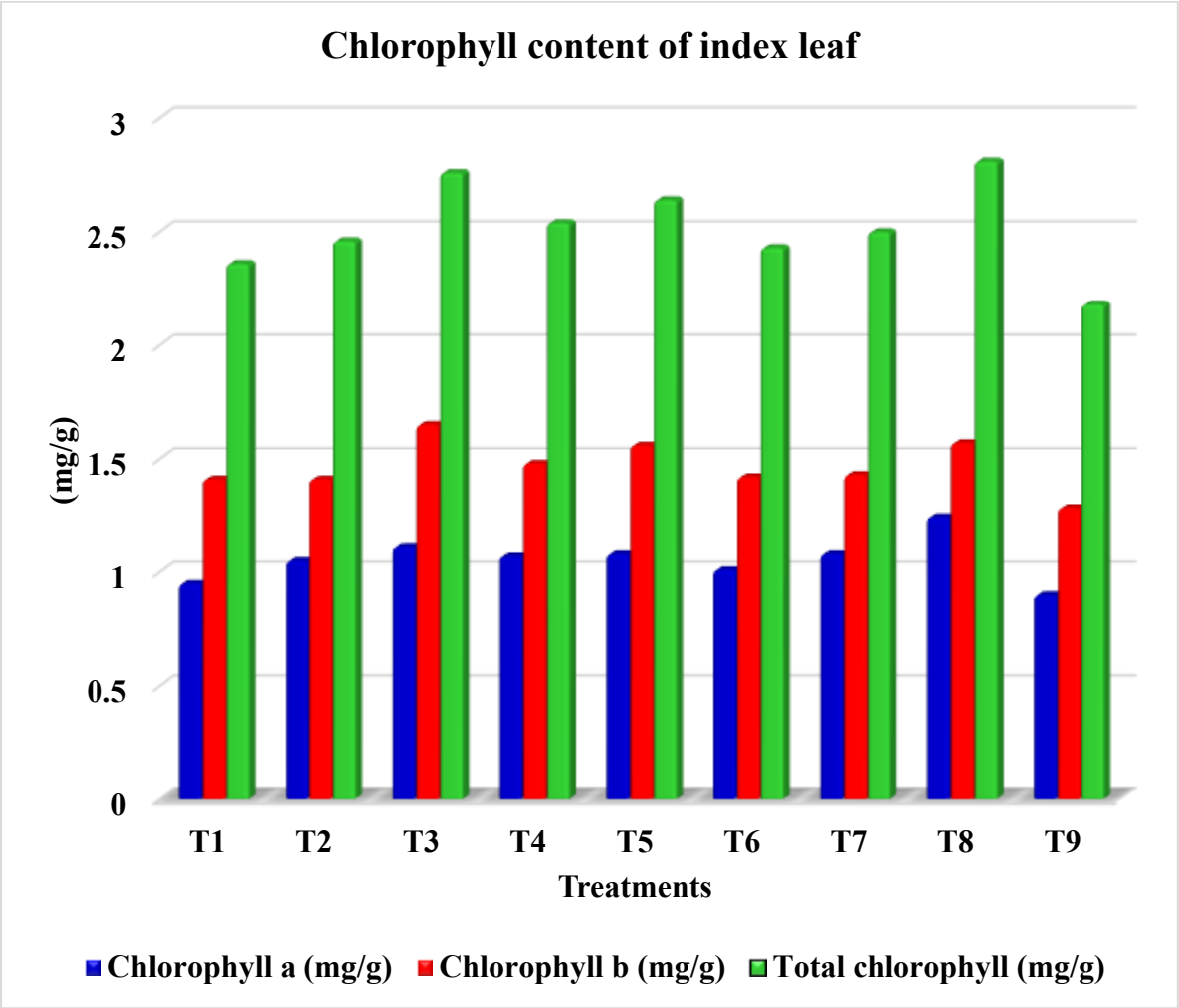

Fig.3. Chlorophyll content in the index of *Musa* nendran at leaf at 150 DAP

4.15.2

Chlorophyll content of leaf

The pooled results of chlorophyll content showed that chlorophyll content of index leaf of banana was significantly influenced by nutrient sources (table 4.47). Highest chlorophyll a (1.24 mg/g) content was recorded from T_8 and lowest (0.90 mg/g) was in control. Chlorophyll b was highest (1.65 mg/g) in T_3 which was on par with T_8 and lowest was observed in T_9. The highest total chlorophyll (2.81 mg/g) was recorded in T_8 which was on par with T_3 and T_5 while lowest total chlorophyll (2.18 mg/g) was recorded in control (Fig. 3).

Table. 4.47 Pooled data for Chlorophyll content index leaf of *Musa* Nendran

Treatments	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)
T_1	0.95	1.41	2.36
T_2	1.05	1.41	2.46
T_3	1.11	1.65	2.76
T_4	1.07	1.48	2.54
T_5	1.08	1.56	2.64
T_6	1.01	1.42	2.43
T_7	1.08	1.43	2.50
T_8	1.24	1.57	2.81
T_9	0.90	1.28	2.18
C.D.	**0.10**	**0.14**	**0.20**

4.15.2 Pooled results of yield and its attributing characters

The pooled results of yield and its attributing characters of *Musa* Nendran is given in table 4.48.

Days to flowering/shooting

The pooled data showed that the effect of nutrient sources for days to flowering of *Musa* Nendran was not significant. The values ranged from 188.96 to 231.67 days (Fig.4) & (Plate 6.)

Days to harvesting (Total duration of crop)

From the pooled analysis data presented in table, it could be observed that the days to harvesting of bunch of Nendran banana was significantly affected by nutrient sources. Earliest harvesting (300.97 days) was from treatment T_5 .which was on par with T_3, T_4, T_7 and T_8 Maximum number of days for harvesting was recorded in control. (Fig. 5)

Bunch weight

Significant difference for bunch weight was obtained between the treatments. Highest bunch weight (10.73 kg) was obtained in T_8 and the treatments T_2, T_3, T_4, T_5, T_6 and T_7 were on par whereas lowest bunch weight (7.44 kg) was observed in control. (Fig.6)& (Plate 7)

Number of hands

Pooled analysis data showed no significant response for number of hands per bunch. The number of hands varied from 5.17 to 5.91.

Total number of fingers

Significant difference for the total number of fingers per bunch was observed from the results. Maximum number of fingers (59.83) was recorded in T_8 which was on par with T_3, T_5 and T_6 and lowest number of fingers (46.87) was recorded in control. (Fig.7).

Finger weight

There was significant difference in finger weight between the treatments. The highest finger weight (169.20 g) was observed in T_3 and lowest finger weight (131.07 g) was recorded in treatment with no manures and fertilizers (control).

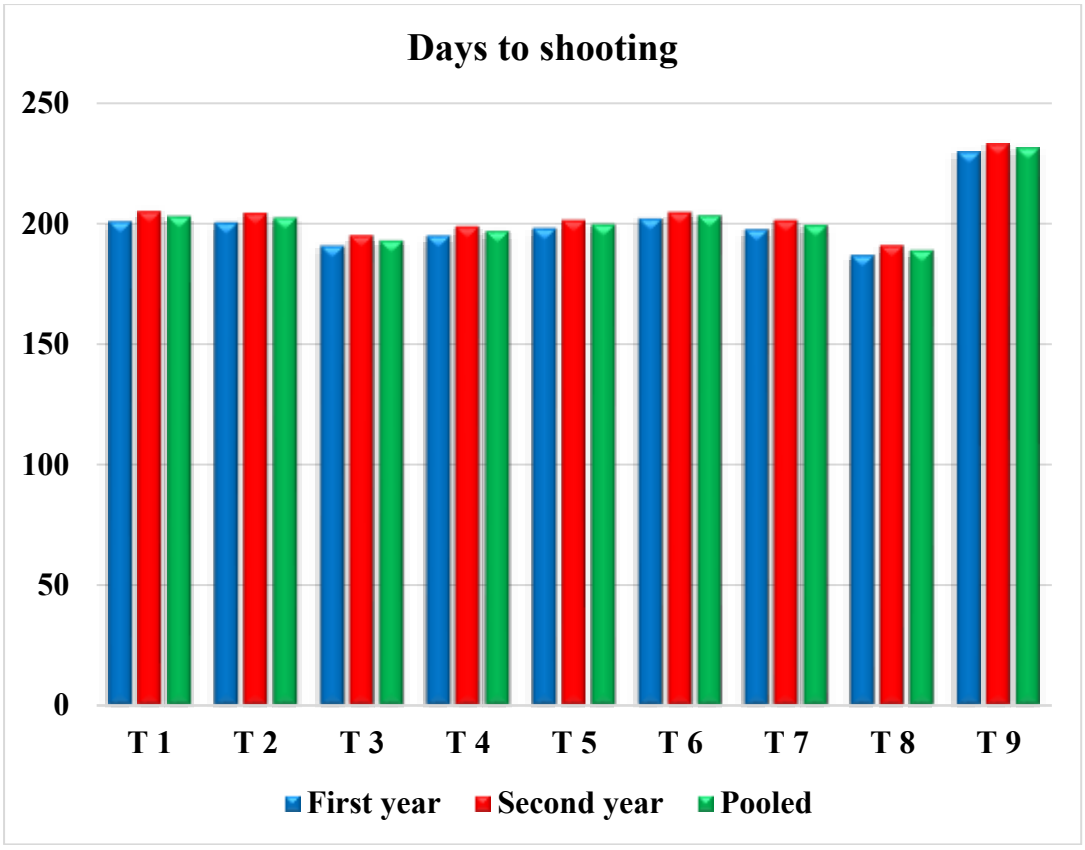

Fig.4 Days to flowering/shooting of *Musa* Nendran banana

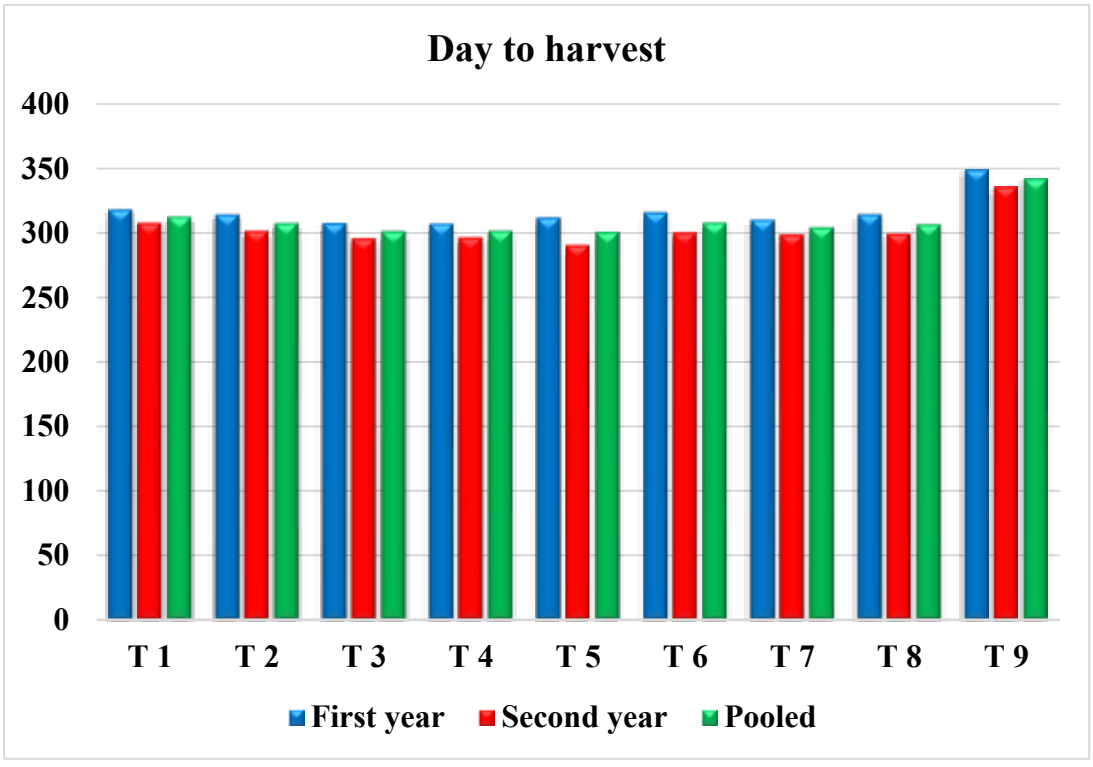

Fig. 5 Days to harvest (Total crop duration) of *Musa* Nendran banana

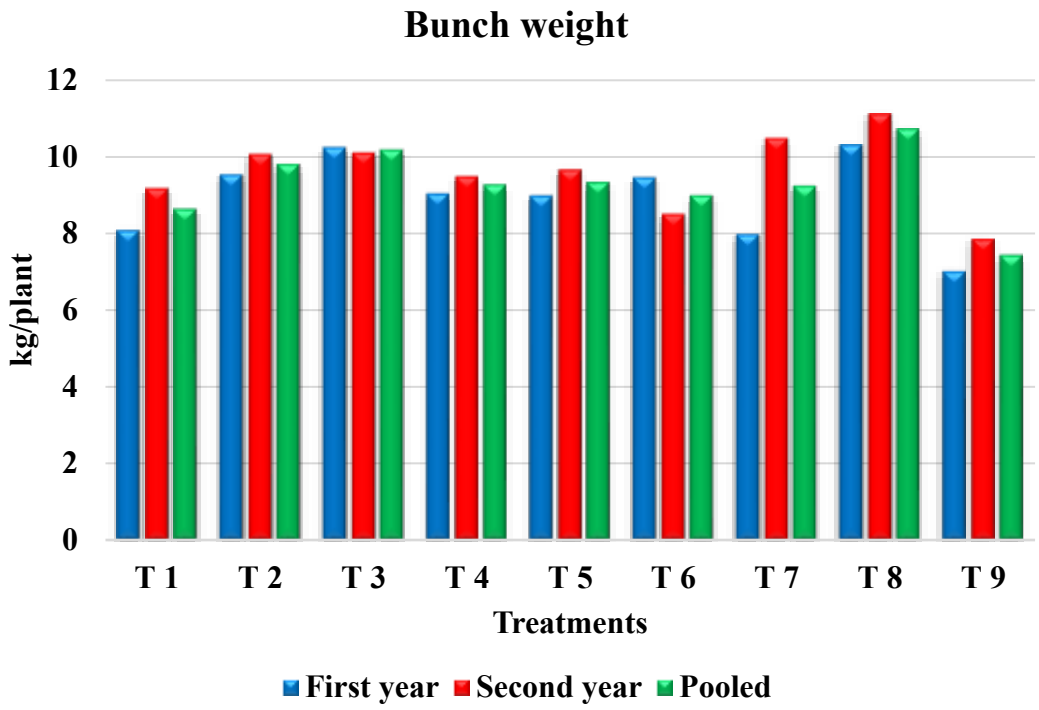

Fig. 6 Bunch weight of *Musa* Nendran banana

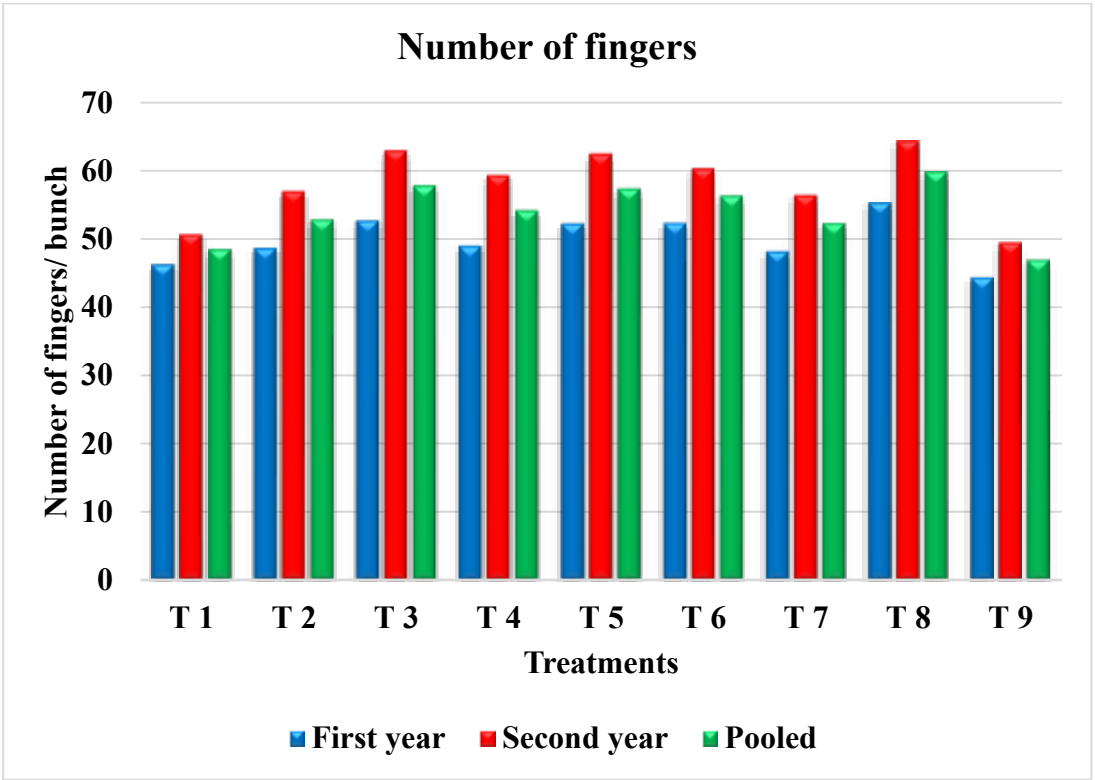

Fig. 7 Number of fingers of *Musa* Nendran banana

Plate.6 Various stages of bunch emegence of Nendran banana

Plate 7. Fruit bunches of Nendran banana

Plate 8. Hands from different treatments

Finger length

There was no significant difference between the treatments. Finger length varied from 23.43cm to 25.77cm.

Finger girth

Pooled results of the data showed that there was no significant difference between treatments on finger girth. Finger girth varied from 11.57 cm to 13.22cm (plate 7 &8).

Table: 4.48 Pooled analysis results of yield and yield attributing characteristics

Treatment	Days for shooting	Days for harvesting	Weight of bunch (kg)	Number of hands	Number of fingers	Finger weight (g)	Finger length (cm)	Finger girth(cm)
T_1	203.08	312.70	8.63	5.54	48.42	146.31	24.14	12.49
T_2	202.50	307.77	9.81	5.83	52.79	152.36	25.22	13.22
T_3	192.96	301.45	10.18	5.88	57.79	169.2	25.55	12.63
T_4	196.92	301.65	9.27	5.71	54.13	151.08	24.97	12.74
T_5	199.79	300.97	9.33	5.88	57.33	153.61	25.77	12.67
T_6	203.42	308.01	8.99	5.79	56.29	150.61	25.33	12.96
T_7	199.51	304.36	9.24	5.58	52.25	145.29	24.49	13.04
T_8	188.96	306.77	10.73	5.92	59.83	152.86	25.95	12.43
T_9	231.67	342.42	7.44	5.17	46.88	131.07	23.43	11.57
CD	**NS**	**6.56**	**1.81**	**NS**	**4.19**	**1.27**	**NS**	**NS**

Pulp to peel ratio

The pooled analysis data showed significant difference for pulp to peel ratio of Nendran banana fruits. Highest pulp peel ratio (3.06) of fruits was observed in T_8 which was on par with all other treatments except T_1 and T_9. Lowest pulp peel ratio (2.40) was recorded in control (table.4.49).

Table.4.49 Pooled analysis of different characters of *Musa* Nendran

Treatment	Pulp peel ratio	Peel thickness (mm)	Days for ripening	Shelf life (Days)	Total biomass production (kg/plant)
T 1	2.54	2.74	5.50	5.63	53.48
T 2	2.87	2.88	5.42	5.88	58.16
T 3	2.98	2.94	6.17	6.46	63.87
T 4	2.98	2.89	5.58	7.29	59.08
T 5	3.05	2.96	5.75	7.08	60.14
T 6	3.05	2.99	5.38	7.33	61.04
T 7	2.95	2.80	5.96	6.63	60.04
T 8	3.06	2.92	6.00	7.21	64.75
T 9	2.40	2.92	5.92	6.13	51.94
CD	**0.23**	**NS**	**0.61**	**1.30**	**4.48**

Peel thickness

The pooled analysis of result showed that peel thickness was not significantly influenced by nutrient sources. Peel thickness varied from 2.74 to 2.92 mm (table 4.49).

Days for ripening

Significant difference for days for ripening of fruits was observed between the treatments (table.4.49). Number of days required for ripening was highest in T_3 (6.17) which was on par with T_4, T_5, T_7, T_8 and T_9 and lowest in T_2.

Shelf life of fruits

Pooled analysis of the results showed that there was significant difference for the shelf life of Nendran banana fruits between the treatments. (Table.4.49). Maximum shelf life (7.29 days) was obtained in T_4 which was on par with T_3 T_5, T_6, T_7, T_8 and T_9. Lowest shelf life (5.63 days) of fruits was observed in T_1 (Fig.8).

Total biomass production

Results showed that the total biomass production of Nendran banana plants was influenced by the nutrient sources significantly (table.4.49). The highest total biomass (64.75 kg plant^{-1}) was recorded from T_8 and it was on par with T_3 and T_6 and lowest biomass (51.94 kg plant^{-1}) was produced in control. (Fig.9)

Dry matter partitioning

Pooled results of total dry matter partitioning showed that there was significant difference between treatments in all plant parts other than peduncle (table 4.50). In male bud maximum value was obtained from treatment T_1 and minimum from treatments T_3 and T_6. In leaves, maximum value was obtained from treatment T_2 and minimum from treatment T_9. In pseudostem maximum value was recorded from treatment T_6 and it was on par with treatments T_3, T_4, T_5 and T_8. Control recorded the maximum value for rhizome and minimum from treatment T_2. In fruits lowest value was from treatment T_9. All treatments other than T_6 and control (T_9) were on par.

Table. 4.50. Pooled data of Total Dry matter (%) partitioning

Treatment	Male bud	Leaves	Pseudostem	Peduncle	Rhizome	Fruit
T1	0.87	5.45	24.24	1.63	50.71	14.97
T2	0.84	6.41	24.02	1.68	50.07	15.42
T3	0.74	5.65	25.57	1.62	51.32	14.67
T4	0.95	6.20	25.80	1.75	51.34	14.67
T5	0.76	5.61	25.24	1.71	52.71	14.37
T6	0.74	6.36	26.11	1.66	50.88	13.64

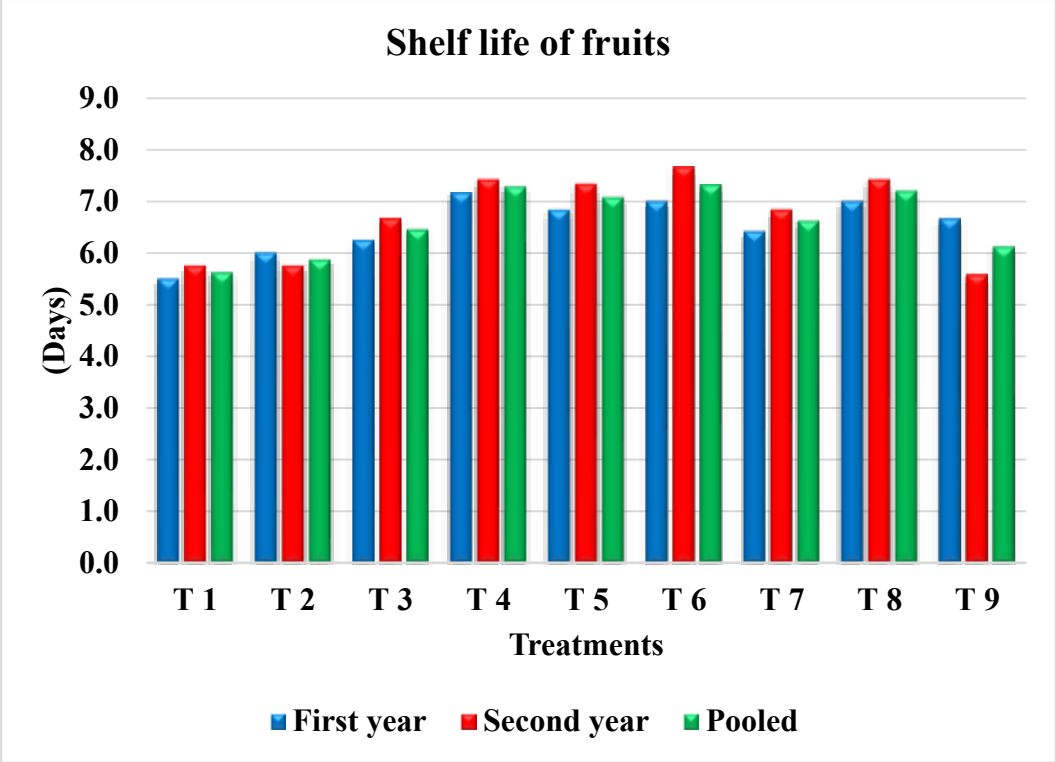

Fig. 8 Shelf life of fruits of *Musa* Nendran banana

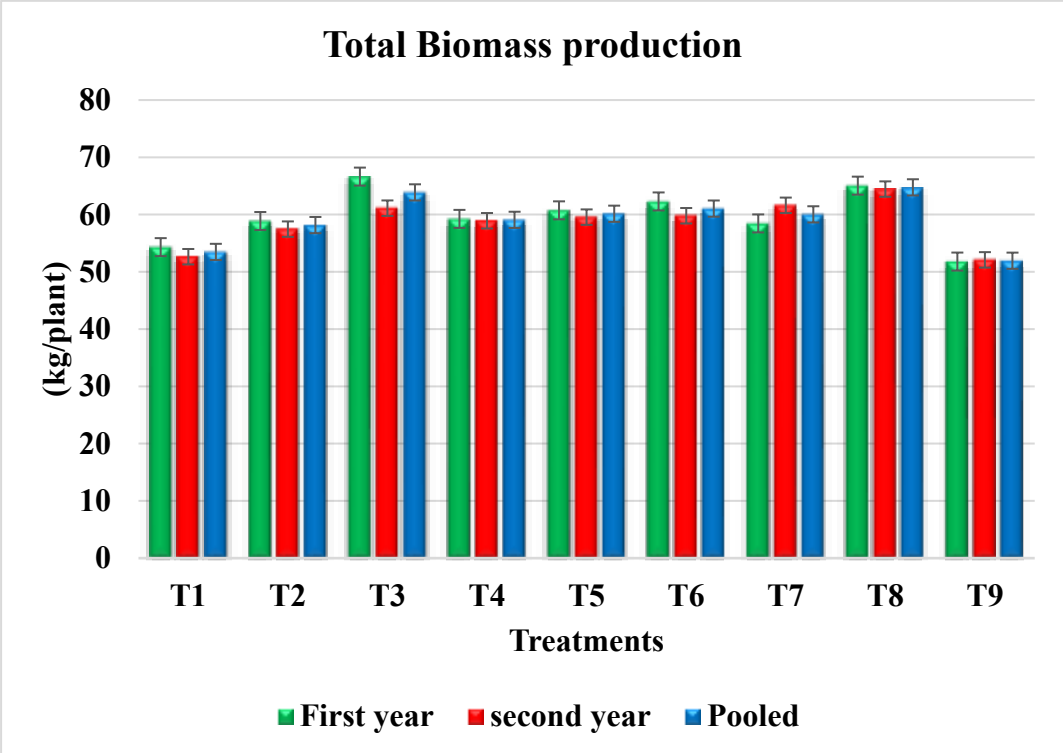

Fig.9 Total biomass production of *Musa* Nendran banana

T7	0.81	6.02	23.94	1.68	53.15	14.37
T8	0.76	5.46	25.84	1.63	51.84	15.19
T9	0.77	5.29	24.26	1.47	55.98	13.56
CD	**0.16**	**0.75**	**1.62**	**NS**	**1.48**	**1.41**

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4.15.3 Biochemical parameters of mature and ripe banana

Pooled analysis data on biochemical analysis of mature and ripe banana fruits of *Musa* (AAB) Nendran is presented in the Table.4.51.

Starch content

Starch content of mature banana fruits was significantly different between the treatments. Among the treatments highest starch content (101.30 mg) was found in T_8 whereas the lowest starch content (64.08 mg) was obtained in T_1.(Fig.10)

Protein content

The result of pooled analysis showed that significant difference was there in protein content of mature green banana fruits. Highest protein content (10.412 mgg^{-1}) was observed in T_2 which was on par with T_3, T_4, T_5, and T_8. Lowest protein content (7.49 mg) was observed in control (T_9). (Fig.11).

Crude fibre

Pooled results showed that there was significant difference in crude fibre content of mature fruits. Highest crude fibre (3.80 %) was obtained in T_8 and lowest crude fibre content of mature green fruits (2.78 %) was observed in control.

Tannin content

Significant difference between the treatments for tannin content of mature green banana fruits was observed. Highest tannin content 0.86 g was obtained in treatment T_8 and it was on par with T_3 and T_7 while lowest tannin content (0.68 g) was recorded in control.

Total Soluble Solids (TSS)

Results showed significant difference in TSS content of ripe fruits. Highest TSS content (26.88^o brix) was observed in T_6 which was on par with other

treatments *viz*., T_2, T_3, T_4, T_5 and T_8. Lowest TSS content (23.30 ^{o} brix) was recorded in control (T_9) (Fig.12)

Titrable acidity

Acidity of ripe fruits was not significantly between the treatments. Titrable acidity values ranged between 0.38 to 0.46 per cent.

Total sugars

Significant difference in total sugars content of ripe banana fruits was recorded from the pooled results. Highest total sugars (17.55 %) was observed in T_3 which was found to be on par with T_4 and T_6. Lowest total sugars (14.51 %) was obtained in control (T_9).

Reducing sugars

Pooled analysis results showed that there is significant difference in reducing sugars between the treatments. Reducing sugars content (11.49 %) was maximum in T_3 which was on par with T_4, T_5, T_6 and T_8. Lowest reducing sugars (9.21 %) was recorded in control (T_9).

Ascorbic acid

Results of pooled analysis for ascorbic acid content of ripe banana fruits indicated significant difference between the treatments. Ascorbic acid (37.98 mg) was maximum in T_3 which was on par with T_2, T_4, T_5, T_6, T_7 andT_8. Lowest ascorbic acid content (28.32 mg) of ripe banana fruits was recorded in T_1.

Sugar acid ratio

Sugar acid ratio of ripe banana fruits varied significantly between the treatments. Maximum sugar/acid ratio (45.14) was recorded in T_3 and minimum (32.45) in control. (Fig 13)

β-carotene content

The results of pooled analysis of data indicated that there were significant difference between treatments in β-carotene content. Highest β-carotene content (599.50 µg) was obtained in T_8 and lowest β-carotene content (434.92 µg) was found in T_1. (Fig.14)

Table. 4.51 Pooled analysis results of biochemical parameters of mature and ripe banana

Treatment	Mature fruits				Ripe fruit						
	Starch content (mg/g)	Protein (mg/g)	Crude fibre (%)	Tannin content (g/100g)	TSS (° brix)	Acidity (%)	Total Sugars (%)	Reducing Sugars (%)	Ascorbic acid (mg/100g)	Sugar Acid ratio	β carotene (µg/100g)
T_1	64.09	7.86	2.82	0.73	23.55	0.42	15.07	9.53	29.13	36.25	434.92
T_2	70.60	10.41	3.25	0.74	26.10	0.46	16.17	10.67	36.70	36.09	536.54
T_3	83.13	9.57	3.19	0.80	25.57	0.39	17.55	11.49	37.98	45.15	544.21
T_4	74.70	9.58	3.53	0.75	25.44	0.42	17.50	11.24	33.93	42.23	564.33
T_5	78.97	9.62	3.36	0.75	26.25	0.42	16.16	11.23	34.74	38.48	552.17
T_6	69.77	8.54	3.38	0.73	26.88	0.43	16.68	11.28	35.68	38.88	516.00
T_7	83.44	8.83	3.37	0.83	24.55	0.40	15.83	10.14	37.23	40.78	518.58
T_8	101.30	10.00	3.80	0.86	26.01	0.38	16.22	11.11	36.01	43.62	599.50
T_9	69.77	7.49	2.78	0.68	23.30	0.46	14.51	9.22	31.79	32.45	449.42
CD	**5.37**	**1.31**	**0.20**	**0.08**	**1.59**	**NS**	**1.15**	**0.40**	**4.14**	**2.80**	**7.30**

Sensory evaluation of ripe fruits

Analysis of pooled data showed that the score for sensory characters of ripe banana fruits other than that for appearance was significantly influenced by nutrient sources. The highest score for colour of fruits (7.21) was recorded in T_8 which was on par with all other treatments except control. Highest flavour score (7.25) was recorded in T_4 on par with T_1, T_2, T_3, T_5, T_8 and T_7 lowest was in control (6.29). The sensory score of texture was highest (7.21) in T_8 on par with T_3, T_4, T_5, T_6 and T_7. Lowest score for texture was from control. Highest score for taste was observed in T_8 on par T_1, T_5, T_6 and T_7 while lowest (6.42) was in control. The highest overall acceptability of fruits was noticed in T_5 on par with all treatments except T_1 and control (table.4.52) &(Plate 9 and plate 10).

Table.4.52 Pooled results of sensory scores of ripe fruits

Treatment	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	7.04	6.67	6.92	6.67	6.96	6.75
T_2	7.38	6.63	7.17	6.63	6.88	7.00
T_3	6.79	6.71	6.63	6.71	6.88	6.96
T_4	7.21	7.04	7.25	7.04	6.67	7.00
T_5	7.08	6.88	7.13	6.88	7.04	7.50
T_6	6.54	6.79	6.29	6.79	7.29	7.00
T_7	7.13	6.83	7.13	6.83	7.42	7.13
T_8	7.33	7.21	7.17	7.21	7.63	7.29
T_9	6.38	6.04	6.29	6.04	6.42	6.63
CD	**NS**	**0.88**	**0.90**	**0.45**	**0.72**	**0.68**

Sensory evaluation of chips

Sensory evaluation score for appearance of chips was not significantly influenced by the treatments. All other characters were significantly different. Highest colour score for chips (7.38) was recorded in T_8 whereas lowest was in control. T_8 was on par with T_2 T_4, T_5, T_6 and T_7. Highest flavour score of chips

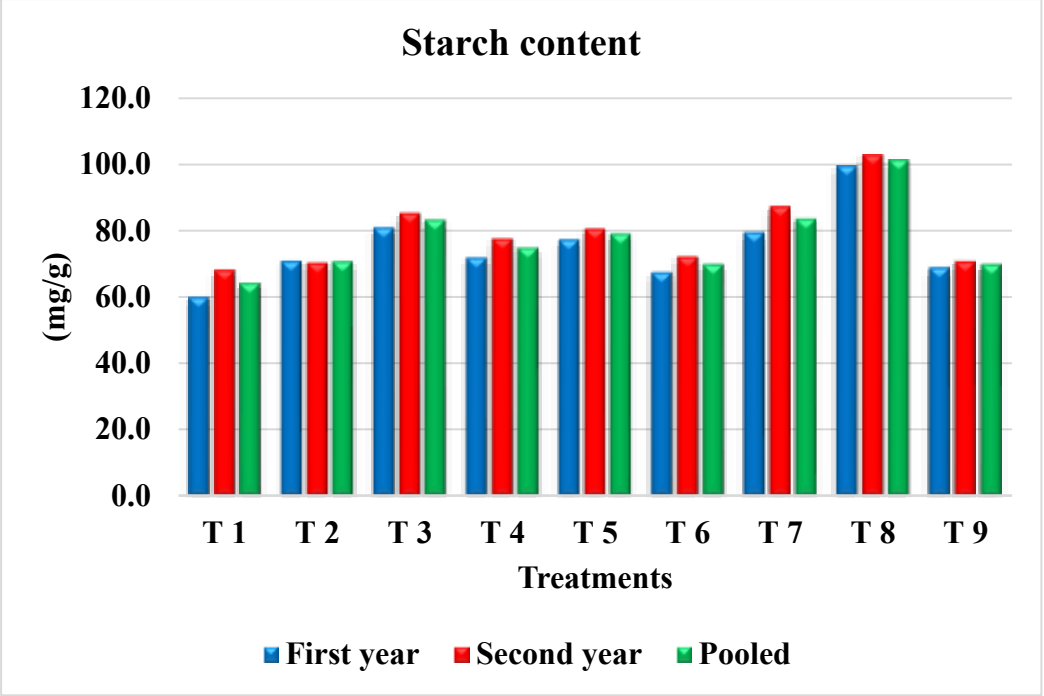

Fig. 10 Starch content of mature fruits of Nendran banana

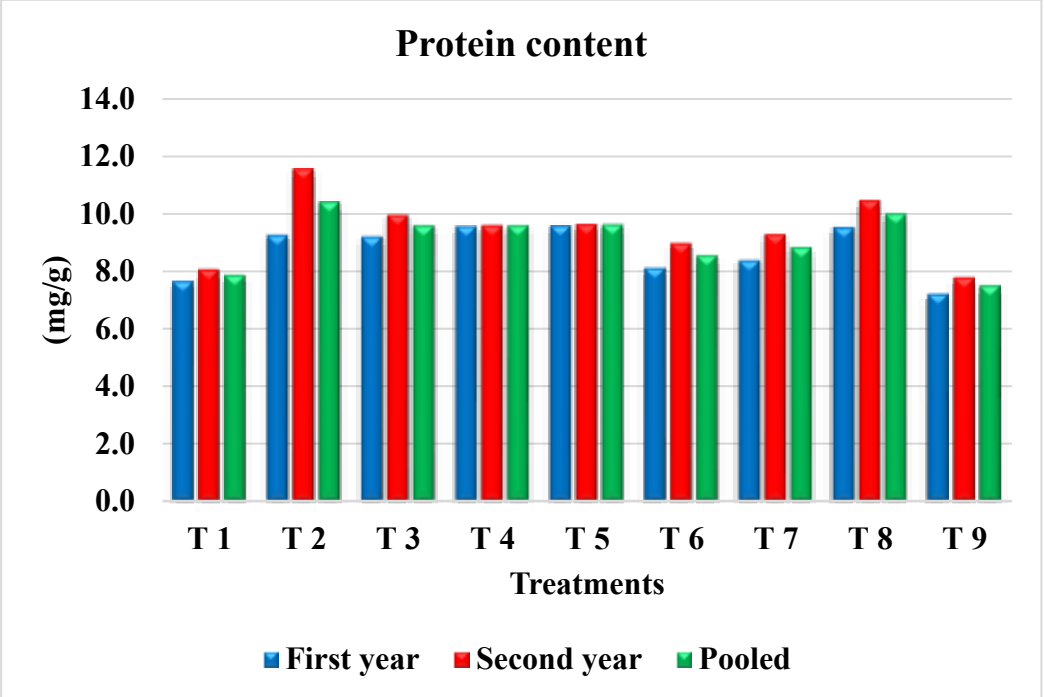

Fig. 11 Protein content of mature fruit of *Musa* Nendran

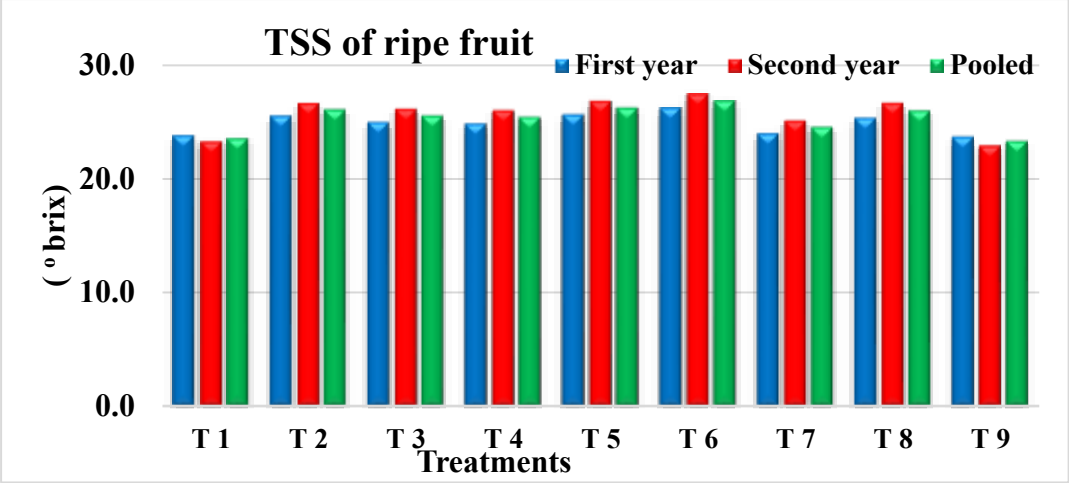

Fig. 12 TSS content of ripe Nendran banana fruits

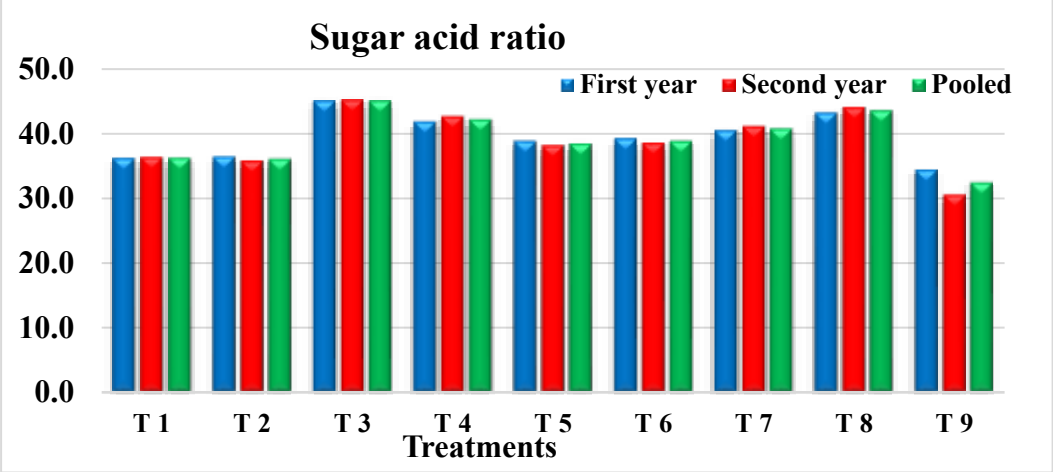

Fig. 13 Sugar acid ratio of ripe banana fruits

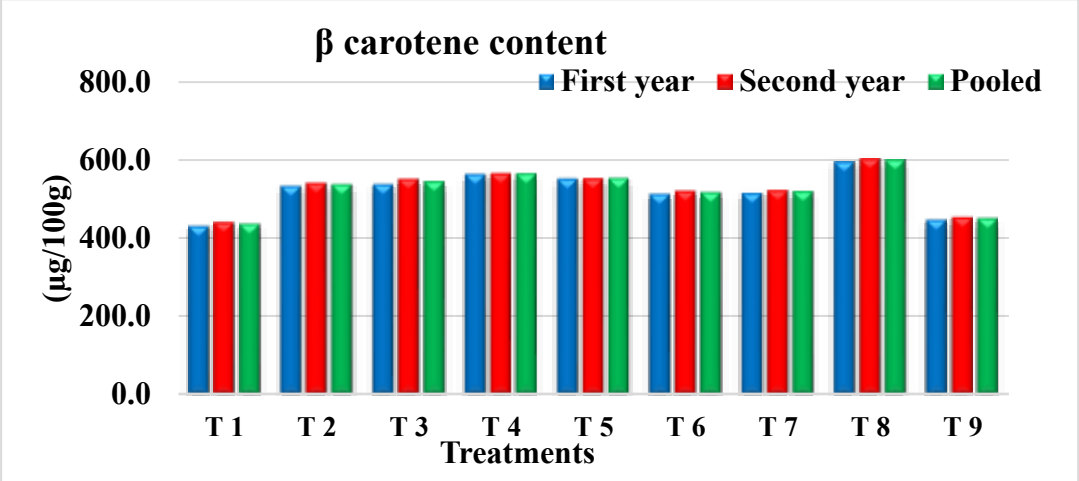

Fig. 14 β-carotene of ripe banana fruits

Plate 9. Fruit hands of Nendran banana in T_8

Plate 10. Sensory evaluation of fruits and chips

(7.38) was recorded in T_8 on par with T_1, T_2, T_4, T_5, T_6 and T_8. Lowest was in control (6.08). The sensory score of texture was highest (7.58) in T_8 which was on par with T_1, T_2, T_4, T_5 T_6 and T_7. Highest score for taste (7.71) was observed in T_8 on par T_1, T_2, T_5 and T_7 while lowest (6.21) was in control. T_8 has the maximum score for overall acceptability of chips (7.33) on par with all treatments other than T_1 and control (table.4.53).

Table.4.53 Pooled results of sensory scores of fruit chips

Treatment	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	6.58	6.33	6.75	6.88	6.71	6.71
T_2	7.38	7.00	6.75	7.13	6.71	7.08
T_3	6.58	6.33	5.92	6.42	6.25	7.08
T_4	6.92	6.58	6.58	6.67	6.29	7.04
T_5	6.88	6.54	6.63	6.96	6.92	6.83
T_6	7.25	7.21	7.00	6.96	6.33	7.25
T_7	6.83	6.75	6.04	6.83	6.67	7.17
T_8	7.67	7.38	7.38	7.58	7.71	7.33
T_9	5.38	6.46	6.08	6.21	5.71	6.33
CD	**NS**	**0.85**	**0.98**	**1.00**	**1.36**	**0.51**

Soil Properties

Results of pooled analysis of soil properties are presented in tables 4.54 and 4.55.

Soil pH

Pooled analysis of the result of two years showed that there was significant difference in soil pH between the treatments. pH was high in T_5 and T_8 (5.4) and lowest in T_1 (4.6).

Electrical Conductivity (EC)

There was significant difference in EC between the treatments. The EC was high in T_7 (0.31dSm^{-1}) and T_4, T_5, T_6 and T_9 were found to be on par while minimum EC was recorded in T_8 (0.16 dSm^{-1}).

Organic carbon

Significant difference was recorded in organic carbon content between the treatments. Organic carbon content was highest in T_8 (1.00 %) and T_5 was found to be on par while minimum organic carbon content was recorded in control (0.61 %) (Fig.15).

Cation Exchange Capacity (CEC)

CEC was not different between the treatments significantly. The value of CEC of experimental soil was varied from 12.85 to 15.73 c mol kg^{1}.

Water holding capacity (WHC)

Water holding capacity of the soils was significantly different between the treatments. The highest WHC was recorded inT_7 (47.73 %) which was on par with T_1, T_3, T_4, T_5, T_6, T_8 and T_9. Lowest value was recorded from control (42.85 %).

Aggregate stability

Pooled analysis of the result showed that there was significant difference in the aggregate stability of experimental soil between the treatments. The highest mean diameter was recorded inT_8 (54.34 mm) and T_3 was found to be on par with T_8 while lowest mean diameter was recorded in T_1 (46.27 mm).

Microbial biomass carbon

Microbial biomass content was significantly different between the treatments. Maximum value was recorded from treatment T_8 (62.55 µg/g of soil) and minimum from treatment T_1 (106.67 µg and minimum from /g of soil). (Fig .16)

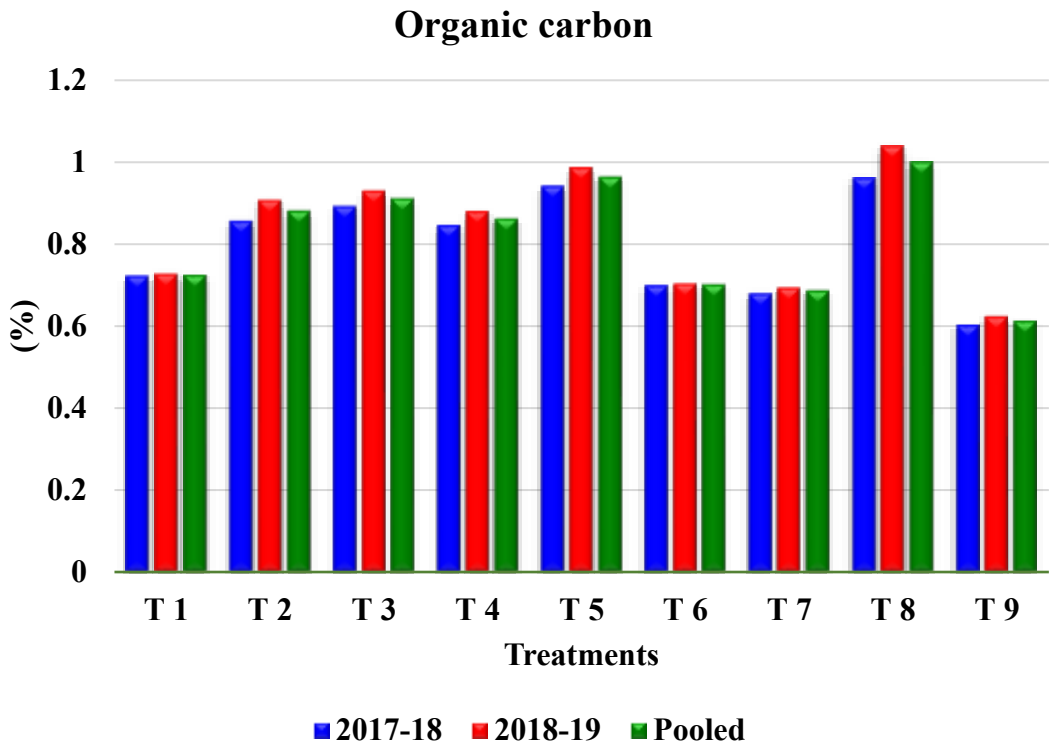

Fig. 15 Organic carbon of the experimental soil

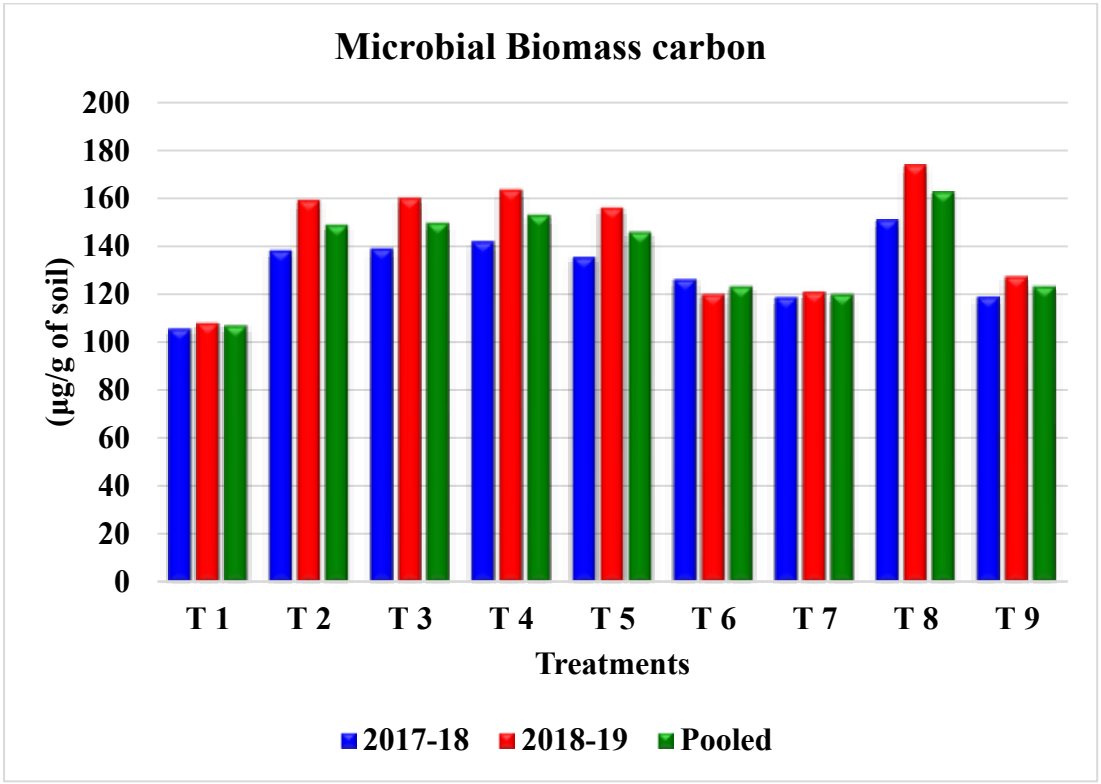

Fig.16 Micro biomass carbon of the experimental soil

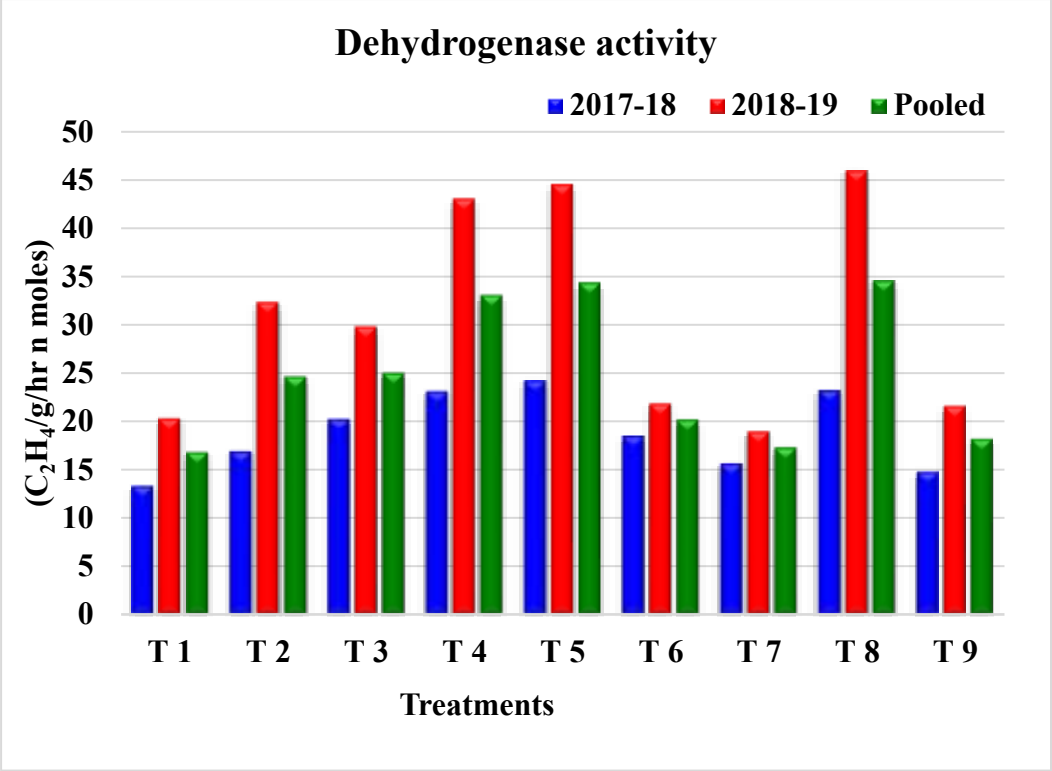

Fig. 17 Dehydrogenase activity of the experimental soil

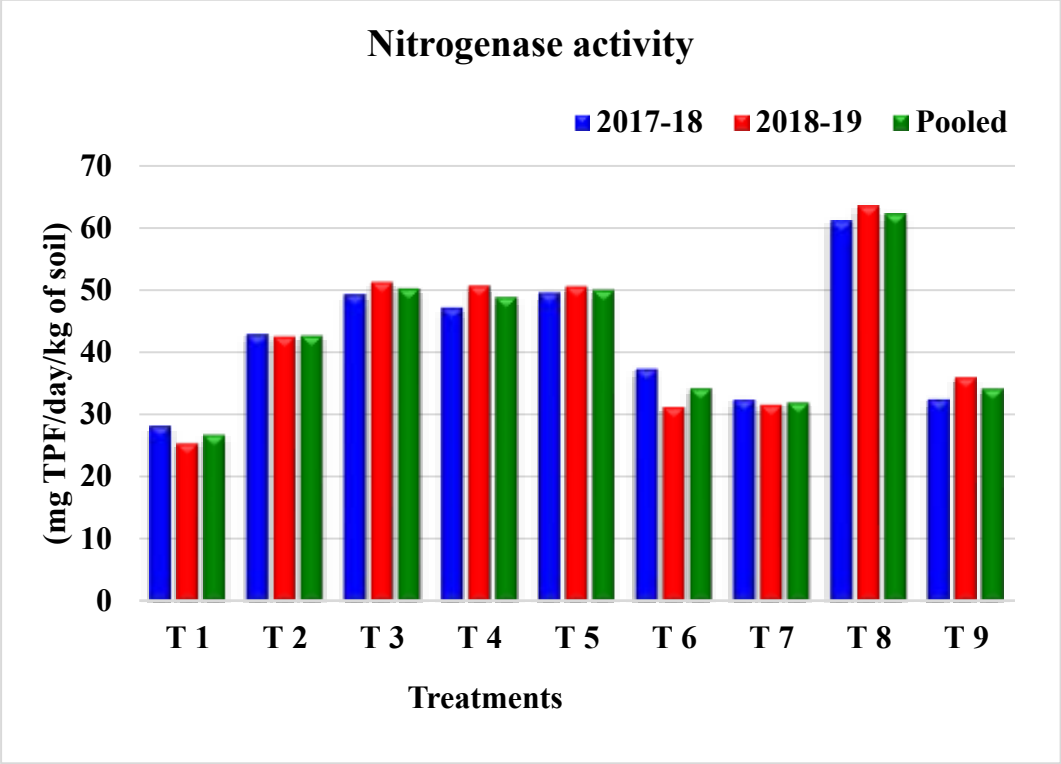

Fig.18 Nitrogenase enzyme activity of the experimental soil

Dehydrogenase activity

There was significant difference in Dehydrogenase activity between the treatments. Maximum value was recorded from treatment T_8 (34.56 mg TPF/day/kg of soil) and minimum from treatment T_1 (16.74 mg TPF/day/kg of soil). T_8 was on par with T_4 and T_5. T_1 was on par with T_2, T_3, T_6, T_7, T_9. (Fig. 17)

Nitrogenase activity

Maximum Nitrogenase activity was recorded in treatment T_8 (62.31 C_2H_4/g/hour n moles). Minimum value was recorded from treatment T_1 (26.68 C_2H_4/g/hour n moles**)** on par with treatment T_6, T_7 and T_9. Significant difference was observed between the treatments on nitrogenase activity in soil. (Fig. 18)

Major and minor nutrients

Significant difference was obtained for available nutrient content for all major nutrients. In minor nutrients, significant difference was obtained for Fe, Zn and Mn but Cu and B values were insignificant.

Available N

Maximum available nitrogen was recorded in T_8 (334.58 kg ha^{-1}) which was on par with T_4 while lowest N content (222.05kg ha^{-1}) was observed in T_9.

Available P

The highest available phosphorous was recorded in T_8 (57.37 kg ha^{-1}) on par with T_4, T_5, T_6 and T_7 while lowest available P (49.82 kg ha^{-1}) was observed in T_9.

Available K

Highest available K content was recorded in T_5 (231.84 kg ha^{-1}) on par with and T_2, T_3, T_6 and T_8. Lowest available K content (195.55kg ha^{-1}) was observed in T_9.

Available Ca

Highest available Ca was recorded in T_8 (498.94 mg kg^{-1} of soil) and lowest available Ca (341.50 mg kg^{-1} of soil) was observed in T_9.

Available Mg

Highest available Mg was obtained in T_8 (85.88 mg kg^{-1} of soil) which was on par with all treatments other than control.

Available S

Highest available S content was observed in T_2 (22.64 mg kg^{-1} of soil) on par with T_1, T_4, T_5, T_6, T_7 and T_8. Lowest available S (14.86 mg kg^{-1} of soil) was observed in control.

Available Fe

Highest available Fe was observed in T_8 (40.87 mg kg^{-1} of soil) and T_2 was found to be on par whereas lowest available Fe (22.35 mg kg^{-1} of soil) was observed in T_9.

Available Cu

Cu content was maximum in T_8 and T_2 (1.95 mg kg^{-1}) which were on par with T_3. Minimum value was recorded from T_9 (0.97 mg kg^{-1}).

Available Zn

Highest available Zn was observed in T_3 (46.61 mg kg^{-1} of soil) on par with T_4, T_5 and T_8. Lowest available Zn (23.71 mg kg^{-1} of soil) was observed in T_9.

Available Mn

The highest available Mn was observed in T_8 (56.07 mg kg^{-1} of soil) on par withT_3 and T_5 whereas lowest available Mn (34.84 mg kg^{-1} of soil) was observed in control.

Available B

Highest available B content was recorded from treatments T_8 and T_5 (0.55 mg kg^{-1} of soil) which were on par with T_2, T_3, T_4 and T_7. Lowest value was recorded from T_9 (0.35 mg kg^{-1} of soil).

Table.4.54 Pooled analysis of available major and minor nutrients

Treatment	N	P	K	Ca	Mg	S	Fe	Cu	Zn	Mn	B
	(kg/ha)			(mg/kg of soil)							
T_1	229.37	51.85	205.16	427.82	71.78	21.79	23.21	1.29	26.65	37.57	0.36
T_2	297.20	53.74	220.32	427.19	78.00	22.64	38.37	1.95	34.86	46.66	0.46
T_3	294.30	55.10	207.44	388.36	81.33	15.04	35.91	1.61	46.61	51.55	0.52
T_4	334.44	56.22	204.70	421.53	84.05	18.39	35.89	1.16	43.30	48.63	0.47
T_5	283.66	55.79	231.84	416.97	78.69	19.29	35.84	1.18	46.40	49.83	0.55
T_6	267.35	55.23	226.40	473.64	72.55	17.28	27.93	1.22	31.16	39.48	0.33
T_7	278.20	55.58	201.79	441.21	77.89	19.58	33.36	1.29	36.97	47.75	0.53
T_8	334.58	57.37	223.32	498.94	85.88	20.24	40.87	1.95	39.76	56.07	0.55
T_9	222.05	49.82	195.55	341.50	63.60	14.86	22.35	0.97	23.71	34.84	0.35
CD	**36.09**	**2.20**	**26.14**	**16.87**	**15.29**	**7.73**	**4.45**	**NS**	**8.73**	**6.93**	**NS**

Table. 4.55 Pooled analysis result of different soil characteristics

Treatment	Soil pH	EC (dS/m^1)	Organic Carbon (%)	CEC (c mol $kg^1$of soil)	WHC (%)	Aggregate stability (mm)	Nitrogenase activity (C_2H_4/g/hour n moles)	Dehydrogenase activity (mg TPF/day/kg of soil)	MBC (µg/g of soil)
T_1	4.65	0.19	0.73	13.88	43.88	46.27	26.68	16.74	106.67
T_2	5.11	0.17	0.88	13.47	43.47	50.72	42.65	24.58	148.65
T_3	5.00	0.19	0.91	14.76	44.76	51.81	50.23	24.98	149.53
T_4	5.16	0.21	0.86	15.08	45.08	50.36	48.86	33.04	152.80
T_5	5.41	0.23	0.97	16.21	46.21	50.51	50.00	34.36	145.68
T_6	4.85	0.27	0.70	15.06	47.06	46.78	34.18	20.13	122.99
T_7	4.88	0.31	0.69	15.73	45.73	51.52	31.88	17.24	119.77
T_8	5.41	0.16	1.00	15.06	45.06	54.34	62.31	34.56	162.55
T_9	4.96	0.22	0.61	12.85	42.85	47.74	34.12	18.13	123.08
CD	**0.22**	**0.11**	**0.12**	**NS**	**3.28**	**2.63**	**9.86**	**8.60**	**12.23**

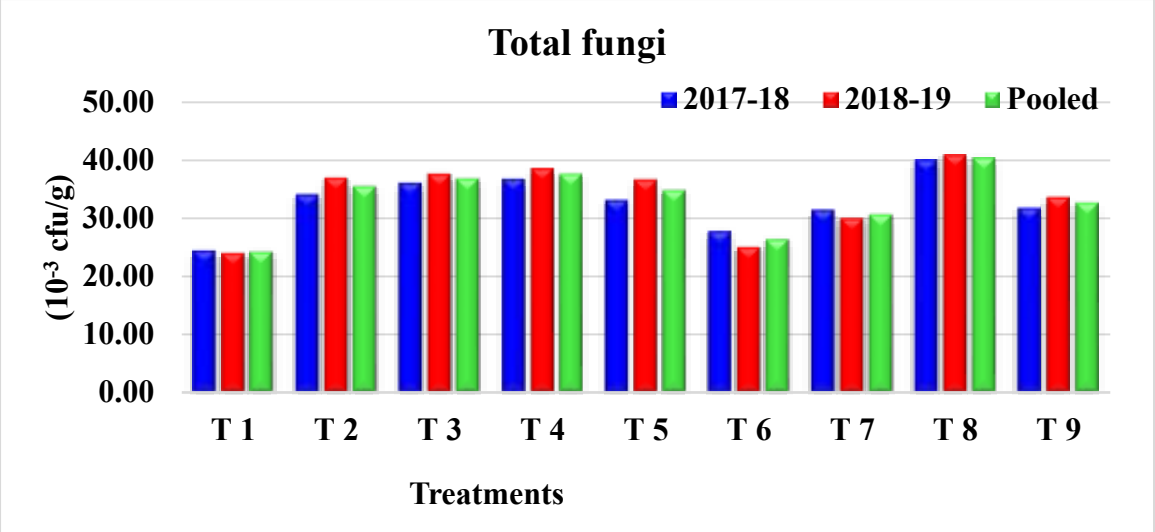

Fig.19 Total viable counts of fungi of experimental soil

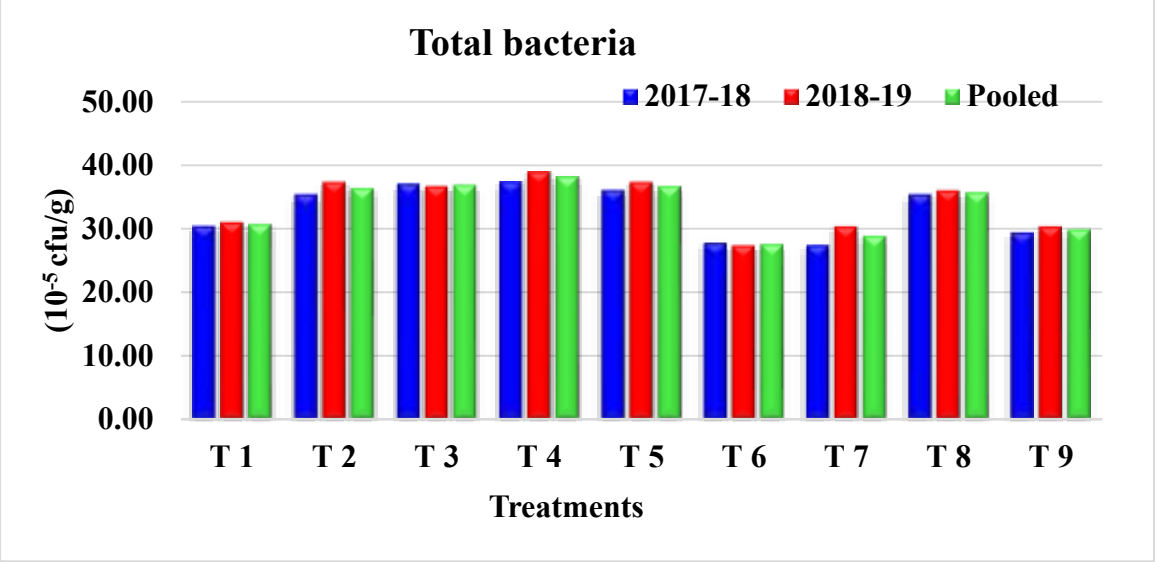

Fig.20 Total viable counts of bacterial cells of experimental soil

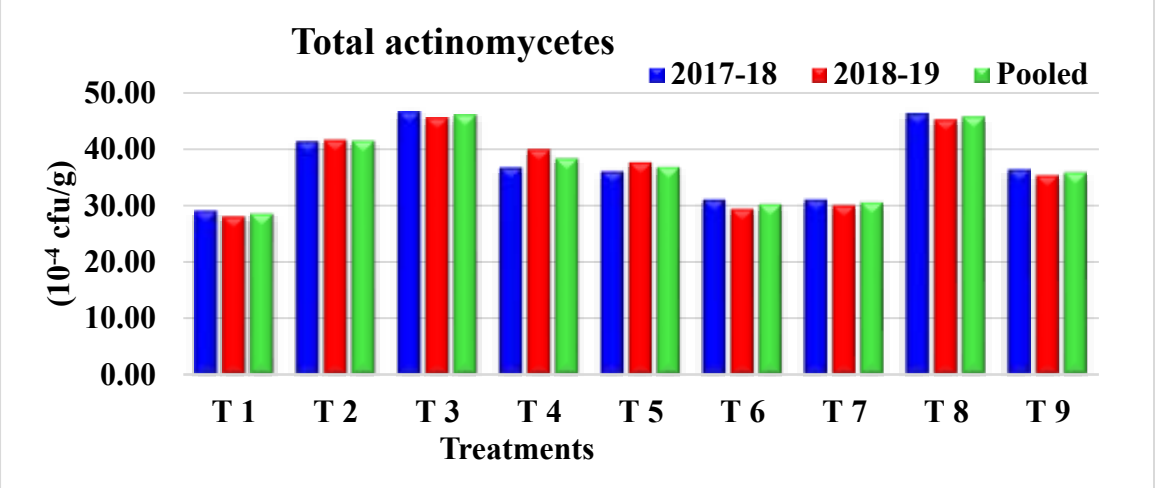

Fig.21 Total viable counts of actinomycetes of experimental soil

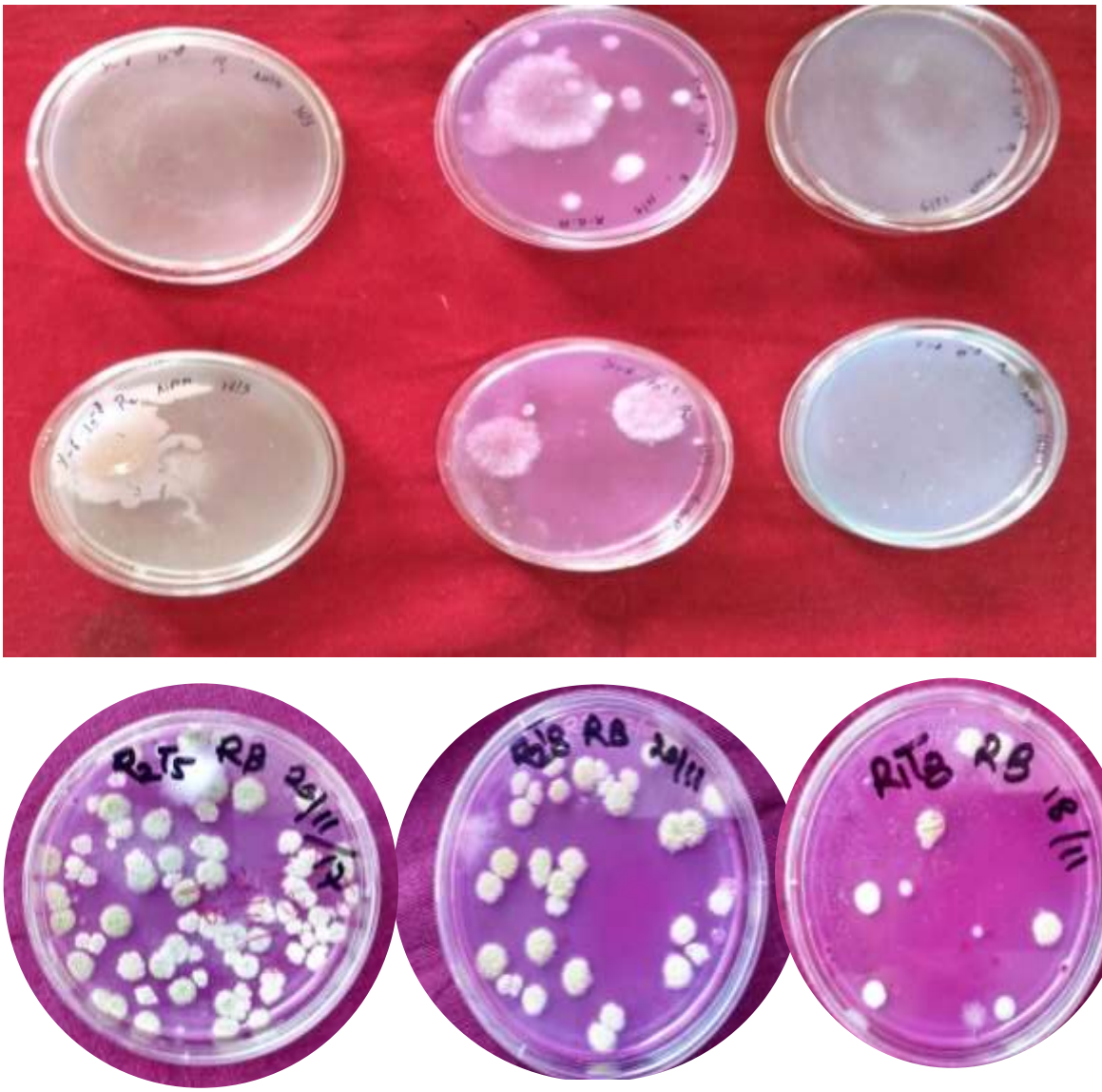

Plate 11. Microbial analysis of soil and orgnic manures

Microbial analysis of soil

Pooled results of viable counts of total fungi, bacteria and actinomycetes in soil showed significant difference between the treatments (table 4.56). Highest total fungi count (40.50 X 10^3 cfu/g) was observed in treatment T_8 which was on par with T_3 and T_4 whereas lowest fungi (24.17 X 10^3 cfu/g) was recorded in T_1. The highest bacterial count (38.17 X 10^5 cfu/g) was recorded in T_4 on par with T_2, T_3, T_5 and T_8 whereas lowest (27.50 X 10^5 cfu/g) was in T_6. The highest actinomycetes (46.17 X 10^4 cfu/g) was recorded in T_3 on par with T_2 and T_8 and lowest was recorded in T_1. (Fig. 19, 20 and 21)& Plate 11.

Table. 4.56 Pooled analysis data of microbial analysis of experimental soil

Treatment	Total Fungi (10^3 cfu/g)	Total Bacteria (10^5 cfu/g)	Total actinomycetes (10^4 cfu/g)
T1	24.17	30.67	28.50
T2	35.50	36.33	41.50
T3	36.83	36.83	46.17
T4	37.67	38.17	38.33
T5	34.83	36.67	36.83
T6	26.33	27.50	30.17
T7	30.67	28.83	30.50
T8	40.50	35.67	45.83
T9	32.67	29.83	35.83
CD	**3.99**	**5.78**	**6.03**

Nutrient content in different plant parts

Leaf

Results of pooled analysis of nutrient content in leaves are presented in table 4.57.

It was observed that K, Ca, Fe, Mn, Zn and B content of leaves were significantly different between the treatments. However there was no significant difference between the treatments in N, P, Mg, S and Cu content. Treatment T_8 recorded the maximum values for K, Ca, Fe, Mn, B content which were 1.98%, 2.01%, 1254.82ppm, 5124.45ppm and 58.16 ppm respectively. Lowest values were obtained from control (T_9). The values obtained for control were 0.99%, 1.29%, 594.020 ppm, 3220.49 ppm and 27.17 ppm respectively. T_8 was on par with T_3 and T_5 in Fe content, with T_3, T_4, T_5 and T_7 in Mn content and with T_6 and T_7 in B content. Zn content was maximum in T_2 (18.46 ppm) on par with T_3, T_6 and T_7. Minimum value was recorded from control (11.69 ppm).

N content varied from 1.07% to 1.49%, P content from 0.18% to 0.23%, Mg content from 0.26% o 0.49%, S content from 0.32% to 1.12% and Cu content from 5.44ppm to 8.45ppm.

Psuedostem

Results of pooled analysis of nutrient content in psuedostem are presented in table 4.58.

K, Fe, Mn, Zn and B content of pseudostem varied significantly between the treatments. There was no significant variation in N, P, Ca, Mg, S and Cu content of pseudostem between the treatments. K, Fe, Mn and Zn content were maximum in T_8 which were 11.02%, 725.50 ppm, 1160.20 ppm and 45.22 ppm respectively. T_8 was on par with T7 in K content, with T_5 in Fe content, with T_4 and T_5 in Mn content and with T_6 in Zn content. Minimum was recorded from T_9 (control) and the values were 7.76%, 347.40 ppm, 756. 87 ppm and 30.21 ppm. B content was highest in treatment T_6 (45.37 ppm.) which was on par with T_4, T_5, T_7 and T_8 and the lowest was recorded from T_1 (27.75 ppm).

N content varied from 0.65% to 0.98%, P content from 0.1% to 0.15%, Ca from 0.57% to 0.98%, Mg from 0.16% to 0.29%, S from 0.18% to 0.61% and Cu from 8.44 ppm to 12.67 ppm.

Fruit

Results of pooled analysis of nutrient content in fruits are presented in table 4.59.

Results of analysis of pooled data showed that Fe, Mn, Zn and B content of fruits were significantly influenced by the nutrient sources. Major elements, Zn and Cu content of fruits was not significantly different between the treatments. Maximum Fe (185.47ppm), Mn (991.12 ppm) and Zn (11.18 ppm) content was recorded from treatment T_8. T_8 was on par with T_5 in Fe content, with T_5 and T_6 in Mn content and with T_2, T_3, T_4, T_5 and T_8 in Zn content. Minimum values for these nutrients were recorded from T_9 (93.82 ppm, 648.18 ppm, 7.36 ppm and 12.38 ppm respectively). B content was maximum in treatment T_6 (27.32 ppm) on par with treatments T_7 and T_8 and minimum was from T_9 (12.38 ppm).

N content varied from 0.61% to 0.95%, P from 0.13% to 024%, K content from 1.19% to 2.04%, Ca content from 0.24% to 0.39%, Mg content from 0.15% to 0.32%, S content from 0.14% to 0.52% and Cu content from 6.59 ppm to 10.19 ppm.

Peduncle

Results of pooled analysis of nutrient content in peduncle are presented in table 4.60.

K, Fe, Mn, Zn and B content of peduncle was significantly different between the treatments. However there was no difference between treatments in N, P. Ca, Mg, S and Cu content. K, Fe, Mn, Zn and B content was maximum in treatment T_8 (11.06%, 556.03ppm, 1141.51ppm and 27.71ppm respectively). T_8 was on par with T_5 in Fe content, with T_6 in Mn content and with T_2, T_3 and T_4 in Zn content. Minimum value was recorded from T_9 which were 6.78%, 203.58ppm, 767.23ppm and 17.15ppm respectively. B content was maximum in T_6 (38.93ppm) on par with T_5, T_7 and T_8 and minimum was from T_9 (17.04ppm).

N content varied from 1.35% to 2.12%, P content from 0.24% to 0.49%, Ca content from 0.59% to 0.9%, Mg content from 0.15% to 0.35%, S content from 0.4% to 0.75%, Cu content from 7.29ppm to 11.55ppm.

Rhizome

Results of pooled analysis of nutrient content in rhizome are presented in table 4.61.

Results showed that treatments had significant influence on K, Fe, Mn, Zn and B content of rhizome. N, P, Ca, Mg, S and Cu content were not significantly influenced by the treatments. K, Fe, Zn and B content were highest in treatment T_8 (9.88%, 2003.31ppm, 28.47 ppm and 49.06 ppm respectively). T_8 was on par with T_2, T_3, T_4, T_5 and T_7 in Fe content, with T_2 in Zn content and with T_2, T_5, T_6 and T_7 in B content. T_9 recorded the lowest values of 5.63%, 1133.87ppm, 18.59 ppm and 24.09 ppm respectively). Mn content was maximum in treatment T_7 (1369.32 ppm) on par with T_8 and minimum was from T_9 (1108.06 ppm).

N content varied from 1.07% to 1.68%, P from 0.29% to 0.6%, Ca content from 0.6 to 0.95%, Mg from 0.36% to 0.68%, S content from 0.49% to 0.87% and Cu content from 8.77 ppm to 1.70 ppm.

Table. 4.57. Pooled data of major and minor nutrients in leaf after harvest

Treatment	Major nutrients (%)						Minor nutrients (ppm)				
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
T_1	1.14	0.19	1.07	1.43	0.35	0.34	699.02	3579.74	13.35	6.06	27.92
T_2	1.31	0.19	1.38	1.60	0.41	0.51	914.32	3842.88	18.46	6.88	41.41
T_3	1.28	0.21	1.24	1.67	0.39	0.62	1040.35	4650.95	15.82	7.28	37.73
T_4	1.47	0.20	1.22	1.81	0.44	0.54	967.92	4970.88	15.32	7.73	44.35
T_5	1.35	0.20	1.40	1.78	0.49	0.74	1140.25	4718.43	15.16	6.87	45.25
T_6	1.27	0.19	1.67	1.67	0.31	0.42	896.56	4413.64	15.69	6.71	55.57
T_7	1.28	0.20	1.71	1.68	0.47	0.81	973.23	4590.90	15.10	6.71	54.97
T_8	1.49	0.23	1.98	2.01	0.43	1.12	1254.82	5124.45	18.31	8.45	58.16
T_9	1.07	0.18	0.99	1.29	0.26	0.32	594.02	3220.49	11.69	5.44	27.17
C.D.	**NS**	**NS**	**0.23**	**0.19**	**NS**	**NS**	**224.45**	**639.93**	**2.82**	**NS**	**7.63**

Table.4.58.Pooled data of major and minor nutrients in pseudostem after harvest

Treatment	Major nutrients (%)						Minor nutrients (ppm)				
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
T_1	0.70	0.11	7.87	0.57	0.20	0.20	404.14	854.20	33.38	9.36	27.75
T_2	0.79	0.12	8.91	0.70	0.24	0.27	534.61	881.01	43.62	10.71	40.16
T_3	0.78	0.13	8.69	0.65	0.23	0.32	607.10	951.35	36.94	11.19	35.49
T_4	0.87	0.12	8.32	0.67	0.26	0.30	567.76	1066.00	36.77	11.61	40.31
T_5	0.83	0.12	9.14	0.72	0.26	0.41	662.03	1057.04	36.86	10.66	40.59
T_6	0.84	0.12	9.40	0.85	0.20	0.22	514.06	1016.39	40.18	10.12	45.37
T_7	0.84	0.13	10.20	0.88	0.29	0.44	557.59	1032.45	37.85	10.25	44.02
T_8	0.98	0.15	11.02	0.98	0.25	0.61	725.50	1160.20	45.22	12.67	44.44
T_9	0.65	0.10	7.76	0.59	0.16	0.18	347.40	756.87	30.21	8.44	28.42
C.D.	**NS**	**NS**	**1.18**	**NS**	**NS**	**NS**	**98.31**	**118.48**	**5.84**	**NS**	**7.01**

Table.4.59 .Pooled data of major and minor nutrients in fruit after harvest

Treatment	Major nutrients (%)						Minor nutrients (ppm)				
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
T_1	0.63	0.14	1.39	0.28	0.17	0.15	108.48	676.23	8.44	7.63	13.22
T_2	0.77	0.17	1.64	0.31	0.18	0.22	145.08	768.94	10.56	8.47	18.48
T_3	0.80	0.19	1.70	0.31	0.19	0.26	163.75	742.41	9.77	8.94	17.38
T_4	0.85	0.20	1.81	0.33	0.20	0.25	151.39	853.89	11.13	9.34	20.50
T_5	0.88	0.20	1.81	0.33	0.20	0.35	169.51	893.38	10.36	7.97	23.00
T_6	0.69	0.22	1.49	0.30	0.32	0.17	115.99	948.43	9.83	8.51	27.32
T_7	0.90	0.22	1.73	0.32	0.21	0.37	125.86	831.22	9.19	8.55	25.43
T_8	0.95	0.24	2.04	0.39	0.25	0.52	185.47	991.12	11.18	10.19	27.11
T_9	0.61	0.13	1.19	0.24	0.15	0.14	93.82	648.18	7.36	6.59	12.38
C.D.	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**23.96**	**131.13**	**1.76**	**NS**	**3.96**

Table.4.60 .Pooled data of major and minor nutrients in peduncle after harvest

Treatment	Major nutrients (%)						Minor nutrients (ppm)				
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
T_1	1.35	0.29	7.68	0.64	0.19	0.42	223.26	795.76	20.27	8.58	19.79
T_2	1.69	0.35	8.98	0.71	0.20	0.62	359.52	933.16	24.24	9.57	27.86
T_3	1.78	0.41	9.31	0.74	0.21	0.65	424.85	960.12	25.26	10.09	25.59
T_4	1.83	0.42	9.31	0.82	0.22	0.63	394.91	956.55	25.94	10.66	29.59
T_5	2.00	0.42	9.34	0.81	0.22	0.74	474.66	990.28	21.67	9.18	34.32
T_6	1.57	0.49	8.00	0.76	0.35	0.53	331.67	1101.63	22.85	9.81	38.93
T_7	2.02	0.46	9.39	0.77	0.22	0.75	370.92	979.75	23.28	9.73	34.93
T_8	2.12	0.43	11.06	0.91	0.26	0.74	556.03	1141.51	27.71	11.55	37.32
T_9	1.36	0.24	6.78	0.59	0.15	0.40	203.58	767.23	17.15	7.29	17.04
C.D.	**NS**	**NS**	**1.21**	**NS**	**NS**	**NS**	**104.19**	**131.31**	**3.60**	**NS**	**7.09**

Table.4.61.Pooled data of major and minor nutrients in rhizome after harvest

Treatment	Major nutrients (%)						Minor nutrients (ppm)				
	N	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**	**B**
T_1	1.10	0.35	6.24	0.71	0.48	0.53	1288.34	1222.91	19.10	10.09	30.34
T_2	1.29	0.44	7.13	0.82	0.56	0.78	1781.91	1172.08	25.92	11.45	39.90
T_3	1.30	0.54	7.70	0.85	0.53	0.77	1860.93	1111.40	22.99	12.10	35.03
T_4	1.33	0.54	6.37	0.91	0.61	0.73	1907.55	1206.93	22.24	12.66	35.45
T_5	1.39	0.51	7.16	0.88	0.63	0.86	1966.63	1260.28	22.46	11.16	43.05
T_6	1.14	0.60	8.87	0.80	0.42	0.62	1771.82	1183.61	24.32	11.10	48.82
T_7	1.58	0.57	8.16	0.82	0.64	0.87	1943.59	1369.32	23.34	11.16	44.99
T_8	1.68	0.55	9.88	0.95	0.68	0.84	2003.31	1330.51	28.47	13.70	49.06
T_9	1.07	0.29	5.63	0.60	0.36	0.49	1133.87	1108.06	18.59	8.77	24.09
C.D.	**NS**	**NS**	**0.87**	**NS**	**NS**	**NS**	**223.84**	**108.16**	**3.84**	**NS**	**12.47**

Total Nutrient uptake

Nitrogen uptake

Nitrogen uptake by different plant parts was significantly different. Treatment T_8 recorded maximum N uptake in pseudostem, peduncle, rhizome and fruit. Total uptake was also high in T_8. However in leaves maximum uptake was recorded from treatment T_4. In leaf T_4 was on par with all treatments other than T_9. In peduncle, treatment T_8 was on par with all treatments other than control. Minimum value was recorded from control in leaf, pseudostem, peduncle, fruit and also in total uptake. In rhizome minimum value was recorded from T_1 which was on par with T_9 (table 4.62) (Fig.22)

Table 4.62. Treatment effect on Nitrogen uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	6.17	14.60	1.31	48.02	8.59	78.68
T_2	8.95	17.81	1.81	60.42	11.78	100.77
T_3	8.43	19.96	2.01	67.29	12.63	110.33
T_4	9.65	21.03	2.05	63.19	12.29	108.20
T_5	8.23	19.87	2.24	69.20	12.67	112.21
T_6	8.96	21.05	1.75	56.55	9.56	97.86
T_7	8.36	19.14	2.21	80.52	13.36	123.58
T_8	9.36	25.43	2.38	88.30	15.53	141.01
T_9	5.29	12.89	1.11	48.98	7.22	75.48
C.D.	**1.42**	**2.79**	**0.40**	**13.35**	**1.86**	**13.97**

Phosphorous uptake

P uptake in pseudostem, rhizome and fruit was significantly influenced by the treatments. Significant difference was also recorded in total uptake of P. In pseudostem maximum value was recorded from T_8 on par with T_3. In rhizome maximum was from T_7 on par with T_3, T_4, T_5, T_6 and T_8. In fruits and also the total uptake of P was maximum in T_8. In fruits T_8 was on par with T_7. Treatment T_8 was on par with T_3, T_4, T_5, T_6 and T_7 in total uptake of P. Minimum value for uptake of P was recorded from control in pseudostem, rhizome, fruit and total uptake. P uptake values ranged from 0.8 to 1.32 in leaf and 0.2 to 0.55 in peduncle (table 4.63) & (Fig.23).

Table.4.63. Treatment effect on P uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	0.92	2.26	0.29	14.75	1.98	20.21
T_2	1.17	2.66	0.38	20.31	2.68	27.19
T_3	1.23	3.29	0.47	25.33	3.05	33.36
T_4	1.17	2.97	0.48	25.23	2.96	32.80
T_5	1.09	2.99	0.47	25.20	2.94	32.69
T_6	1.22	3.07	0.55	28.89	3.07	36.79
T_7	1.18	2.97	0.50	29.10	3.62	37.39
T_8	1.32	3.96	0.49	27.97	4.04	37.78
T_9	0.80	1.98	0.20	13.42	1.55	17.94
C.D.	**NS**	**0.82**	**NS**	**6.88**	**0.70**	**7.15**

K uptake

K uptake was significantly influenced by the treatments in different plant parts as well as in total uptake. Maximum uptake was recorded in T_8 in plant parts and minimum from T_9. In leaf, T_8 was on par with T_6 and T_7 and

in peduncle T_8 was on par with T_3, T_4 and T_5. Total uptake of K was also maximum in T_8 and minimum in T_9 (table 4.64) & (Fig.24).

Table.4.64 Treatment effect on K uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	5.87	163.29	7.39	274.89	19.06	470.49
T_2	9.65	199.95	9.57	337.31	25.08	581.56
T_3	8.20	221.30	10.32	401.30	26.70	667.82
T_4	8.05	197.61	10.20	303.64	26.20	545.70
T_5	8.62	217.57	10.27	358.53	26.20	621.18
T_6	11.88	235.85	8.74	437.91	20.70	715.08
T_7	11.36	232.03	10.14	421.03	25.49	700.05
T_8	12.55	285.21	12.19	518.12	33.22	861.28
T_9	4.93	153.32	5.47	258.49	14.02	436.24
C.D.	**2.00**	**29.52**	**2.04**	**71.34**	**3.77**	**75.89**

Ca uptake

Pooled results showed that treatments significantly influenced Ca uptake by plant parts. Total Ca uptake as well as uptake by pseudostem, peduncle, rhizome and fruit was significantly different between the treatments. Maximum values were recorded from T_8 and minimum from T_9. T_8 was on par with T_3 in rhizome (table4.65) & (Fig.25)..

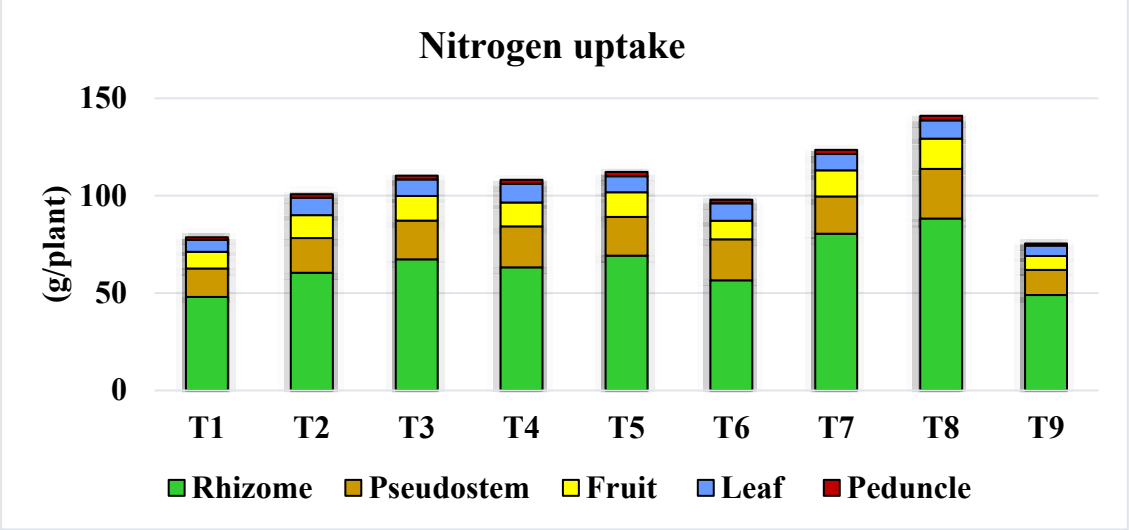

Fig.22 Total N uptake in different plant parts at harvest

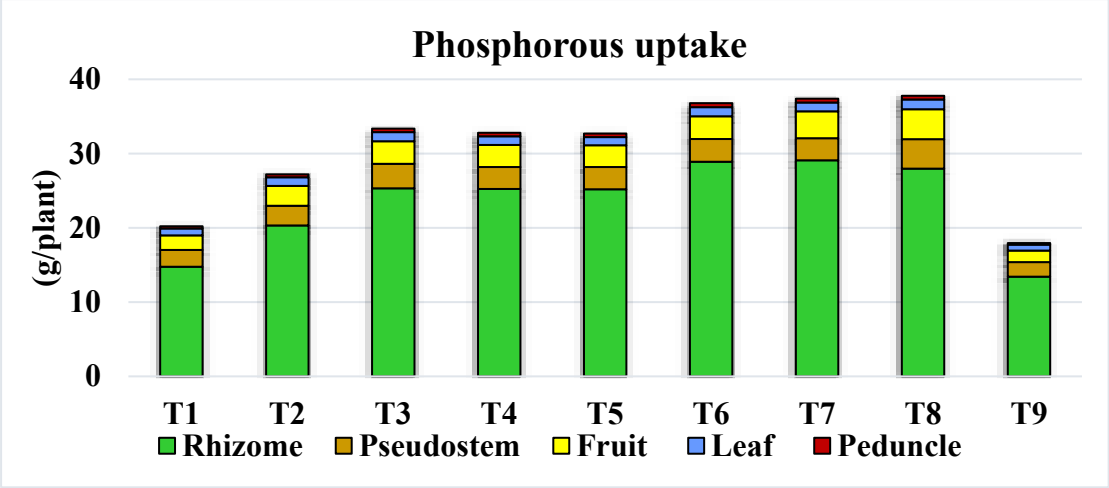

Fig.23 Total P uptake in different plant parts at harvest

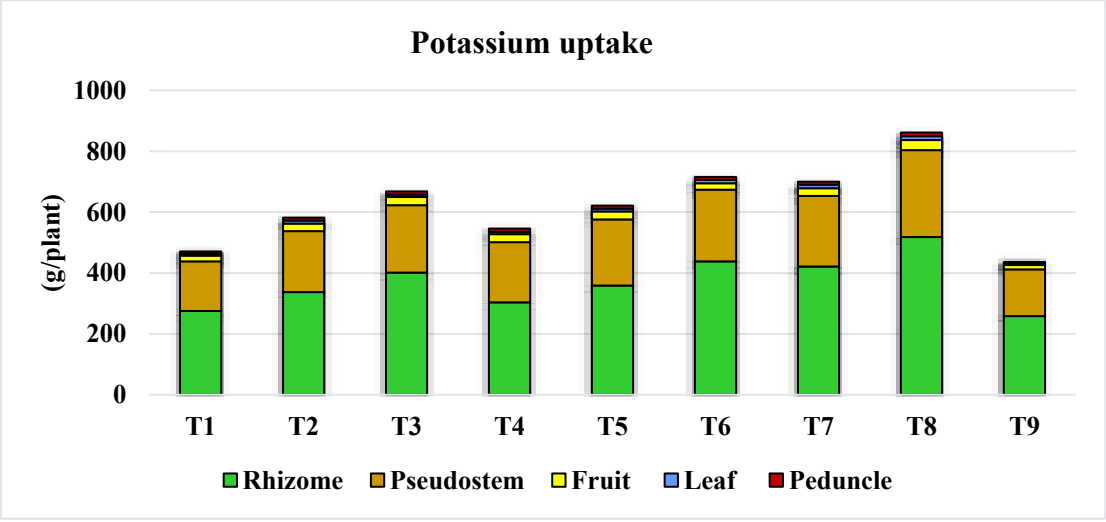

Fig.24 Total K uptake in different plant parts at harvest

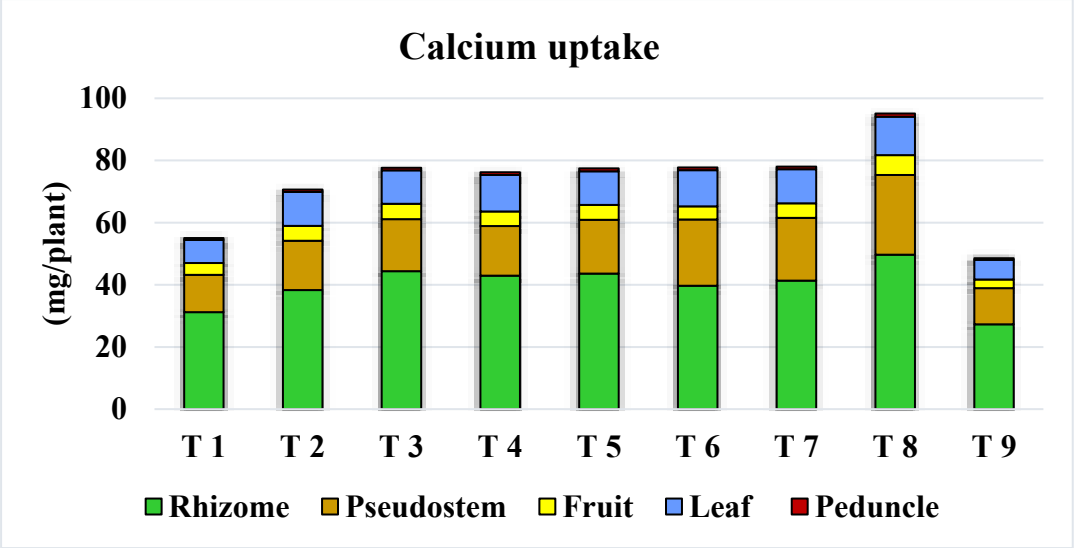

Fig.25 Total Ca uptake in different plant parts at harvest

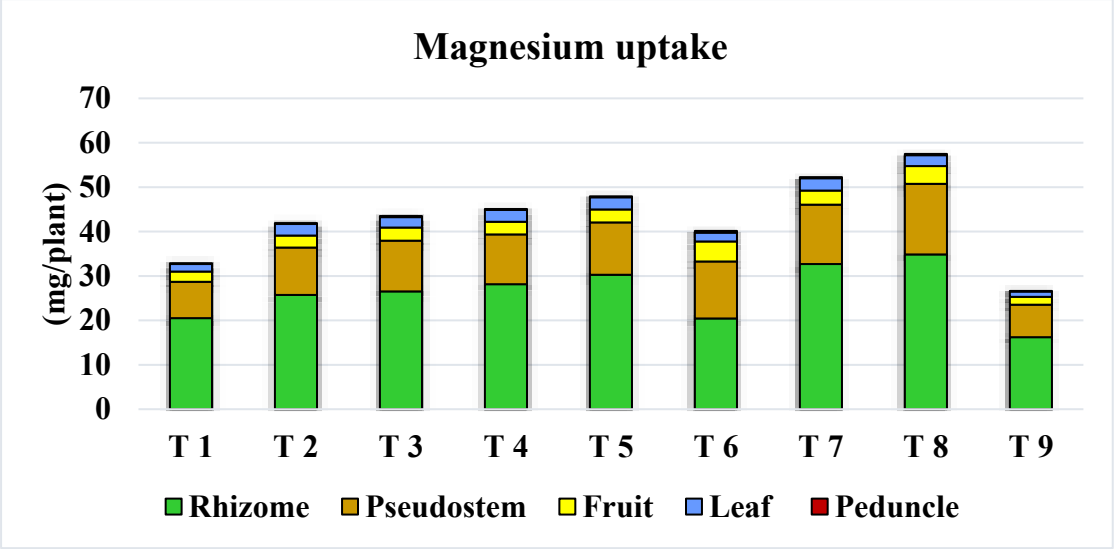

Fig.26 Total Mg uptake in different plant parts at harvest

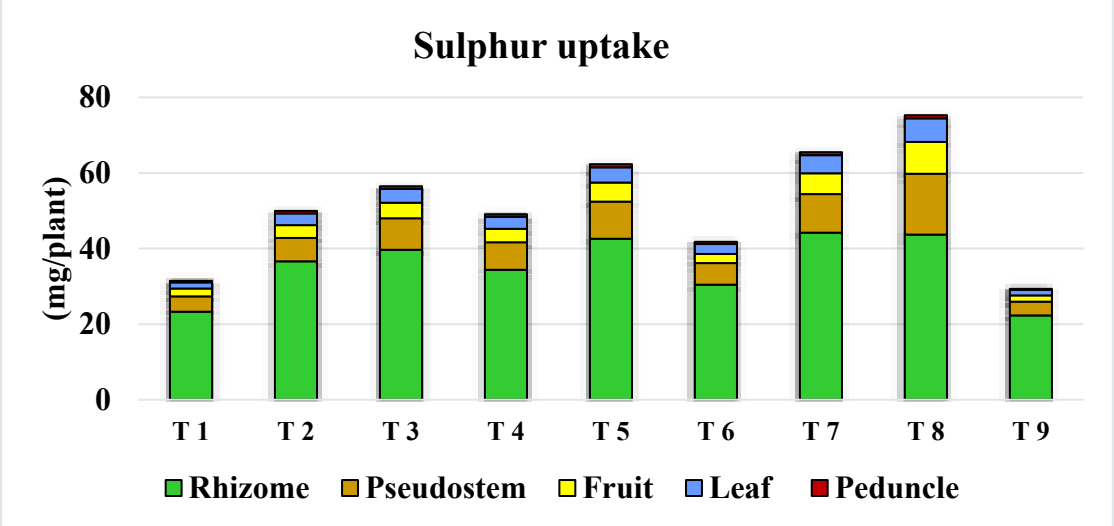

Fig.27 Total S uptake in different plant parts at harvest

Table. 4.65. Treatment effect on Ca uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	7.44	12.00	0.62	31.19	3.81	55.05
T_2	10.94	15.85	0.77	38.33	4.78	70.67
T_3	10.76	16.79	0.84	44.36	4.90	77.65
T_4	11.70	15.95	0.92	42.94	4.73	76.24
T_5	10.82	17.32	0.92	43.59	4.81	77.46
T_6	11.65	21.30	0.85	39.72	4.22	77.73
T_7	10.93	20.17	0.84	41.35	4.73	78.01
T_8	12.35	25.65	1.03	49.68	6.39	95.10
T_9	6.32	11.64	0.49	27.31	2.79	48.54
C.D.	**NS**	**1.46**	**0.09**	**5.83**	**1.04**	**6.18**

Mg uptake

Mg uptake by different plant parts as well as the total uptake was significantly influenced by the treatments. Mg content was maximum in leaf in treatment T_7 found to be on par with T_2, T_4, T_5 and T_8. In psuedostem maximum was in T_8, in peduncle maximum was in T_6, in rhizome it was in T_8 found to be on par with T_2, T_3, T_4 T_5 and T_7. In fruit, maximum uptake was in T_6 on par with T_8. Maximum total uptake was in T_8 on with par T_4, T_5 and T_7. Minimum was in control in all plant parts. Total uptake was also minimum in T_9 (table 4.66) & (Fig.26).

Table. 4.66. Treatment effect on Mg uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	1.68	8.19	0.18	20.51	2.30	36.01
T_2	2.60	10.68	0.21	25.73	2.70	45.48
T_3	2.34	11.42	0.24	26.54	2.96	47.38
T_4	2.65	11.24	0.24	28.14	2.85	48.21
T_5	2.73	11.81	0.25	30.26	2.90	50.30
T_6	1.99	12.85	0.39	20.43	4.49	43.39
T_7	2.80	13.36	0.25	32.70	3.16	54.72
T_8	2.44	15.90	0.29	34.84	4.03	59.09
T_9	1.20	7.33	0.13	16.22	1.74	28.32
C.D.	**0.40**	**1.93**	**0.05**	**11.15**	**0.82**	**11.29**

S Uptake

Pooled results of data show that total S uptake as well as S uptake by different plant parts was significantly influenced by treatments. However S uptake by peduncle was not significantly influenced by nutrient sources. Total uptake, uptake by leaf, pseudostem and fruit was maximum in treatment T_8. In rhizome the maximum value were recorded from T_7 which was on par with T_3, T_5 and T_8. Lowest value was recorded from control (table 4.67) & (Fig.27).

Table. 4.67. Treatment effect on S uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	1.62	4.09	0.41	23.27	2.06	31.46
T_2	3.10	6.18	0.67	36.64	3.37	49.96
T_3	3.63	8.36	0.74	39.67	4.11	56.49
T_4	3.18	7.31	0.71	34.37	3.52	49.10
T_5	4.03	9.84	0.84	42.60	5.02	62.32
T_6	2.62	5.74	0.60	30.43	2.41	41.79
T_7	4.78	10.21	0.84	44.20	5.50	65.53
T_8	6.22	16.09	0.84	43.68	8.44	75.28
T_9	1.42	3.64	0.33	22.33	1.65	29.36
C.D.	**1.38**	**2.03**	**NS**	**5.30**	**1.22**	**8.71**

Fe uptake

Fe uptake in leaf was maximum in treatment T_8 on par with T_2, T_3, T_4 and T_5. Uptake by pseudostem, rhizome and fruit was also maximum inT_8. In rhizome T_8 was on par with T_3 and T_5. Total uptake was highest in T_8 on par with T_5. Minimum values for uptake by plant parts and total uptake was recorded from control. S uptake by peduncle was not significant (table 4.68)& (Fig.28).

Table. 4.68. Treatment effect on Fe uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	3.42	8.49	0.22	57.28	1.45	70.87
T_2	5.83	12.04	0.39	85.68	2.19	106.12
T_3	6.15	15.76	0.48	110.26	2.57	135.23
T_4	5.80	13.75	0.44	92.35	2.18	114.52
T_5	6.40	15.96	0.52	109.67	2.44	135.00
T_6	5.71	12.97	0.36	87.93	1.63	108.60
T_7	5.75	12.79	0.40	98.27	1.79	119.00
T_8	7.09	18.91	0.61	126.25	3.32	156.19
T_9	2.66	6.88	0.17	52.33	1.09	63.13
C.D.	**1.33**	**0.76**	**NS**	**26.37**	**0.46**	**29.27**

Manganese uptake

Manganese uptake values by different plant parts and total uptake was highest in treatment T_8. Mn uptake was significantly different in plant parts other than peduncle. Uptake by leaf in T_8 was on par with T_3 and T_6, in rhizome T_8 was on par with T_4, T_5 and T_6 and in fruit T_8 was on par with T_5 and T_6. Minimum uptake was observed from treatment T_9.Total uptake was also significantly different between the treatments. Maximum was recorded from T_8 and minimum from T_9 (table 4.69) & (Fig.29).

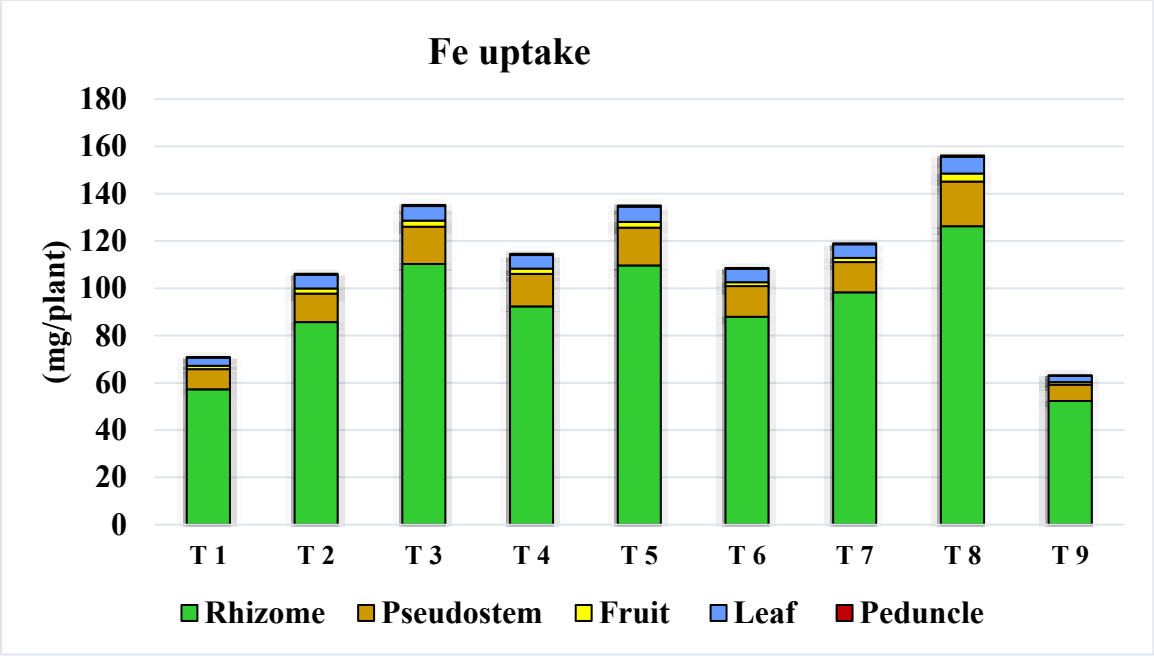

Fig.28 Total Fe uptake in different plant parts at harvest

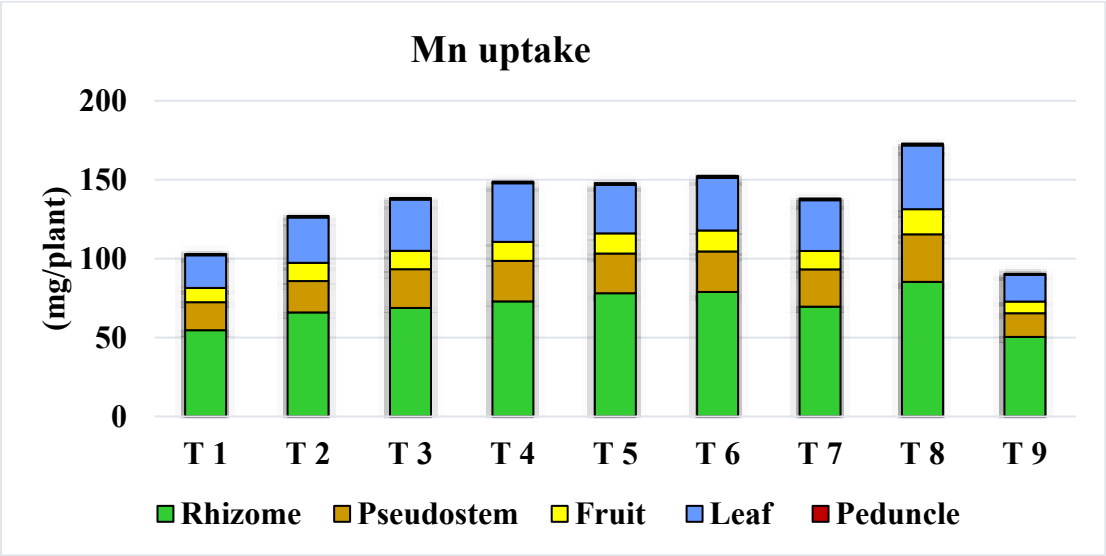

Fig.29 Total Mn uptake in different plant parts at harvest

Table. 4.69 Treatment effect on Mn uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	20.70	17.77	0.76	54.69	8.98	102.90
T_2	28.65	19.86	0.99	65.92	11.62	127.04
T_3	32.49	24.51	1.07	68.80	11.61	138.48
T_4	37.10	25.63	1.05	72.90	12.12	148.80
T_5	30.70	25.21	1.09	78.06	12.77	147.84
T_6	33.33	25.72	1.21	78.88	13.27	152.42
T_7	32.24	23.59	1.06	69.61	11.62	138.12
T_8	40.38	30.19	1.27	85.25	15.86	172.96
T_9	17.01	14.99	0.62	50.39	7.39	90.40
C.D.	**8.05**	**3.41**	**NS**	**16.01**	**3.33**	**21.78**

Zn uptake

Uptake of Zn was significantly different in pseudostem and rhizome. Maximum values were recorded from T_8 in both plant parts. Minimum values were recorded from T_9 in pseudostem and from T_1 and T_9 in rhizome. T_8 was on par with T_6 in pseudostem (table 4.70)& (Fig.31).

Table.4.70 Treatment effect on Zn uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	0.07	0.71	0.02	0.85	0.12	1.77
T_2	0.13	0.99	0.03	1.23	0.16	2.54

T_3	0.10	0.97	0.03	1.22	0.15	2.48
T_4	0.10	0.90	0.03	1.07	0.16	2.26
T_5	0.09	0.90	0.02	1.14	0.15	2.31
T_6	0.11	1.03	0.03	1.20	0.14	2.50
T_7	0.10	0.87	0.03	1.20	0.14	2.33
T_8	0.11	1.19	0.03	1.51	0.18	3.03
T_9	0.06	0.61	0.01	0.85	0.09	1.62
C.D.	**NS**	**0.18**	**NS**	**0.27**	**NS**	**NS**

Cu uptake

Copper uptake by individual plant parts was not significantly different between treatments. However significant difference was observed in total uptake which was maximum in T_8 and minimum in T_9 (table 4.71) & (Fig.30).

Table. 4.71. Treatment effect on Cu uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	0.03	0.20	0.01	0.44	0.11	0.79
T_2	0.05	0.24	0.01	0.54	0.13	0.97
T_3	0.05	0.29	0.01	0.62	0.14	1.12
T_4	0.05	0.28	0.01	0.60	0.14	1.09
T_5	0.04	0.26	0.01	0.55	0.12	0.98
T_6	0.05	0.26	0.01	0.55	0.12	0.99
T_7	0.04	0.24	0.01	0.57	0.13	0.99

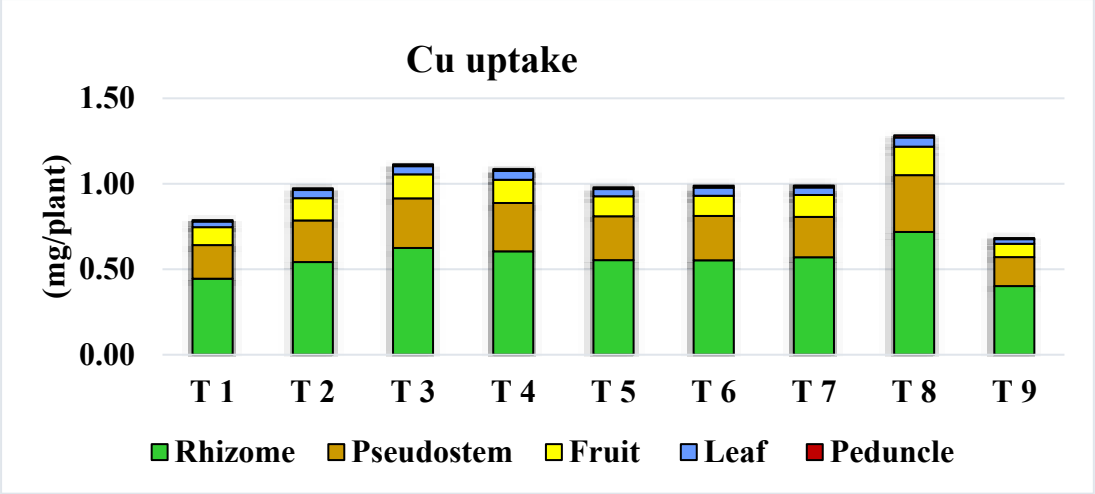

Fig.30 Total Cu uptake in different plant parts at harvest

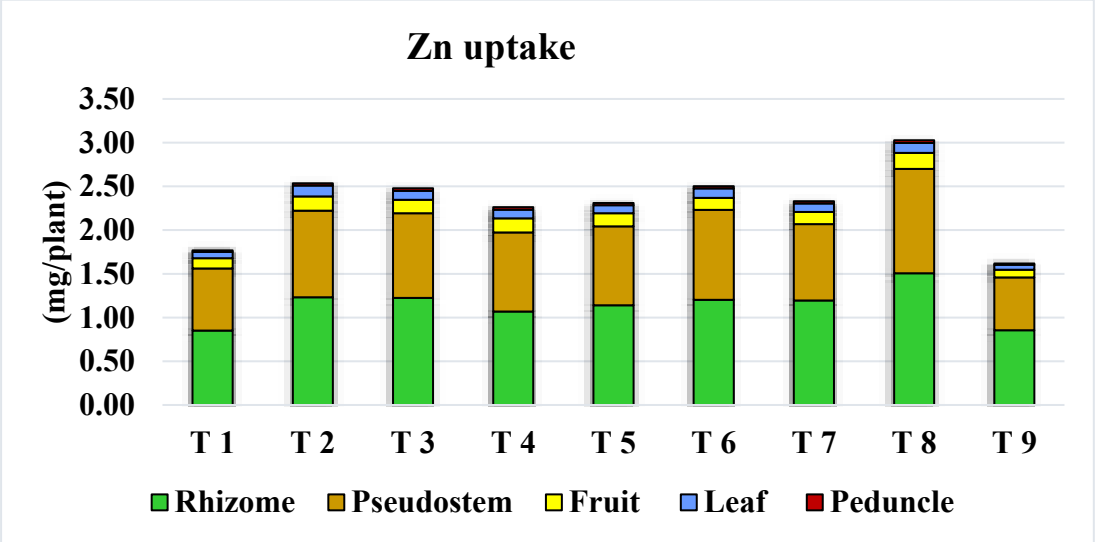

Fig.31 Total Zn uptake in different plant parts at harvest

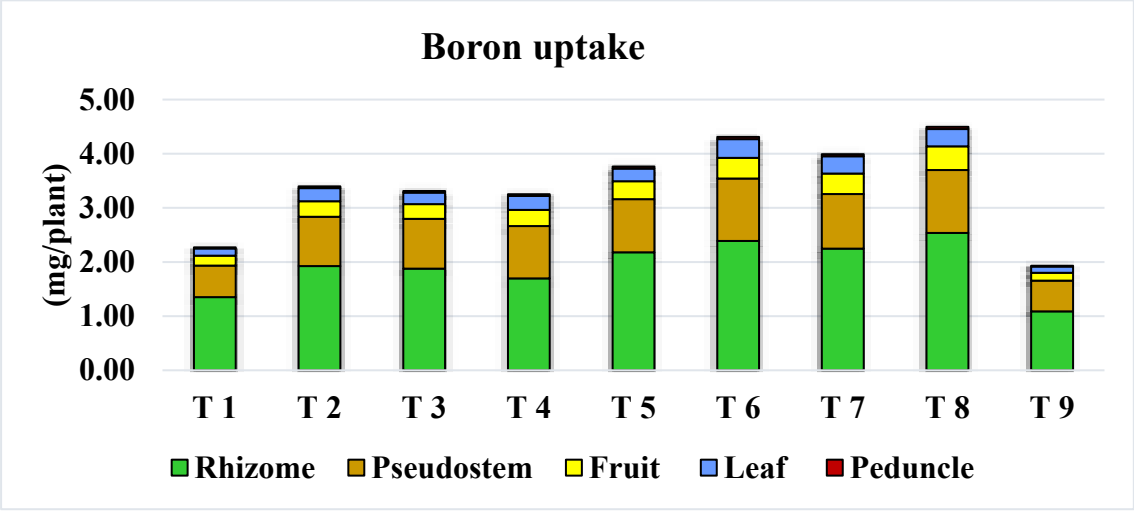

Fig.32 Total B uptake in different plant parts at harvest

T_8	0.05	0.33	0.01	0.72	0.17	1.29
T_9	0.03	0.17	0.01	0.40	0.08	0.68
C.D.	**NS**	**NS**	**NS**	**NS**	**NS**	**0.15**

B uptake

Total uptake boron and uptake by pseudostem and rhizome were significantly different between the treatments. T_8 recorded highest values for total uptake and uptake by pseudostem and rhizome. T_8 was on par with T_4, T_5, T_6 and T_7 for B uptake in pseudostem and with T_2, T_3, T_5, T_6 and T_7 in rhizome. T_8 was on par with T_5, T_6 and T_7 in total B uptake. Minimum values were recorded from T_9. (table 4.72) & (Fig.32).

Table. 4.72. Treatment effect on B uptake in different plant parts

Treatment	Leaf	Pseudostem	Peduncle	Rhizome	Fruit	Total uptake
T_1	0.13	0.58	0.02	1.35	0.18	2.27
T_2	0.24	0.91	0.03	1.93	0.29	3.40
T_3	0.21	0.92	0.03	1.88	0.27	3.31
T_4	0.26	0.97	0.03	1.70	0.30	3.25
T_5	0.23	0.98	0.04	2.18	0.33	3.76
T_6	0.35	1.15	0.04	2.39	0.38	4.31
T_7	0.32	1.01	0.04	2.25	0.38	3.99
T_8	0.32	1.16	0.04	2.54	0.44	4.50
T_9	0.12	0.57	0.01	1.09	0.15	1.93
C.D.	**NS**	**0.19**	**NS**	**0.76**	**NS**	**0.90**

4.16 Correlations between the different characters

Correlations were worked out for growth, yield, quality, biochemical characters and soil properties and nutrient uptake (appendix-III).

Growth

Positive and significant correlations were recorded between plant height at 210 days with leaf number, pseudostem girth and leaf area index. It was negatively correlated with phyllocron. Number of leaves at bunching stage was positively correlated with pseudosem girth, leaf area index and negatively correlated with phyllocron. Psuedostem girth at 180 DAP was positively correlated with phyllocron and Leaf area index (Fig.33).

Yield

Bunch weight was positively and significantly correlated with number of hands, number of fingers, finger weight, finger length. Yield was also correlated positively with total biomass, LAI at 210 DAP and with number of leaves at 210 DAP. Bunch weight was negatively correlated with phyllocron 180 DAP (Fig.34).

Correlations were also worked out between the yield per plant and the soil properties. Positive correlations were obtained between yield per plant and N, P, K, Ca, Mg, S, Zn, Cu, B, content of the soil. Yield was also positively correlated with soil properties like pH, organic carbon content, CEC, Bulk density, and Dehydrogenase enzyme activity.

Fruit quality

Fruit quality parameters and sensory characters were also found to be correlated. Overall acceptability of ripe fruits was found to be positively correlated with protein, crude fibre and tannin content of mature fruits.

Positive correlations were also noticed between overall acceptability of ripe fruits and TSS, total sugars, reducing sugars and B-carotene content. Overall acceptability was also significantly and positively correlated with taste of fruits.

Taste of ripe fruits was positively correlated with TSS, carotene and crude fibre content (Fig.35).

Overall acceptability of chips was positively correlated with starch, protein, crude fibre and total dry matter content of mature fruits.

Shelf life of ripe fruits was significantly and positively correlated with starch, crude fibre, N, P, K, Ca and Mg content of fruits.

Soil properties

MBC was positively and significantly correlated with dehydrogenase, nitrogenase, organic carbon, available N, K, Mg, Fe, Zn, Mn and Cu. Dehydrogenase activity was positively correlated with organic carbon, available N, K, Ca, S, Fe, Mn and B. Nitrogenase activity was positively correlated with organic carbon, available N, Ca, Fe, Mn and B. No significant correlations were obtained between the microbial count and other soil properties.

Soil pH was positively correlated with N, P, Mg and S uptake. Soil organic carbon content was positively correlated with N, P, Ca, Mg, S, Zn, Cu and B uptake.

N, P, Mg, S and Cu uptake was positively correlated with nitrogenase activity.

Similarly positive correlations were obtained between N, P, Mg, S and Zn uptake and dehydrogenase activity (Fig.36).

Microbial biomass carbon was positively correlated with N and Ca uptake and Nitrogenase and Dehydrogenase activity. Positive correlations were obtained between nitrogenase and dehydrogenase activity.

Comparison of treatments with organic manures and integrated nutrient management for growth, yield, quality of Nendran banana and soil parameters

Observations recorded from treatments where organic manures alone were given viz: T_2, T_3, T_4, T_5 and T_8 were combined into one group and observation

recorded from treatments with integrated nutrient application viz: T_1, T_6 and T_7 were grouped separately as given table 4.71.

Table.4.73 Treatments details of organic and integrated nutrient management

Organic nutrient management **Treatments**	**Integrated nutrient management** **Treatments**
T_2: POP recommendation of KAU with organic manures (wood ash etc.) T_3: POP recommendation of KAU with organic manures (poultry manure etc.) T_4: Best treatment from AICRP trials at BRS, Kannara (*Trichoderma harzianum etc.*) T_5: Best treatment from AICRP trials at BRS, Kannara (*Trichoderma viridae etc.*) T_8 : Fertigation with organic sources	T_1 : POP recommendation of KAU for TC banana T_6: Modified POP recommendation of KAU including micro nutrients as per soil test. T_7 : Fertigation with inorganic manures (adhoc recommendation):

Comparison of the treatments with organic manures alone with integrated nutrient management was done using t test. Significant results are presented below (table 4.72).

Application of organic manures alone resulted in better bunch weight, number of hands in bunch, number of fingers, finger weight, finger length, fruit girth, total biomass production, starch, protein and crude protein of mature fruits. TSS, total sugars, reducing sugars, sugar acid ratio, ascorbic acid and B carotene content of ripe fruits were high in organic manure application. However delay in flowering as indicated by days for shooting was recorded when nutrients were applied in integrated manner.

Table.4.74 Comparison of organic and integrated group of treatments for yield and quality parameters

Parameters	Organic treatments	Integrated treatments
Bunch weight (kg)	9.86	8.95
Number of hands	5.84	5.64
Number of Fingers	56.67	52.57
Finger weight(g)	155.82	146.68
Finger length(cm)	25.49	24.65
Finger girth(cm)	14.53	12.83
Days for shooting	196.22	202.00
Total Biomass production (kg/plant)	61.20	58.59
Starch content(mg/g) of mature fruit	81.73	72.43
Protein content(mg/g)of mature fruit	9.83	8.40
Crude fibre (%) of mature fruit	3.43	3.19
TSS (^{o} brix) of ripe fruit	25.87	24.99
Total Sugars (%) of ripe fruit	16.72	15.88
Reducing Sugars (%) of ripe fruit	11.15	10.22
Ascorbic acid (mg/100g) of ripe fruit	35.86	34.00
Sugar acid ratio	41.11	38.64
β carotene content of ripe fruit (µg/100g)	559.35	488.17

Significant differences were obtained for various soil parameters which are summarised in table 4.73. T test results show that soil pH, electrical conductivity, organic carbon content, available, N, P, K, Mg, Iron, Copper, Zinc, Mn and boron were better in soils receiving organic manures alone. Similarly

microbial biomass carbon, dehydrogenase and nitrogenase activity was also more in soils applied with organic manures alone.

Table 4.75 Comparison for soil properties of organic and integrated treatments

Parameters	Organic group of treatments	Integrated group of treatments
Soil pH	5.21	4.79
EC (dSm^{1})	0.91	0.25
Organic carbon (%)	0.92	0.72
Aggregate stability (mm)	48.18	30.91
CEC (c mol/kg of soil)	13.39	14.23
Available N (kg/ha)	308.83	258.31
Available P (kg/ha)	55.64	54.22
Available K (kg/ha)	217.52	209.03
Available Mg (mg/kg)	81.59	74.07
Available Iron (mg/kg)	37.38	28.16
Available Cu (mg/kg)	1.57	1.26
Available Zn (mg/kg)	42.18	31.59
Available Mn (mg/kg)	41.60	31.59
Available B (mg/kg)	0.51	0.40
MBC (µg/g of soil)	151.84	116.47
Dehydrogenase activity (mg TPF/day/kg of soil)	30.30	18.04
Nitrogenase activity (C_2H_4/g/hour n moles)	50.80	30.91

Total uptake of nutrients in organic and integrated nutrient management system was compared and significant results are shown in table. Uptake of N, Ca, S, Fe, Mn, Zn and Cu was higher in organic system of cultivation of banana significantly compare to integrated system (table 4.74).

Table.4.76 Comparison of organic and integrated treatments for nutrient uptake

Parameters	Organic treatments	Integrated treatments
N uptake	114.50	100.04
Ca uptake	79.41	70.26
S uptake	58.63	35.60
Fe uptake	139.40	99.48
Mn uptake	147.0	131.14
Zn uptake	2.52	2.20
Cu uptake	1.08	0.92

There was no significant difference in organoleptic characters of ripe fruits and chips between the organic and integrated nutrient management group of treatments

4.17 Experiment II

Quality analysis of fruits of banana Musa (AAB) 'Nendran' from farmers field

Details of the farmers collected from different panchayaths under the conventional system of banana cultivation and organic system of banana cultivation. The details are given as Appendix- IV and Appendix V and Plate.12

Range of values obtained for the different parameters are presented in tables from 4.75 to 4.79.

Differences were prominent in the case of shelf life of fruits, biochemical characters and fruit quality characters**.**

Table.4.77 Range of values for fruit characters

Character	**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

Table.4.78 Range of values for biochemical characters of ripe fruits

Character	**Conventional system**	**Organic system**
TSS (^{o} 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

Plate 12. Survey of organic and conventional farmers

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

Table.4.79 Range of values for organoleptic evaluation of ripe chips

Character	**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.4.80 Range of values for organoleptic evaluation of banana chips

Character	**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

Table.4.81 Range of values for soil analysis

Character	**Conventional system**	**Organic system**
pH	4.6 – 5.4	4.9 – 6.5
EC (dSm^1)	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 ($kg\ ha^1$)	170.32 – 304.92	175.43 – 332.37
P ($kg\ ha^1$)	181.87 – 266.25	190.96 – 256.71
K ($kg\ ha^1$)	186.98 – 222.73	195.66 – 258.57
Ca ($mg\ kg^1$)	350.87 – 500.48	368.41 – 545.53
Mg ($mg\ kg^1$)	13.52 – 15.58	14.26 – 18.69
S ($mg\ kg^1$)	23.98 – 29.74	25.18 – 29.86
Fe ($mg\ kg^1$)	29.06 – 36.92	31.67 – 36.50
Cu ($mg\ kg^1$)	1.09 – 1.80	1.19 – 2.16
Zn ($mg\ kg^1$)	31.50 – 41.61	33.08 – 46.17
Mn ($mg\ kg^1$)	37.71 – 45.53	41.18 – 51.93
B ($mg\ kg^1$)	0.41 – 050	1.29 – 1.55

Comparison was done between the observations recorded from conventional fields and organic field. Significant difference obtained as per the test is presented in the table 4.80.

Shelf life of fruits, starch content of mature fruits, fibre content of mature fruits, TSS of ripe fruits, sugar acid ratio and ascorbic acid content of ripe fruits were significantly different between the conventional system and organic system of banana cultivation. Shelf life of fruits, starch and fibre content of mature fruits were better in organic fields. Ripe fruit colour, flavour and overall acceptability was better from organically cultivated crops. Similarly chips prepared from organically cultivated fields had better flavour, texture, taste and overall acceptability.

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.

Table.4.82 Comparison of observations from conventional and organic fields

Character	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
EC (dS/m^{-1})	0.33	0.22
Organic carbon (%)	0.22	0.74
BD (g/cm^3)	1.57	1.216
WHC (%)	46.0	50.24

Discussion

5. DISCUSSION

5.1 Experiment I

The research results obtained in the study on Effect of different sources of nutrients on quantitative and quality characters of banana *Musa* (AAB) 'Nendran' conducted during 2017-18 and 2018-19 at Banana Research Station, Kannara are discussed in this chapter. The study aimed to elucidate the response of banana *Musa* (AAB) 'Nendran' in terms of growth, yield and quality to nutrient sources. Nutrient sources included organic manures alone, integrated nutrient management and control without manures and fertilisers. Results of the study showed that the vegetative growth, yield and quality of banana were influenced by the different nutrient sources in both the years.

5.1.1 Effect of nutrient sources on growth parameters

Vegetative growth of banana was not influenced by different sources of nutrients in early stage in both the years but later differences were recorded between the treatments. Observations were recorded from 30 days after planting. Plant height, number of leaves and psuedostem girth showed significant differences from 90 DAP. Since the planting material used was tissue culture plants growth in early stages was delayed. Results showed that till the plants attained bunching stage plant height was higher in organic treatments. Similar results were obtained for psuedostem girth. There was significant difference in pseudostem girth between the treatments throughout the growth stages of Nendran banana. Among the treatments, treatment T_8 resulted in better growth of plants.

Observations recorded on number of leaves produced showed that there was no significant difference between organic and integrated nutrient management. There was no significant difference in leaf area index also. Early leaf production was also noticed in treatment T_8 as indicated by the observations on phyllocron. Growth was delayed in control where no manures and fertilizers were given as evidenced from the observations recorded. In

general more number of leaves per plant was recorded in both the years in organic treatments.

Plant growth parameters like plant height, pseudostem girth and number of leaves were positively correlated. Phyllocron was negatively correlated with plant height and leaf number.

Mustaffa *et al*. (2004) reported that there was significant improvement in growth parameters with application of organic manures in banana varieties Rasthali and Karpuravalli. Patil and Shinde (2013) reported that the maximum plant height (190.84 cm) and plant girth (81.34 cm) was obtained from treatment with 50% RDF + FYM+ *Azotobacter* (50 g/plant) + PSB (50 g/plant) + VAM (250 g/plant) in banana *cv.* Ardhapuri**.** Chattopadhayay *et al.* (1980) reported that increased level of nitrogen significantly increased plant height and girth in banana**.** Soorianathasundaram *et al*. (2000) found that in Nendran banana, plant height was higher when plants were supplied with 75 % of nitrogen as urea, than when supplied with N at 50 %; whereas, pseudostem girth was maximum in plants when the entire N was supplied as urea.

Athani *et al.* (2009) observed that plant growth parameters like pseudostem height, girth, number of functional leaves, leaf area and leaf area improved through *in situ* vermi composting in banana *cv*. Rajapuri.

Chlorophyll a, b and total chlorophyll was distinctly higher in treatment T_8 (fertigation with FYM) which was on par with treatments T_3 and T_5 where organic manures alone were given.

Fertigation with organic manures improved soil organic carbon and nutrient availability in banana (Kaswala *et al*., 2017). Decomposition of organic matter facilitate humus formation thus preventing leaching of nutrients. Fertigation with organic manures ensure better supply of nitrogen, magnesium and amino acid which are directly involved in chlorophyll synthesis. From the present study it could be seen that the leaf parameters and

chlorophyll level in banana leaves were better when organic manures alone was used compared to the use of manures and fertilisers in integrated manner. Nitrogen is the major constituent of proteins, amino acids and chlorophyll and the increased supply of nitrogen increase the synthesis.

Positive influence of nitrogen on plant growth, flowering and productivity in banana cultivars is reported from many studies (Arunachalam *et al*., 1976; Mustaffa, 1983). Ramaswamy and Muthukrishnan (1973) suggested that number of functional leaves increased with increase in nitrogen application. According to Chattopadhayay *et al*. (1980) increase in level of nitrogen significantly increased height and girth in banana. Soorianathasundaram *et al*. (2000) observed that in cv. Nendran, pseudostem girth was maximum in plants when the entire N was supplied as urea. In the present study, better response was obtained when N was applied as organic manures than through inorganic fertilisers.

Balakrishna *et al.* (2005) reported that increased leaf production may enhance photosynthesis and flowering stimulus, thus influencing early flowering as there was maximum leaf number at shooting stage. Venkatesan *et al*. (1985) suggested that among the various leaf parameters, the rate of leaf production (Phyllochron) is an important one and it should be at closer interval so that the vegetative phase is not extended unduly. According to Murray (1960), phyllochron is under the influence of mineral nutrition. Number of functional leaves is a good index for the nutritional status in banana and the rate of production of leaves is influenced by mineral nutrition. Any crop management practice should aim at reducing the crop duration without affecting the productivity. The shorter crop duration manifested by shorter vegetative cycle and bunch development phases in these treatments may be attributed to improved vegetative growth as well as availability of more photosynthates for the development of fingers in the bunch development phase.

Badgujar *et al.* (2010) recorded higher pseudostem height, pseudostem girth, total number of leaves, days taken to shooting and less number of days for harvesting with application of 20 kg FYM + 1 kg *neem* cake + 200: 40:200g NPK plant-1.

Application of 300g nitrogen in both the first and second crop recorded maximum pseudostem height and circumference at shooting stage and significantly reduced phyllochron in cv. Robusta (Pandey *et al,* 2005).

Sundararaju and Kiruthika (2009) found that application of *Paecilomyces lilacinus* 10g plant-1 + *neem* cake 100g plant^{-1} improved growth characters like pseudostem height, girth, number of leaves, number of roots, root length and root weight in cv. Robusta.

Pooled analysis of observations recorded from the two crops of banana showed that there was no significant difference between treatments in days to flowering. In the second year however, early flowering was noticed in organic treatments compare to inorganic treatments. Maximum number of days to flowering was recorded in control in both the years. Bhan and Muzumdar (1956) reported that shooting in banana was earlier with nitrogen (100g N/plant). Similar results were reported by Ramaswamy and Muthukrishnan (1974).

Days to harvesting or the total duration of crop was however significantly influenced by the treatments where the maximum number of days for harvesting 342.42 was recorded from control. Earliest harvesting could be made from treatment T_5 (300.97) which was on par with other organic management treatments and integrated nutrient management given as fertigation (T_7). There was delay of more than 40 days for harvest when no manures and fertilizers were given. Total duration of crop was less in second year than first year (fig. 5)

Bhan and Muzumdar (1956) found that shooting was earlier by about 31 days with lowest level of nitrogen (100g N/plant). Similar results were

reported by Ramaswamy and Muthukrishnan (1974). Flowering was delayed considerably with no nitrogen application (Kohli *et al,* 1984). The required net assimilation was presumably reached early in the plants receiving higher dose of nitrogen, thus hastening the process of initiation and emergence of inflorescence (Chattopadhayay *et al,* 1980; Israeli and Lahav, 1986; Ghosh *et al,* 1989; Singh *et al,* 1990; Praburam and Sathiyamoorthy, 1993; Parida *et al,* 1994; Hansan *et al,* 2001).

Bunch maturity period was less in second year in all the treatments. Selvamani and Manivannan (2009) reported that integrated supply of nutrients to plants led to reduction in crop duration, which was similar to results reported by Naresh and Anamika (2005), in banana. Arunachalam *et al* (1976) reported that nitrogen shortened maturation period by 14 days and time from planting to shooting by 10 days, thus, reducing the entire crop cycle by one month in Cavendish banana. According to Soorianathasundaram *et al,* 2000, plants receiving 100 % N as urea were the earliest to shoot (265 days), while, reduction in supply of inorganic N delayed shooting markedly in cv. Nendran

Nutrient sources influenced total biomass production of banana significantly in both the years in the present study. Biomass of male bud, peduncle and rhizome was not affected significantly by nutrient sources in Nendran banana. Total biomass production was lowest in control where no manures and fertilizers were supplied.

Higher biomass production was recorded in plants that received nutrients from organic sources compared to integrated nutrient management and control. It could be due to better supply of nutrients like nitrogen, potassium and micronutrients which directly influenced the vegetative growth and finally total biomass production.

Among all the treatments, rhizome contributed maximum to the total biomass production in both years.

Combined application of NPK (100%) along with 10kg FYM plant-1 and Azospirillum and Phosphate solubilizing bacteria 25g plant1 resulted in increase in pseudostem height, girth, yield attributes, minimum days to flower and lesser total crop duration (Bhalerao *et al*., 2009). Similar results were reported by Mustaffa *et al* (2004); Bhalerao *et al.* (2009), Hazarika and Ansari (2010); Badgujar *et al.* (2010) and Barakat *et al.* (2011) in banana.

5.1.2 Effect of nutrient sources on yield characters

Significant differences were observed between all the treatments with respect to yield and its attributing characters.

The mean bunch weight was influenced significantly by organic and inorganic sources of nutrients. Fertigation with organic sources of nutrients resulted in the production of heavier bunches in both years. Yield from organic treatments increased in second year (Fig.6).

Maximum bunch weight was recorded from treatment T_8 which was on par with organic management as well as integrated management either when need based fertilisers were given or fertilizers were given as fertigation. POP recommendation of KAU with integrated nutrient management gave only lower yields. Reduction in yield was recorded when no manures and fertilizers were given.

Influence of nutrients on yield attributing characters were observed. No variation was observed between treatments on number of hands but number of fingers were found to be significantly influenced by the treatments. Finger number was high in organic treatments and low in control. Finger characters like finger length and girth were not significantly different between the treatments. Finger weight was however significantly different. Among the yield attributing characters, number of fingers and finger weight contributed for the difference in bunch weight between the treatments. Influence of different sources of nutrients on other physical attributes of the fruit was also studied. Peel thickness of fruits was not significantly influenced but the pulp

to peel ratio was significantly influenced by the treatments. Pulp to peel ratio was higher in all treatments other than T_1 and control where T_1 is the POP recommendation for TC banana. Yield attributing character like number of hands is specific to varieties which could be the reason for similar results from all treatments.

The total number of fingers per bunch was influenced significantly by nutrient sources in both the years. More total number of fingers was recorded in organic group of treatments compared to integrated nutrient management and control. Finger length and finger girth of Nendran banana were not influenced by organic and inorganic sources of nutrients in both the years.

Nitrogen application increased the number of hands, number of fruits and weight of fruit in cvs. Dwarf Cavendish, Giant Cavendish, Robusta and Lacatan (Arunachalam *et al,* 1976), Giant Governor (Venketasan *et al,* 1985) and in Karpura Chakrakeli (Ghosh *et al,* 1989). Application of 150 to 260g N plant-1 in banana cv. Robusta registered vigorous plant growth, early flowering, highest bunch weight and yield (Randhawa *et al* 1973; Kotur and Mustaffa, 1984; Kohli *et al*, 1984; Mustaffa, 1988). According to Nair *et al* (1990), application of 400g N in four splits increased fruit length up to 26.6cm in Nendran banana. According to Soorianathasundaram *et al* (2000) application of 100% nitrogen as urea recorded heaviest bunches (10.80 kg) in cv. Nendran.

Herath *et al.* (1977) reported that cattle manure along with cattle-shed washings and slurry applied @ 8.25t ha^{-1}at every four months increased yield attributes in banana. Mustaffa *et al.* (2004) studied the influence of different organic manures on *cvs*. Rasthali and Karpuravalli and concluded that application of 2.5kg compost + 1kg vermicompost + 1kg *neem* cake + 2.5kg poultry manure at 3rd, 5th and 7th month after planting recorded maximum values for yield parameters. Application of organic amendments such as farmyard manure, green leaves, wood ash, neem cake and other oil cakes produced bunches weighing 25- 30kg as compared to 10-12kg under normal

production systems in Chengalikodan (Menon *et al.*, 2004). Pushpakumari *et al* (2008) revealed that application of coir pith compost increased bunch weight (18.9t ha^{-1}) compared to application of FYM (17.4 t ha^{-1}), poultry manure (17.9t 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 + green manure + *neem* cake 1.0kg + bio-fertilizer) on *cv*. Grand Naine and found lesser yield of banana over that with INM practices. Thomas (2009) elucidated that oil cakes from *neem, marotti,* castor, groundnut and mustard markedly influenced yield in banana owing to their higher nutrient content. 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.

Yield was significantly and positively correlated with number of hands, number of fingers, finger weight and finger length. Yield was also correlated positively with total biomass, LAI at 210 DAP and with number of leaves at 210 DAP. Bunch weight was negatively correlated with phyllocron 180 DAP.

Significant positive correlations were obtained for yield with available N, P, K, Ca, Mg, S, Zn, Cu, and B content of the soil. Yield was also positively correlated with soil properties like pH, organic carbon content and dehydrogenase enzyme activity.

According to Herath *et al,* 1977, application of FYM along with slurry at four months interval increased yield attributes in banana.

Chattopadhaya and Bose (1986) reported that bunch size of banana was significantly increased by application of 240 and 480g K_2O per plant through soil in Dwarf Cavendish resulting in an increase in sugar content from 11-13.1% and TSS content. Mustaffa (1988) reported that with increase in level

of soil applied K from 0-400 g K_2O per plant in Dwarf Cavendish banana significantly reduced acid content of finger.

Geetha and Nair (2000) reported that the application of *Azospirillum*, cowpea as green manure and vermicompost *(Eudrilus euginiae*) in banana *cv.* Nendran resulted in increased bunch weight (13.15 and 12.19 % respectively) over control. Significantly higher content of quality parameters like total sugar, reducing sugar, non-reducing sugar, TSS, more shelf life, less acidity and maximum sugar: acid ratio was obtained by *in situ* vermicomposting at 1,25,000 worms per hectare in both plant and ratoon crop of banana *cv.* Rajapuri (Athani and Hulamani, 2000).

Mustaffa *et al.* (2004) studied the impact of various organic manures on c*vs*. Rasthali and Karpuravalli and reported that the application of 2.5 kg compost + 1 kg vermicompost + 1 kg *neem* cake + 2.5 kg poultry manure at 3, 5 and 7 month after planting recorded high values for yield characters. Patel *et al*. (2012) conducted an experiment where banana cv. Basrai plants treated with 10 kg FYM + 180 g N in organic form (Castor cake) + 90 g P_2O_5 + 180 g K_2O/plant produced highest fruit yield (17.50 kg/plant).

Thangaselvabai *et al*. (2009) reported that fertilizer dose consisting of 20 ton FYM, 5 kg Azospirillum and PSB/ ha, 250 g neem cake / plant+ 200:35:330 g NPK / plant with foliar application of micro nutrients increases quality of fruit in banana. Thangaselvabai *et al*. (2009) reported that application of higher level of nitrogen and Azospirillum along with 100g inorganic N produced higher yield (19kg/plant) of better quality fruits with cost benefit ratio 2.41 and recorded minimum days for shooting (272days). Similarly application of inorganic N (200g/plant) in 4 split also increased the quality of banana.

Effect of nutrient application through drip irrigation has been studied extensively. However, limited studies have been conducted on fertigation with organic manures. Under drip irrigation, banana plants flowered 15 days

earlier and recorded higher yields with higher finger, hand and bunch weight as compared to basin-irrigation (Hedge and Srinivas, 1991). Fertigation proved successful in commercial banana cultivars like Robusta (Mahalakshmi *et al*., 2000), Nendran (Pandey *et al*., 2001) and Ney Poovan with fertilizer and water economy. Fertigation can save 20 to 30 % on fertilizer while improving yield and quality compared to conventional fertilizer application (Srinivas, 1996).

The effect of organic and inorganic sources of nutrients in pulp to peel ratio of fruits was significantly influenced. Pulp peel ratio of ripe banana fruits was significantly higher in the organic treatments. The fruit characters like peel thickness of ripe fruits and days to ripening were not influenced significantly with nutrient sources in both the years.

Dinesh *et al*. (2012) observed that application of 50% RDF (150g N:60 g P: 155 g K/plant/crop cycle) + application of N: P: K in the ratio 3:2:1 at vegetative stage and 1:3:2 at flowering stage and 2:1:3 at fruit development stage resulted in maximum pulp: peel ratio(2.68) in Monthan banana.

Shelf life of banana fruit was not influenced with nutrient sources during first year but in the second year organic and inorganic nutrition in banana significantly influenced shelf life of banana fruits. Shelf life of fruits was extended in organic treatments compared to integrated and control treatments. Organic management in general delayed ripening and improved shelf life as evidenced from the results. Shelf life of fruits improved in second year (Fig. 8).

The shelf life of mango fruit was influenced significantly due to INM treatment reported by Talang, *et al*. (2017). The treatment T_2 (T_1+Zn+B+Mn+Ca), T_6 (half of T_1 + 50 kg FYM+ Azospirillum 250 g), T_7 (half of T_1 + 50 kg FYM +Azotobacter 250 g) and T_9 (half of T_1 + 50kg FYM + *Pseudomonas fluorescens* 250 g) resulted in maximum period of storage (>15 days) at room temperature. On the other hand the control treatment

having full dose of NPK only T_1 reduced the storage or shelf life (9.9 days) of fruits.

Trivedi *et al*. (2012) investigated the response of guava varieties with the application organic manures, inorganic fertilizer and biofertilizer and found that Allahabad Safeda recorded higher TSS. Application of biofertilizer recorded higher fruit yield and available phosphorus content in the soil. Marathe *et al.* (2012) reported that application of FYM, vermicompost, wheat straw and green manuring with sun hemp as singly or in combination with inorganic or biofertilizer like Azotobacter and PSB resulted in positive correlation between quality and fruit yield and leaf micronutrient contents in sweet orange and saved 25% dose of organic manures or fertilizers.

5.1.3 Effect of nutrient sources on fruit quality characters

Fruit quality parameters like TSS content, total sugars, reducing sugars, ascorbic acid and sugar acid ratio of ripe fruits were influenced significantly with nutrient sources.

Starch and protein content of mature fruits, TSS, sugar acid ratio, β-carotene and crude fibre content were high in organic management. Highest starch content was noticed in plants receiving fertigation with organic manures. It was noticed that the biochemical attributes like tannin content, total dry matter and moisture content of mature fruit and titrable acidity of ripe fruits were not influenced significantly by nutrient sources.

Quality parameters were lower in control. Starch, ascorbic acid and β-carotene content were low in treatment T_1 also.

Results obtained by Mustaffa *et al.* (2004) showed that in banana *cv.* Rasthali and Karpuravalli plants when applied with 2.5 kg compost + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure at 3, 5 and 7 months after planting, resulted in fruits with maximum TSS (29.40^0 B and 32.20^0 B), titrable acidity (0.59 % and 0.61 %), sugar - acid ratio (49.8 and 52.8), total sugars (25 % and 26.3 %) and low starch (3.2 % and 3.4 %)

contents respectively. Thangaselvabai *et al*. (2007) reported that the application of biofertilizers enhanced the quality of banana. Medhi *et al.* (2007) reported that the application of mustard oil cake (10 kg/plant), bio fertilizers (*Azotobacter* and PSB) and K_2O (600 g/plant) enhanced the fruit quality (juice, TSS, Total sugar and ascorbic acid content. Dinesh and Pandey (2008) also reported that application of recommended fertilizers with organic manures increased the total sugars due to higher uptake of N and K by the plant and it also influenced the TSS and reducing sugars of fruits.

Ghosh *et al.* (2012) observed that highest TSS (14 °brix), reducing sugar (12%) and vitamin-c (12.5mg/100ml) content was recorded in pomegranate where FYM 20kg along with NPK (400:100:300g/year) was applied and associated with the foliar N/K ratio of 1:3. The fruit from organic fertilized plant showed maximum storage life. Kashyap *et al.* (2012) reported that maximum TSS, total sugars, non-reducing sugars and reducing sugar were recorded with the treatment of N-500g and K-500g per plant. The fruit with minimum yield, lowest TSS, total sugar, non-reducing and reducing sugars were obtained with higher doses of N and K (750:600g) application. Goswami *et al.* (2012) found that application of biofertilizer along with FYM+ half dose of recommended fertilizer (225g N: 195gP: 150gK) enhanced the quality of guava.

The effects of sources of nutrients on β-carotene content of ripe banana fruits was noticed significant between the treatments in the experiment. The improvement in β-carotene content was recorded in organic treatments alone. Highest β-carotene content was found in plants which received fertigation with organic sources.

Organoleptic evaluation of ripe banana fruits was done by five panellists in both the years. The sensory scores for appearance, colour of fruits were not different in the first year while the score for appearance and colour was varied in second year. Higher score for appearance and colour was recorded in organic group of treatments than integrated nutrient management and control.

Among all the sensory characteristics only taste score was influenced significantly both the years. The taste of ripe banana fruits was improved in plants grown under organic treatments compare to integrated nutrient application and control.

Sensory score for ripe fruits and banana chips prepared from mature fruits were high for organic nutrient management practices. Among the different sensory parameters, most important in the case of ripe fruits are taste and color which were higher in treatment T_8. Control had the minimum score for all sensory parameters. Overall acceptability was high in all treatments other than T_1 and control. Sensory score values for chips were high for organic nutrition as well as integrated nutrient management. However score values for overall acceptability of chips were less for treatment T_1 and control.

Result showed that overall acceptability of ripe fruits was positively correlated with protein, crude fibre and tannin content of mature fruits. Positive correlations were also noticed between overall acceptability of ripe fruits and TSS, total sugars, reducing sugars and β -carotene content. Overall acceptability was also significantly and positively correlated with taste of fruits. Taste of ripe fruits was positively correlated with TSS, carotene and crude fibre content.

Overall acceptability of chips was positively correlated with starch, protein, crude fibre and total dry matter content of mature fruits.

Shelf life of ripe fruits was significantly and positively correlated with starch, crude fibre, N, P, K, Ca and Mg content of fruits.

Suresh and Hasan (2001) evaluated the response of inoculation with Azospirillum and Phospho bacteria on fruit quality of banana (*Musa* AAA) cv. Giant Governor with nitrogen and potassic fertilizer. The result revealed that application of biofertilizer along with recommended doses of fertilizer proved most effective in improving fruit quality of banana.

In general, application of organic manures resulted in better quality fruits. *In-situ* green manuring with sunnhemp and mulching with banana residues improved fruit quality in terms of TSS, sugars, acidity and sugar:acid ratio (Sathyanarayana and Babu, 1992). Menon *et al.* (2004) observed that application of organic amendments, *viz.* FYM, green leaves, wood ash, neem cake and groundnut cake improved the quality of fruits and organic manures produced uniform golden yellow bunches at maturity, and fetched 4 to 5 times higher price in cv. Chengalikodan. Mustaffa and Kumar (2008) found that combined application of compost, vermi-compost, *neem* cake and poultry manure recorded maximum TSS, acidity, total sugars and starch content in Rasthali and Karpuravalli cultivars. Moniem *et al.* (2008) observed that application of 100 % RDF through FYM or banana compost registered values statistically on par as regard fruit quality parameters. In cv. Grand Naine, application of vermicompost (3kg plant^{-1}) and castor cake (3kg plant-1) produced superior quality fruits with shelf life (Patel *et al,* 2010).

Pandey *et al*. (2002) studied the performance of tissue culture banana *cv*. Robusta under different combination of N and K and reported that quality parameters like TSS, acid sugar ratio were best with 7 splits of 300 g N and 400 g K.

Reddy *et al*. (2012) reported that combined application of 50 % recommended dose of fertilizer in form of FYM + Azospirillum + PSB + Mycorrhiza + vermicompost showed high level of fruit quality parameters such as total carotenoids, lycopene, TSS and low levels of ascorbic acid content. Singh *et al*. (2012) reported that application of standard dose of inorganic fertilizer along with organic nutrient sources like oilcake, FYM increased the fruit yield and quality parameter like TSS, total sugar, vitamin C, total phenol content in aonla cv. NA-7.

5.1.4 Effect of nutrient sources on soil properties

Influence of treatments on soil parameters were evident from the results obtained. There was improvement in soil properties under organic crop nutrition. Organic and inorganic nutrition in banana significantly influenced soil pH in both the year. Soil pH was increased in organic group of treatments compared to control and integrated nutrient management. EC values were also high in general for integrated management and control. The cation exchange capacity of the soil was not significantly affected by nutrient sources in both the years. Aggregate stability was also high in treatment T_8 and T_3 while lowest was from treatment T_1.

Organic and inorganic sources of nutrient were not observed to influence bulk density of the experimental soil in both the years. Nutrient sources influenced water holding capacity of the rhizospheric soil significantly in the second year. Water holding capacity of the soil was improved in organic group of treatments compared to inorganic treatments and control. Granular nature of organic manures like vermicompost improve soil aeration, water holding capacity and thus root growth of banana. The use of poultry manure with Azospirillum, Azotobacter and P-solublizing bacteria biofertilizer for a soil cultivated with banana (*Musa paradisiaca,* AAA Simmonds), had improved plant performance and soil physical and biological properties (Maria *et al*., 2008).

Organic carbon of rhizosphere soil was affected significantly by nutrient sources in both the years. Organic carbon was high in T_8 and T_5 and lowest in T_9. Organic carbon values were low for integrated nutrient management which were on par with T_1, T_6 and T_7. Fertigation with organic manures resulted in improvement of organic carbon of the experimental soil. Use of organic sources of nutrients improved the organic carbon content in the soil. Soil organic carbon improved in the second year of the study (Fig. 15).

Mayadevi (2016) studied that the cultivation of banana caused a reduction in electrical conductivity of rhizosphere soils.

Higher EC was recorded in plants which received inorganic fertilizers which might be due to the increase in salt concentration due to presence of various ions like nitrates (Atiyeh *et al*., 2000).

Application of organic manures and amendments to soil increases crop yield by enhancing the latter's physical properties besides improving availability of nutrients, to the plant and organic carbon and cation exchange capacity of the soil. Soil physical characteristics such as texture, compaction and drainage influence banana growth and development, and limit the effective soil depth and aeration in the rhizosphere. Owing to their effect on water retention capacity, permeability and water-air-balance, presence of coarse fragments (above 15% by volume) is considered as a limiting factor for root growth in banana. Majumdar *et al.* (2002) reported that application of 50 % RDF along with10t ha^{-1} vermicompost improved soil porosity and reduced bulk-density of the soil. Mustaffa *et al* (2004) observed that application of organic manures (2.5kg compost + 1kg vermicompost + 1kg *neem* cake + 2.5kg poultry manure plant-1 at 3rd, 5th and 7th month after planting) improved soil physical-properties. The effect of organic farming practices in banana on soil quality improvement was due to increased cation exchange capacity, lesser bulk-density and, in turn, increased porosity (Mei *et al,* 2007). Singh *et al* (2000) found application of organic manures (FYM @ 330qha-1 + pongamia oil cake @ 8.30qha-1 + neem oil cake @ 8.30qh^{-1} + Sterameal @ 8.30qh-1 + rock phosphate @ 8.30qha-1 + wood ash @ 8.30qha-1) increased the physical properties and water holding capacity of the soil. Phirke and Mahorkar (2010) concluded that fortification of soil with organic manures like nitrogen fixers, phosphate solubilizing microbes, Vesicular Arbuscular Mycorrhizae (VAM) and bio-fertilizers not only increased soil porosity, but also infiltration of water in banana fields.

Significant difference was recorded for available nutrients *ie.* all major nutrients and for Fe, Zn and Mn. Treatment T_8 recorded higher values for all nutrients and lowest was from control.

Mineralizable nitrogen and phosphorus availability increased in treatments with organic manures. Lowest availability was noticed in treatment with no manures and fertilizers (control). Available K and organic carbon was high in treatment T_8 and T_5 and lowest in T_9. Organic carbon values were low for integrated nutrient management *viz.* T_1, T_6 and T_7. Calcium in the experimental soil was not influenced significantly with nutrient sources in both the years.

However, available Mg and boron were in the deficient range even in plots which received the nutrient sources as per soil test indicating the highly mobile behaviour of both the nutrients in soil.

Between the treatments, contents of the micronutrients were higher in organic treatments while lowest contents were recorded in control in both the years. The integrated use of organic manures like *Neem* cake, vermicompost, poultry manures, and wood ash increased the availability of micronutrients in organic treatments.

Available nutrient content was higher in the second year of study.

Availability of nutrients might be due to several factors influenced by the use of organic manures. Green manure legumes having symbiotic association with Rhizobium can be an important source of nitrogen and other nutrients. The rhizobium legume association with cowpea can fix 300 kg N/ha in a single crop season (Mustaffa and Kumar, 2008).

Soil population of bacteria, fungi and actinomycetes were high in organic nutrient management and were low either in control or integrated nutrient management. Similarly microbial biomass carbon, nitrogenase and dehydrogenase activity was high in treatment T_8 and lowest in treatment T_1. Nitrogenase activity was low in treatment T_6, T_7 and control. Dehydrogenase values were high in treatments T_4 and T_5 and low in treatments T_2, T_3, T_6, T_7 and T_9. Enzyme activity was high in organic manure application and lesser in integrated nutrient management and without any manures and fertilisers.

The soil microbial biomass carbon was significantly influenced with the use of different nutrient sources. Higher MBC was recorded in plots supplied with organic manures with *in situ* green manuring. Among the various treatments, fertigation with organic manures along with *in situ* green manuring was significantly superior to inorganic treatments in enriching the soil with high content of MBC. Mustaffa *et al.* (2003) also reported that there was significant improvement in various soil properties in which banana plants treated with distillery sludge, vermicompost, neem cake and poultry manure. The quantity and quality of organic sources of nutrients are the most important factors affecting microbial biomass and community structure (Cerny *et al.,* 2008).

Mayadevi (2016) revealed that the production of vermicompost in planting pits could manifest a 24 percent increase in MBC of soil. Mayadevi (2016) also reported that the highest microbial counts was recorded in the soils treated with vermicompost prepared using native earthworms. The sustained supply of nutrients and organic matter in the rhizosphere of vermicompost treated soils provide energy sources to microbes and thereby encourage their proliferation (Khaddar and Yadav, 2006).

Dehydrogenase activity was improved in treatments in which plant received organic manures with *in situ* green manuring and treatments with fertigation along with organic sources of nutrients. Dehydrogenase activity is an index of biological activity of soil. The dehydrogenases activity was the highest in organically treated plots. The greater biological activity coupled with stabilization of extracellular enzymes through complexation with humic substances through organic manures might be the reason for continuous availability of substrate for enzymes (Adak *et al.*, 2014).

Organic and inorganic nutrient sources significantly influenced nitrogenase activity in rhizosphere soils in both the years. The nitrogenase enzyme activity was improved in organic group of treatments than integrated

nutrient management and control. Nitrogenase activity improved in the second year.

Total microbial counts of soil

The total viable counts of fungi were analysed after the crop and significant difference were observed between the treatments. Total counts were recorded more in organic group of treatments. The highest fungal counts were recorded in fertigation with organic manures with *in situ* green manuring (T_8) in both the year. The use of organic manures significantly improved the viable cells of total fungi in organic group of treatments. Microbes act as transient nutrient sink and MBC is that living pool of C which is fixed by microbial body cells present in the rhizosphere (Cerny *et al*., 2008) and serves as a valuable tool for understanding effects on soil properties and in the degree of soil degradation or soil quality.

Viable counts of bacterial cells was varied significantly in both the year. The integrated use of different organic manures along with bio control agents significantly increased the total bacterial counts in the soil compared to integrated nutrient application and control. The highest bacterial counts were observed in treatment with organic manures along with bio control agents.

In both the year significant difference was observed for viable counts of total actinomycetes. Viable counts of total actinomycetes were found more in organic group of treatments. Highest actinomycetes counts was recorded in treatment which received POP recommendation of KAU with organic manures with poultry manure in both the year. Significant role of organic sources of nutrients like vermicompost and bio control agents; native isolates were evident for total microbial counts of soils. Vermicmpost, FYM and poultry manures contain more counts of plant beneficial microbes such as nitrogen fixing bacteria, phosphate solubilizing bacteria, fungi, actinomycetes, and several other microbes capable of degrading a number of biopolymers such as cellulose and lignin (Singh and Mustaffa, 2009).

5.1.5 Effect of nutrient sources on plant nutrients and its uptake

Plant nutrients analysis

All the major and minor nutrients were analysed in the index leaf of banana at vegetative growth stages and in different plant parts at harvest during both the year. Nutrient content of different plant parts showed significant difference. Differences were more for micro nutrients. In leaf significant variation was recorded for K, Ca, Fe, Mn, Zn and B. In psuedostem, peduncle and rhizome significant difference was recorded for K, Fe, Mn, Zn and B, in fruit for Fe, Mn, Zn and B.

Nutrient uptake was also significantly different between the treatments. Treatment T_8 recorded higher values for uptake of nutrients by different plant parts as well as the total nutrient uptake. Minimum was from control.

Results showed that the K, Ca, Fe, Mn, Zn and B content of index leaf were significantly different between the treatments. However there was no significant difference between the treatments in N, P, Mg, S and Cu content of leaf. The highest K, Ca, Fe, Mn, Zn and B content were observed in plants which received fertigation with organic manures along with *in situ* green manuring in both the years.

The nutrient contents in different plant parts of banana varied with the use different nutrient sources and the nutrient contents were improved in organic group of treatments because of improved availability of nutrients in rhizospheric soil. The activity of dehydrogenase enzymes which improved biological oxidation of organic manures resulting in increased microbial populations. Selvamani *et al*. (2009) reported that integrated use of organic manures (FYM, Vermi compost and *neem* cake), biofertilizers (VAM, *Azospirillum*, PSB, *Trichoderma hazianum*) with inorganic fertilizers enhanced the leaf nutrient contents in banana leaf. Significantly high leaf N and K content during vegetative stage and harvesting stages and more micronutrients were found at harvest.

Ratan *et al* (2008) concluded that application of organic manures such as vermicompost, FYM, poultry manure, neem cake and its combinations recorded equal leaf nutrient status compared to100 % inorganic fertilizers in cv. Grand Naine.

Nutrient uptake

Nutrients sources influenced total nutrient uptake by banana plant significantly. Total N uptake was more in fertigation treatments compared to control. Rhizome accumulated more nitrogen and shared highest uptake in both the years. The effect of different nutrient sources on phosphorous uptake was significant in both the years. The total P uptake was also increased in fertigation treatments compared to control. P accumulation was more in the rhizome which was followed by pseudostem in both the years, but the P uptake in rhizome increased in the second year. Potassium uptake also followed the same pattern as that of nitrogen and phosphorus. The uptake of K was the highest among all various nutrients applied. In the first year, rhizome was the major reservoir of potash in various treatments. In the second year, the uptake of K in pseudostem and rhizome increased appreciably.

Nutrient uptake was higher in rhizome followed by pseudostem compared to other pant parts. (fig.22 to fig.31)

Marathe *et al*. (2012) reported that the integrated use of organic manures and inorganic fertilizers with green manuring improved the uptake of N, P, K, Ca and micronutrient in sweet orange.

The response on uptake of Ca, Mg and S was affected significantly by the sources of nutrients in banana plants. Higher uptake of Ca, Mg and S was noticed in organic group of treatments compared to control and integrated treatments. Fertigation with organic manures resulted in highest uptake of Ca, Mg and S in both the years. Total uptake of Mg increased in the second year compared to first year in all the treatments. The uptake of sulphur was also

more in plants which received organic treatments compared to inorganic treatments. The highest S uptake was noticed in plants which received fertigation with organic sources of nutrients.

The uptake of micronutrients by banana plants was significantly influenced with organic and inorganic nutrition. The uptake of micronutrients like Fe, Cu, Zn, Mn and B was higher in plants which received nutrients from organic sources. The use of organic manures like FYM, neem cake, poultry manures, vermicompost increased the availability of micronutrients in the soil. The uptake of micronutrients could have increased in organic treatments because of *in situ* green manuring followed in all these treatments. In both the year, the uptake of micronutrients like Fe, Mn, Cu and B was highest in plot that received fertigation with organic manures along with *in situ* green manuring. The activity of different soil enzyme like dehydrogenase and nitrogenase activity improved in plants receiving nutrients from organic sources. It could result in improvement of uptake of micronutrients in organic treatments. The Fe and Mn uptake was more in organic treatments due to the use of organic manures like FYM and poultry manure. The higher content of metals in FYM and poultry manures was attributed to the presence of soluble organics in formation of metal humic complexes.

Correlations between soil properties and nutrient uptake

Correlations were worked for the different soil properties. MBC was positively and significantly correlated with dehydrogenase, nitrogenase, organic carbon, available N, K, Mg, Fe, Zn, Mn and Cu content in soil. Dehydrogenase activity was positively correlated with organic carbon, available N, K, Ca, S, Fe, Mn and B. Nitrogenase activity were positively correlated with organic carbon, available N, Ca, Fe, Mn and B.

Soil pH was positively correlated with N, P, Mg and S uptake. Soil organic carbon content was positively correlated with N, P, Ca, Mg, S, Zn, Cu and B uptake.

N, P, Mg, S and Cu uptake was positively correlated with nitrogenase activity.

Similarly positive correlations were obtained between N, P, Mg, S and Zn uptake and dehydrogenase activity. Microbial biomass carbon was positively correlated with N and Ca uptake and Nitrogenase and Dehydrogenase activity. Positive correlations were obtained between nitrogenase and dehydrogenase activity.

No significant correlations were however obtained between the microbial count and other soil properties. The higher nutrient content in plant parts could be attributed to higher availability of nutrients facilitated by the activity of dehydrogenase and nitrogenase enzymes resulting in better uptake of nutrients leading to better growth and yield.

Benefit cost ratio

Cost of production was generally high for organic nutrient management. However BC ratio was high from organic systems of crop nutrition since the yield was either high or on par with integrated nutrient management. The price of banana grown under organic nutrient management was generally high. The price of banana is calculated at Rs. 35/kg of banana for integrated system and Rs. 50/kg of banana from organic nutrient management based on the assessment made from the existing markets. The high cost of production is hence compensated by the better price of the produce. The details are presented in Appendix-II.

Pest and disease

There was no serious pests and diseases attack on banana during both seasons. The infestation of Pseudostem weevil and Sigatoka spot incidence were noticed which could be managed though organic measures without seriously affecting the yield.

Comparison between organic and inorganic systems of nutrient application

Based on the results obtained a comparison of organic and inorganic group of nutrients was attempted through T test. Five organic management and three integrated management treatments were grouped and analysed for difference between the groups through t test. Treatment (T_9) control was excluded from the analysis.

Bunch weight, number of hands in bunch, number of fingers, finger weight, finger length, fruit girth, total biomass production, starch, protein and crude protein of mature fruits, TSS, total sugars, reducing sugars, sugar acid ratio, ascorbic acid and B carotene content of ripe fruits were high in organic manure application. Early flowering was also recorded from the same group of treatments.

Comparison of organic and inorganic group of treatments show that soil pH, electrical conductivity, organic carbon content, cation exchange capacity, available, N, P, K, Mg, Fe, Cu, Zn, Mn and boron were better in soils receiving organic manures alone. Similarly microbial biomass carbon, dehydrogenase and nitrogenase activity was also more in soils applied with organic manures alone. Bulk density of soil was low in soils receiving organic manures alone compared to integrated nutrients.

Total uptake of nutrients in organic and integrated nutrient management system was also compared. Uptake of N, Ca, S, Fe, Mn, Zn and Cu was higher in organic system of cultivation of banana significantly compared to inorganic system.

There was no significant difference in organoleptic characters of ripe fruits and chips between the organic and integrated nutrient management group of treatments

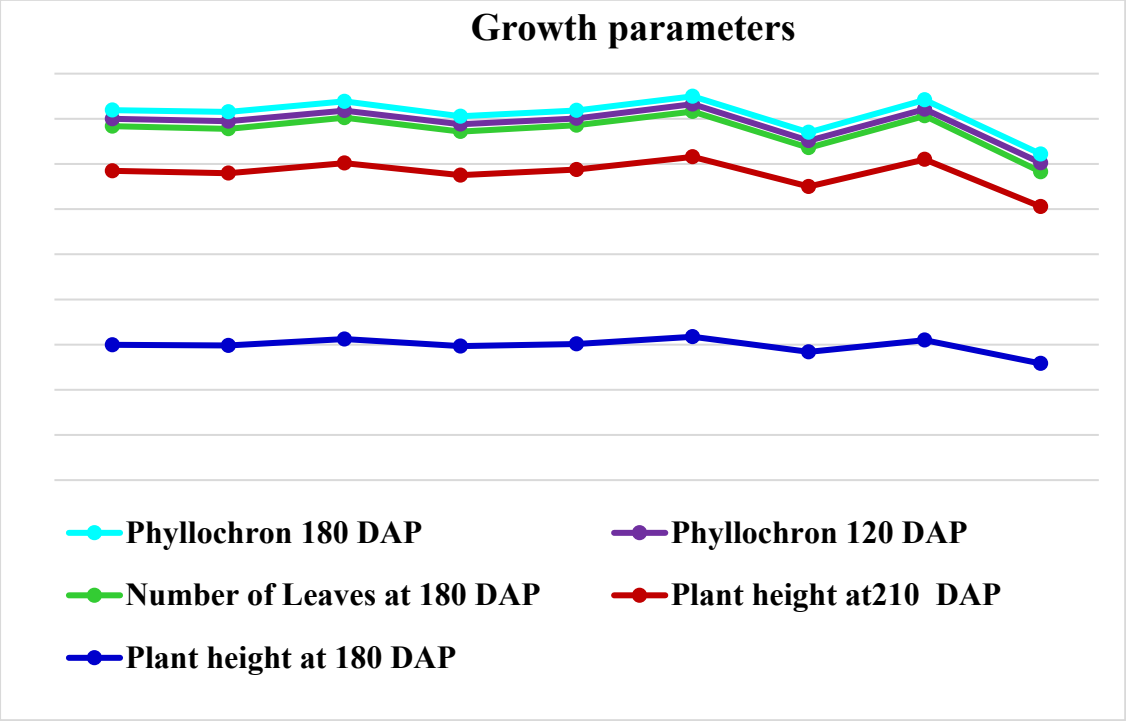

Fig.33 Correlation between different growth parameters

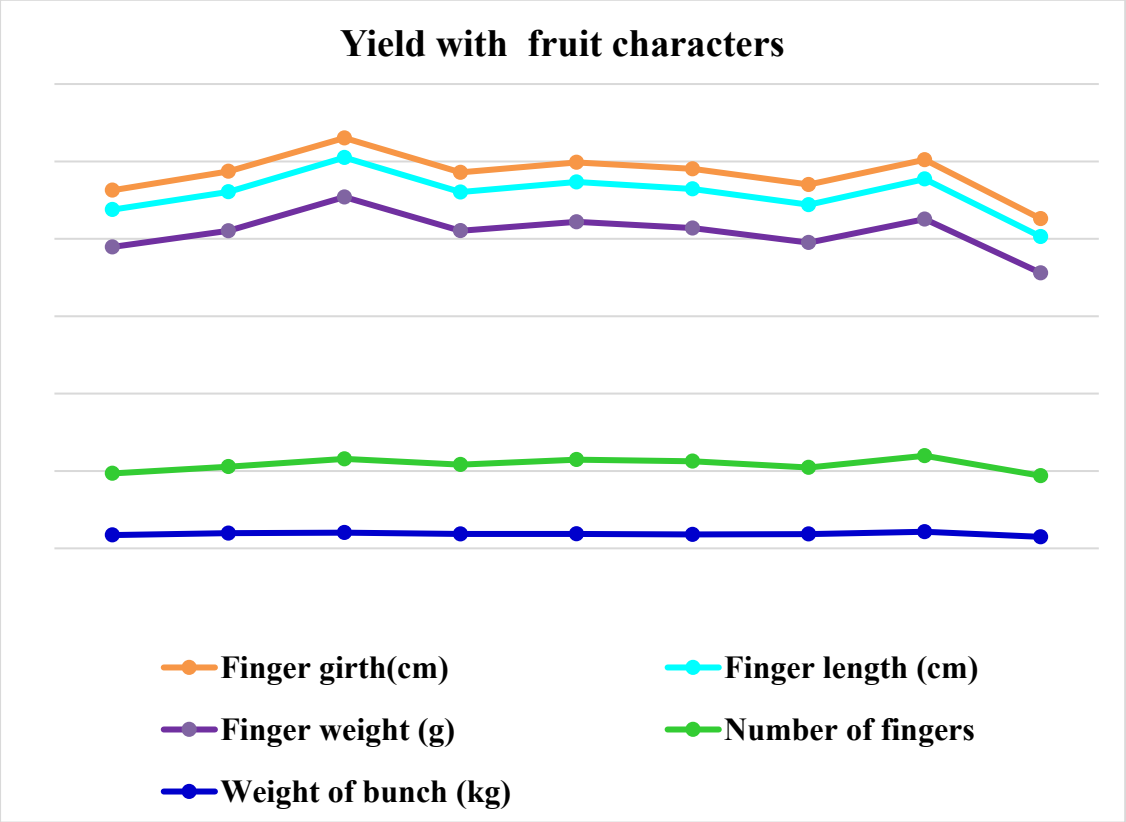

Fig.34 Correlation between yield and fruit characters

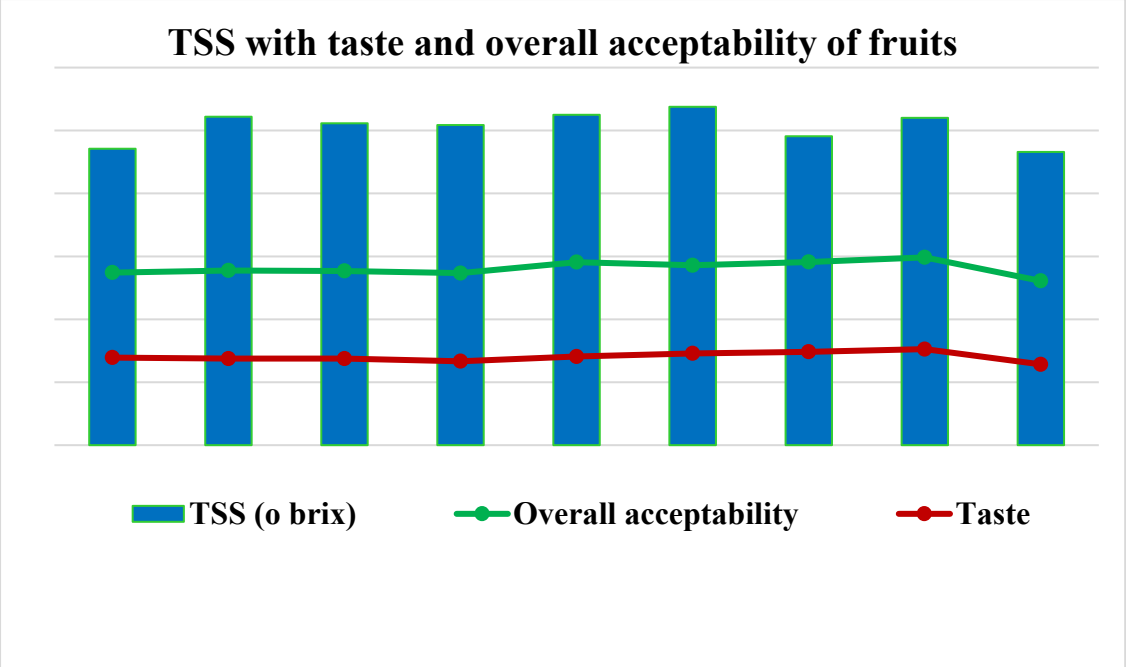

Fig.35 Correlation between TSS with taste and overall acceptability of fruits

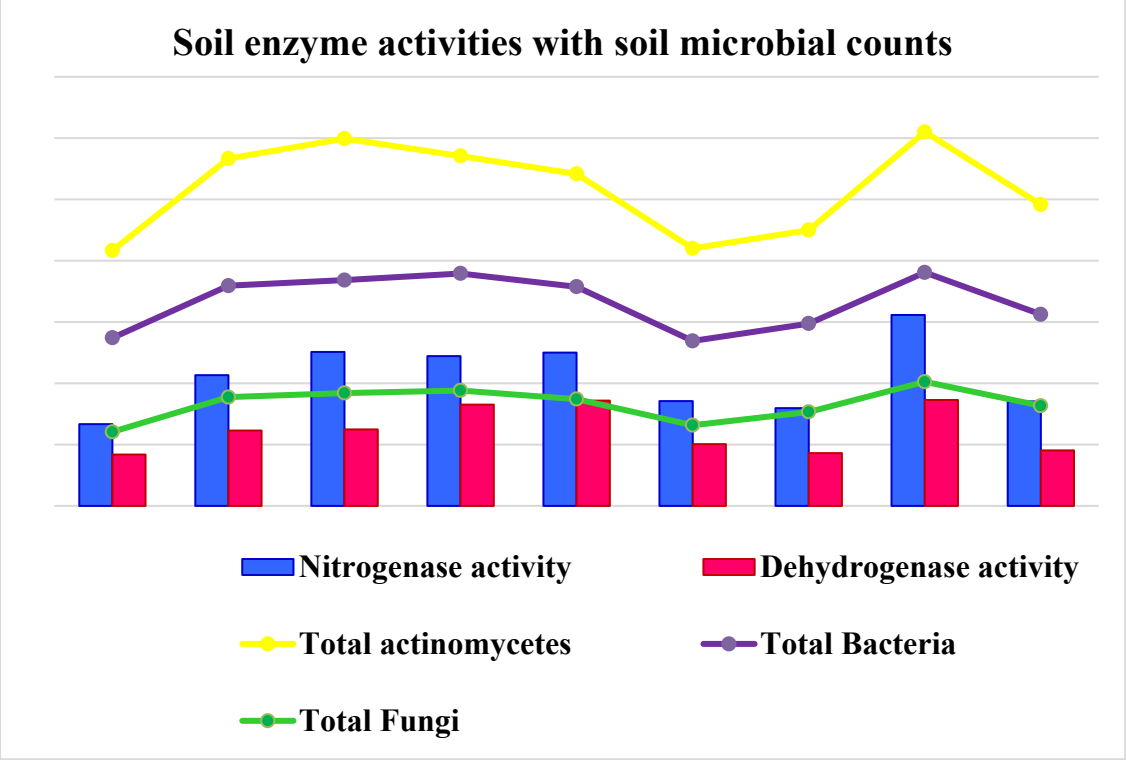

Fig.36 Correlation between soil enzyme activities and soil microbial counts

Experiment- II

Experiment no II was conducted to study the crop growth and yield of banana from farmers field and to compare with the results obtained from experiment I.

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.

Observations were made from five farmers each cultivating banana under conventional system and organic system. Shelf life of fruits, starch content of mature fruits, fibre content of mature fruits, TSS of ripe fruits, sugar acid ratio and ascorbic acid content of ripe fruits were significantly high in organic system of banana cultivation than conventional system. Ripe fruit colour, flavour and overall acceptability was better from organically cultivated crops. Similarly chips prepared from organically cultivated fields had better flavour, texture, taste and overall acceptability.

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 II was similar to the results obtained in experiment I which indicates that organic management of banana improves the fruit and soil quality parameters without compromising yield.

Conclusion

Banana requires high amount of nutrients throughout its growth period which is usually met through inorganic fertilisers and integrated nutrient application. From the study, it could be concluded that organic management of banana fields improved yield and quality of fruits. All the nutrient combinations under organic method were giving better results in terms of

growth, yield and quality. There is also improvement in the soil quality parameters as evidenced from the results of analysis of different soil and plant parameters. Organic measures could be recommended considering the improvement in yield, fruit quality as well the soil properties. Between the different treatments evaluated with organic manures alone, fertigation with FYM along with *in situ* green manuring was found to be superior in most of the characters studied. High B:C ratio was also recorded from this method of nutrient application. Hence this system can to be promoted for cultivation of Nendran banana considering the improvement in yield, quality and soil health.

Summary

6. SUMMARY

The research entitled “Response of banana *Musa* (AAB) 'Nendran' to nutrient sources” was conducted at Banana Research Station, Kannara, Thrissur, Kerala during 2017-2019. The study aimed to elucidate the response of banana *Musa* (AAB) 'Nendran' in terms of growth, yield and quality to nutrient sources and to compare the fruit quality of banana grown under organic and conventional systems in farmer’s field. The effects of nutrient sources on vegetative growth, yield and quality of banana are summarised in this chapter as following subheading and points.

Part-I. Effect of nutrient sources on growth characters

- Early growth stages of the crop was not observed to be influenced by different sources of nutrients but later, differences were recorded between the treatments. Plant height, number of leaves and psuedostem girth showed significant differences from 90 DAP. Observations were recorded from 30 days after planting. Results showed that till the plants attained bunching stage plant height was higher in organic treatments. Similar results were obtained for psuedostem girth also. There was significant difference in pseudostem girth between the treatments throughout the growth stage of Nendran banana.
- Leaf characters like number of leaves and leaf area index were not significantly different between organic and integrated nutrient management. Early leaf production was noticed in treatment T_8 as indicated by the observations on phyllocron. Growth was delayed in control where no manures and fertilizers. In general more number of leaves per plant was recorded in both the years in organic nutrient management..
- Growth parameters like plant height, pseudostem girth and number of leaves were positively correlated. Phyllocron was negatively correlated with plant height and leaf number. Among the treatments, treatementT_8

where organic manures alone were given (as basal and through fertigation along with *in situ* green manuring) resulted in better growth of plants.

- Chlorophyll production in the index leaf of banana was influenced with organic and integrated nutrition management. Chlorophyll a, b and total chlorophyll in the index leaf were distinctly higher in treatment T_8 (fertigation with FYM) found to be on par with treatments T_3 and T_5 where organic manures alone were applied in different combinations.

Part-II. Effect of nutrient sources on bunching and yield characters

- No significant difference was observed between treatments for days to flowering of banana. However, early flowering was noticed in organic treatments in the second year compared to integrated nutrient application. Maximum number of days to flowering was recorded in control in both the years.
- Days to harvesting or the total duration of crop was significantly influenced by the treatments. Earliest harvesting of bunches were recorded from treatment T_5 (300.97) found to be on par with other organic management treatments and integrated nutrient management where top dressing was given with fertilisers as fertigation (T_7). The maximum number of days for harvesting (342.42) was recorded from control (without manures and fertilizers) and a delay of more than 40 days was observed compared to other treatments.
- Significant differences were observed between all the treatments with respect to yield and its attributing characters.
- The mean bunch weight was influenced significantly by organic and integrated sources of nutrients. Fertigation with organic sources of nutrients resulted in the production of heavier bunches in both years. Yield from organic treatments increased in second year.
- Maximum bunch weight was recorded from treatment T_8 found to be on par with organic management as well as integrated management either when need based fertilisers were applied or fertilizers were given as

fertigation. POP recommendation of KAU with integrated nutrient management (T_1) gave only lower yields. Reduction in yield was recorded when no manures and fertilizers were applied.

- No significant variation was observed between treatments on number of hands per bunch but number of fingers per bunch was found to be significantly influenced by the treatments. Finger number was high in organic treatments and low in control.
- Finger characters like finger length and girth were not significantly different between the treatments. Finger weight was however significantly different. Among the yield attributing characters, number of fingers and finger weight contributed for the difference in bunch weight between the treatments. Peel thickness of fruits were not significantly influenced but the pulp to peel ratio was significantly influenced by the treatments. Pulp to peel ratio was higher in all treatments other than T_1 and control where T_1 is the POP recommendation for TC banana.
- Days to ripening also not influenced significantly with nutrient sources in both the years.
- Yield was positively correlated with number of hands, number of fingers, finger weight and finger length. Yield was also correlated positively with total biomass, LAI at 210 DAP and with number of leaves at 210 DAP. Bunch weight was negatively correlated with phyllocron 180 DAP.
- Significant positive correlations were obtained for yield with available N, P, K, Calcium, magnesium, sulphur, Zn, Cu, and B content of the soil. Yield was also positively correlated with soil properties like pH, organic carbon content and dehydrogenase enzyme activity.
- Nutrient sources influenced total biomass production of banana significantly in both the years in the present study. However, biomass of male bud, peduncle and rhizome was not affected significantly by nutrient sources in Nendran banana. Total biomass production was lowest in control where no manures and fertilizers were applied.

- Higher biomass production was recorded in plants that received nutrients from organic sources compared to integrated nutrient management and control. It could be due to better supply of nutrients like nitrogen, potassium and micronutrients which directly influenced the vegetative growth and finally total biomass production.
- Among all the treatments, rhizome contributed maximum to the total biomass production in both years.

Part-III. Effect of nutrient sources on fruit quality attributes

- Shelf life of banana fruit was not influenced with nutrient sources during first year but in the second year organic and integrated nutrition in banana significantly influenced shelf life of banana fruits. More shelf life was noticed in organic treatments compare to integrated and control treatments. Organic management in general delayed ripening and improved shelf life as evidenced from the results.
- Starch, protein, TSS, sugar acid ratio, β-carotene and crude fibre content were high in fruits under organic management. Highest starch content was noticed in plants receiving fertigation with organic manures. It was noticed that the biochemical attributes like tannin content and moisture content of mature fruit and titrable acidity of ripe fruits were not influenced significantly by nutrient sources.
- Quality parameters were lower in control. Starch, ascorbic acid and β-carotene content were low in treatment T_1 (integrated nutrient management) also.
- TSS content, total sugars, reducing sugars, ascorbic acid and sugar acid ratio of ripe were influenced significantly by nutrient sources. Results show that fertigation with organic manures improved fruit quality of Nendran banana in both the years.
- The effects of sources of nutrients on β-carotene content of ripe banana fruits was noticed to be significant. Highest β-carotene content was found in plants which received fertigation with organic sources.

- Organoleptic evaluation of ripe banana fruits was done by five panellists in both the years. The sensory scores for appearance, colour of fruits were not different in the first year while the score for appearance and colour was varied in second year. Higher score for appearance and colour was recorded in organic group of treatments than integrated nutrient management and control.
- Among all the sensory characteristics only taste score was influenced significantly both the years. The taste of ripe banana fruits was improved in plants grown under organic treatments compared to integrated treatments.
- Overall acceptability of ripe fruits was positively correlated with protein, crude fibre and tannin content of mature fruits. Significant positive correlations were also observed between overall acceptability of ripe fruits with TSS, total sugars, reducing sugars. Overall acceptability was also positively and correlated with taste of fruits. Taste of ripe fruits was positively correlated with TSS, carotene and crude fibre content. Sensory score for ripe fruits and banana chips prepared from mature fruits were high for organic nutrient management practices.
- Among the different sensory parameters, most important in the case of ripe fruits are taste and colour which were higher in treatment T_8. Control had the minimum score for all sensory parameters. Overall acceptability was high in all treatments other than T_1 and control. Sensory score values for chips were high for organic nutrition as well as integrated nutrient management. However score vales for overall acceptability of chips were less for treatment T_1 and control.
- Overall acceptability of chips was positively correlated with starch, protein, crude fibre and total dry matter content of mature fruits.
- Shelf life of ripe fruits was found to be significantly and positively correlated with starch, crude fibre, N, P, K, Ca and Mg content of fruits.

Part-IV. Effect of nutrient sources on soil properties

- There was improvement in soil properties under organic crop nutrition. Organic and integrated nutrition in banana significantly influenced soil pH in both the year. Soil pH was higher in organic group of treatments compared to control and integrated treatments. EC values were high in general for integrated management and control. The cation exchange capacity of the soil was not significantly affected by nutrient sources in both the years. Aggregate stability was also high in treatment T_8 and T_3 while lowest was from treatment T_1.
- No significant difference between treatments were recorded for bulk density of the experimental soil in both the years. Nutrient sources influenced water holding capacity of the rhizospheric soil significantly in the second year. Water holding capacity of the soil was improved in organic group of treatments compared to integrated treatments and control.
- Organic carbon content of rhizosphere soil was significantly influenced by nutrient sources in both the years. Organic carbon was high in treatments T_8 and T_5 and lowest in T_9. Organic carbon values were low for integrated nutrient management *viz.* treatments T_1, T_6 and T_7. Fertigation with organic manures and treatments with other organic sources of nutrients resulted in improvement of organic carbon of the experimental soil.
- Application of organic manures and amendments to soil increases crop yield by enhancing the latter's physical properties besides improving availability of nutrients to the plant. Significant difference was recorded for available nutrients for all major nutrients and for Fe, Zn and Mn. Treatment T_8 recorded higher values for all nutrients and lowest was from control.
- Mineralizable nitrogen and phosphorus availability increased in treatments with organic manures. Lowest availability was noticed in treatment with no manures and fertilizers (control). Available K and organic carbon was high in treatment T_8 and T_5 and lowest in treatment T_9. Calcium in the

experimental soil was not influenced significantly with nutrient sources in both the years.

- Between the treatments, contents of the micronutrients in soil were higher in organic treatments while lowest values were recorded in control in both the years. The integrated use of organic manures like *Neem* cake, vermicompost, poultry manures, and wood ash would have resulted in increased availability of micronutrients in organic treatments.
- Soil population of bacteria, fungi and actinomycetes were high in organic nutrient management and were low either in control or integrated nutrient management. Similarly microbial biomass carbon, nitrogenase and dehydrogenase activity was high in treatment T_8 and lowest in treatment T_1. Enzyme activity was high in organic manure application and lesser in integrated nutrient management and without any manures and fertilisers.
- The soil microbial biomass carbon was significantly influenced with the use of different nutrient sources. Higher MBC was recorded in plots supplied with organic manures with *in situ* green manuring. Among the various treatments, fertigation with organic manures along with *in situ* green manuring was significantly superior to integrated treatments in enriching the soil with high content of MBC.
- Organic and integrated nutrient sources significantly influenced nitrogenase activity in rhizosphere soils in both the years. The nitrogenase enzyme activity was improved in organic group of treatments than integrated treatments and control.
- The total viable counts of fungi were analysed and significant difference were observed by nutrient sources. Total counts were recorded more in organic group of treatments. The highest fungal counts were recorded in fertigation with organic manures with *in situ* green manuring (T_8) in both the years.
- Viable counts of bacterial cells varied significantly in both the years. The integrated use of different organic manures along with bio control agents significantly increased the total bacterial counts in the soil compared to

integrated nutrient application and control. The highest bacterial counts were observed in treatment with organic manures along with bio control agents.

- In both the years, significant difference was observed for viable counts of total actinomycetes. Viable counts of total actinomycetes were found more in organic group of treatments. Highest actinomycetes count was recorded in treatment (T_3) which received POP recommendation of KAU with poultry manure in both the years.

Part-V. Effect of nutrient sources on plant nutrients and its distribution

- Nutrient content of different plant parts showed significant difference. Differences were more for micro nutrients. In leaf significant variation was recorded for K, Ca, Fe, Mn, Zn and B. In psuedostem, peduncle and rhizome, K, Fe, Mn, Zn and B, in fruit for Fe, Mn, Zn and B. Nutrient content was more when FYM manure was continuously given through fertigation.
- Nutrient uptake was also significantly different between the treatments. Treatment T_8 recorded higher values for uptake of nutrients by different plant parts as well as the total nutrient uptake. Minimum was from control.
- All the major and minor nutrients were analysed in the index leaf of banana at vegetative growth stages, and in different plant parts at harvest during both the year. Results showed that the K, Ca, Fe, Mn, Zn and B content of index leaf were significantly different between the treatments. However there was no significant difference between the treatments in N, P, Mg, S and Cu content of leaf. The highest K, Ca, Fe, Mn, Zn and B content were observed in plants which received fertigation with organic manures along with *in situ* green manuring in both the years.
- Nutrients sources significantly influenced the K, Fe, Mn, Zn and B content of pseudostem but no significant difference in N, P, Calcium, magnesium, sulphur and Cu content of pseudostem was there between the treatments. Similarly, nutrient content in the leaf, fertigation with organic sources

improved the K, Fe, Mn and Zn content of Pesudostem. Fe, Mn, Zn and B content of fruits were significantly influenced by the nutrient sources. Primary and secondary nutrients, Zn and Cu content of fruits were not significantly different between the treatments. Nutrient sources significantly influenced the K, Fe, Mn, Zn and B content of peduncle. N, P. Calcium, magnesium, sulphur and Cu content of peduncle was not significantly varied between the treatments. Results showed K, Fe, Mn, Zn and B content of rhizome was significantly affected by organic and integrated sources of nutrient. However N, P, Calcium, magnesium, sulphur and Cu contents of rhizome were not significantly influenced.

- The nutrient contents in different plant parts of banana varied with the use different nutrient sources and the nutrient contents were improved in organic group of treatments because of it improved the availability of nutrients in rhizospheric soil. The activity of dehydrogenase enzymes which improved biological oxidation of organic manures was resulted due to increased microbial populations.
- Total N uptake was more in fertigation treatments compared to control. Rhizome accumulated more nitrogen and shared highest uptake in both the years. The effect of different nutrient sources on phosphorous uptake was significant in both the years. The total P uptake was also increased in fertigation treatments compare to control. P accumulation was more in the rhizome which was followed by pseudostem in both the years. Potassium uptake also followed the same pattern as that of nitrogen and phosphorus. The uptake of K was the highest among all various nutrients applied. In the first year, rhizome was the major reservoir of potash in various treatments. In the second year, the uptake of K in pseudostem and rhizome increased appreciably.
- The response on uptake of Ca, Mg and S was affected significantly by the sources of nutrients in banana plants. Higher uptake of Ca, Mg and S was noticed in organic group treatments compared to control and integrated treatments. Fertigation with organic manures resulted in highest uptake of

Ca, Mg and S in both the years. Total uptake of Mg increased in the second year compared to first year in all the treatments. The uptake of sulphur was also recorded more in plants receiving organic treatments compared to integrated treatments. The highest S uptake was noticed in plants receiving fertigation with organic sources of nutrients.

- The uptake of micronutrients by banana plants was significantly influenced by organic and integrated nutrition. In both the year, the uptake of micronutrients like Fe, Mn, Cu and B was highest in plot receiving fertigation with organic manures along with *in situ* green manuring. The use of organic manures like FYM, neem cake, poultry manures, vermicompost increased the availability of micronutrients in the soil. The activity of different soil enzyme like dehydrogenase and nitrogenase improved availability of nutrients from organic sources. The higher content of metals in FYM and Poultry manures was attributed to the presence of soluble organics in formation of metal humic complexes.
- Microbial biomass carbon was positively and significantly correlated with dehydrogenase, nitrogenase, organic carbon, available N, K, Mg, Fe, Zn, Mn and Cu content in soil. Dehydrogenase activity was positively correlated with organic carbon, available N, K, Ca, S, Fe, Mn and B. Nitrogenase activity was positively correlated with organic carbon, available N, Ca, Fe, Mn and B.
- Soil pH was positively correlated with N, P, Mg and S uptake. Soil organic carbon content was positively correlated with N, P, Calcium, magnesium, sulphur, Zn, Cu and B uptake. N, P, Mg, S and Cu uptake was positively correlated with nitrogenase activity. Similarly positive correlations were obtained between N, P, Mg, S and Zn uptake and dehydrogenase activity.
- Microbial biomass carbon was also positively correlated with N and Ca uptake.
- No significant correlations were however obtained between the microbial count and other soil properties.

- The higher nutrient content in plant parts could be attributed to higher availability of nutrients facilitated by the activity of dehydrogenase and nitrogenase enzymes resulting in better uptake of nutrients leading to better growth and yield.
- Cost of production was generally high for organic production. However B:C ratio was high from organic systems of crop nutrition since the yield was either high or on par with integrated nutrient management and better prices were obtained for fruits from crops raised under organic management.
- There was no serious pests and disease attack on banana during both seasons. The infestation of pseudostem weevil and sigatoka leaf spot incidence were noticed which could be managed though organic measures without seriously affecting the yield.
- Comparison of organic and integrated group of treatments was made through t test and it was observed organic manures application alone in banana resulted in better bunch weight, number of hands in bunch, number of fingers, finger weight, finger length, fruit girth, total biomass production.
- Fruit quality of Nendran banana fruit were improved with organic sources of nutrients.The quality attributes like starch, protein and crude protein of mature fruits. TSS, total sugars, reducing sugars, sugar acid ratio, ascorbic acid and B carotene content of ripe fruits were high in organic manure application. Delay in flowering as indicated by days for shooting was recorded when nutrients were applied in integrated manner.
- Soil pH, electrical conductivity, organic carbon content, cation exchange capacity, available, N, P, K, Mg, Iron, Copper, Zinc, Mn and boron were better in soils receiving organic manures alone. Similarly microbial biomass carbon, dehydrogenase and nitrogenase activity was also more in soils applied with organic manures alone.
- Total uptake of nutrients in organic and integrated nutrient management system was compared. Uptake of N, Ca, S, Fe, Mn, Zn and Cu was higher

in organic system of cultivation of banana significantly compare to integrated system.

- There was no significant difference in organoleptic characters of ripe fruits and chips between the organic and integrated nutrient management group of treatments.

Part-VI. Comparison of yield and quality of banana with farmer's field

- Experiment- II was conducted to study the crop growth and yield of banana from farmers' field and to compare with the results obtained from experiment I.
- Comparison was done between the observations received from conventional fields and organic field. Observations were made from five farmers each cultivating banana under conventional system and organic system.
- Shelf life of fruits, starch content of mature fruits, fibre content of mature fruits, TSS of ripe fruits, sugar acid ratio and ascorbic acid content of ripe fruits were significantly high in organic system of banana cultivation than conventional system.
- Ripe fruit colour, flavour and overall acceptability were better from organically cultivated crops. Similarly chips prepared from organically cultivated fields had better flavour, texture, taste and overall acceptability.
- 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 integrated fertilisers are used for cultivation.
- Results obtained in experiment II was similar to the results obtained in experiment I which indicates that organic management of banana improves the fruit and soil quality parameters without compromising yield.

Conclusion

- ❖ Banana requires high amount of nutrients throughout its growth period which is usually met through integrated fertilisers and integrated nutrient application. From the study, it could be concluded that organic management of banana fields improved yield and quality of fruits.
- ❖ All the nutrient combinations under organic method gave better results in terms of growth, yield and quality. There is also improvement in the soil quality parameters as evidenced from the results of analysis of different soil and plant parameters.
- ❖ Between the different treatments evaluated with organic manures alone, treatment where FYM was applied as basal and top dressing through fertigation with FYM was found to be superior in most of the characters studied. High B: C ratio was also recorded from this method of nutrient application. Hence this system can to be promoted for cultivation of Nendran banana considering the improvement in yield, quality and soil health.

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Appendix

Appendix-I Analysis of organic manures before planting each season

Characteristics	FYM		Vermicompost		Wood Ash		Poultry Manure		Neem cake	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
N (%)	0.72	0.68	3.12	3.68	0.82	0.66	3.47	3.56	3.43	3.40
P (%)	0.40	0.35	0.42	0.56	0.42	0.56	1.33	1.52	0.30	0.38
K (%)	0.78	0.75	1.73	1.52	0.80	0.85	1.12	1.25	1.25	0.98
Ca (mg kg^{-1})	85.53	82.18	348.35	288.13	122.26	116.47	167.23	182.63	256.65	247.68
Mg (mg kg^{-1})	47.80	43.56	152.45	147.83	63.49	82.67	78.52	75.12	98.25	106.28
S (mg kg^{-1})	0.69	1.23	1.23	1.32	0.52	0.86	0.56	1.23	0.76	0.85
Fe (mg kg^{-1})	0.18	0.32	0.28	0.26	0.13	0.17	0.37	0.42	0.35	0.52
Mn (mg kg^{-1})	0.37	0.32	0.68	0.65	0.32	0.35	0.52	0.83	0.43	0.67
Cu (mg kg^{-1})	2.09	1.68	2.15	1.92	1.05	1.05	1.19	1.12	1.23	0.95
Zn (mg kg^{-1})	22.80	21.25	1.26	17.56	0.40	0.68	1.07	2.83	0.85	1.06
pH	5.4	5.8	7.2	6.8	6.3	6.4	7.8	7.8	5.35	5.45
EC	4.65	3.88	1.83	1.95	1.06	1.12	1.08	1.05	4.65	3.28
Organic Carbon (%)	23.82	23.52	21.56	22.85	13.65	15.75	52.35	50.05	31.28	28.65
C: N ratio	33.08	34.59	6.91	6.21	16.65	23.86	15.09	14.06	9.12	8.43
Cd (mg kg^{-1})	15.75	13.25	13.17	23.29	18.15	19.80	121.28	123.26	39.28	48.50
Ni (mg kg^{-1})	23.25	18.50	12.35	17.22	12.35	13.51	36.87	42.50	112.17	105.52

Appendix-II Benefit cost ratio

Table. (a) Benefit cost ratio during first year

Treatment	Total yield (kg)	Total income (Rs.)	Total cost (Rs.)	B C Ratio
T1	136.44	4775.28	1815.70	2.63
T2	159.19	7959.33	2744.60	2.90
T3	160.88	8044.00	2822.46	2.85
T4	144.67	7233.33	2565.01	2.82
T5	143.85	7192.50	2514.86	2.86
T6	153.37	5367.83	1951.94	2.75
T7	131.00	4585.00	1554.24	2.95
T8	160.22	8011.00	2626.56	3.05
T9	114.13	3994.67	1650.69	2.42

Table. (b) Benefit cost ratio during second year

Treatment	Total yield	Total income	Total cost	B C Ratio
T1	136.24	4768.52	1753.13	2.72
T2	149.43	7471.63	2524.20	2.96
T3	149.99	7499.38	2466.90	3.04
T4	140.67	7033.65	2306.12	3.05
T5	149.83	7491.44	2539.47	2.95
T6	133.00	4655.00	1662.50	2.80
T7	155.50	5442.67	1755.70	3.10
T8	169.20	8459.95	2677.20	3.16
T9	116.56	4079.69	1631.88	2.50

Appendix –III

Correlation value of yield with growth, yield contributing attributes and soil properties

Plant height 210 DAP

Leaf No.	0.283
Psuedostem girth	0.404
LAI	0.476
Phyllocron	-0.291

No. of leaves at bunching stage

Psuedostem girth	0.568
LAI	0.922
Phyllocron	-0.273

Pseudostem girth at 180 DAP

LAI	0.568
Phyllocron	-.0.435

Bunch weight

No. of leaves 210 DAP	0.486
Phyllocron 210 DAP	0.361
Phyllocron 180 DAP	0.276
LAI 210 DAP	0.573
No. of hands	0.486
No. of fingers	0.361
Finger weight	0.276
Total biomass	0.573
Starch content	0.278
Protein content	0.591
Crude fibre content	0.277
Tannin content	0.494
Available N	0.549

Available P	0.314
Available K	0.351
Available Ca	0.480
Available Mg	0.521
Available S	0.562
Available Zn	0.473
Available Cu	0.595
Available B	0.287
CEC	0.285
Dehydrogenase activity	0.365
Soil pH	0.348
Organic Carbon	0.480
BD	0.370

Overall acceptability of ripe fruits

Protein content	0.287
Crude fibre content	0.309
Tannin content	0.525
TSS	0.376
Total sugars	0.323
Reducing sugars	0.457
B carotene	0.280
Taste of fruits	0.285

Overall acceptability of chips

Protein content	0.302
Crude fibre content	0.418
Tannin content	0.282
Starch content	0.353

Taste of ripe fruits

TSS	0.268
B carotene	0.261
Crude fibre	0.345
Sugar acid ratio	0.280

Shelf life of ripe fruits

Starch content	0.291
Crude fibre content	0.560
N	0.380
P	0.290
Ca	0.436
Mg	0.311

Microbial biomass carbon

Dehydrogenase activity	0.401
Organic carbon	0.574
Available N	0.289
Available K	0.302
Available Mn	0.500
Available Fe	0.300
Available Zn	0.426
Available Mn	0.500
Available B	0.344
N uptake	0.308

Dehydrogenase activity

Organic carbon	0.512
Available N	0.764
Available K	0.352
Available Ca	0.444
Available S	0.386
Available Fe	0.623
Available Mn	0.547
Available B	0.478
N uptake	0.397
P uptake	0.617
Mg uptake	0.649
S uptake	0.466
Zn uptake	0.464

Nitrogenase activity

Organic carbon	0.548
Available N	0.558
Available Ca	0.324
Available Fe	0.591
Available Mn	0.398
Available B	0.441
N uptake	0.315
P uptake	0.481
K uptake	0.649
S uptake	0.466
Cu uptake	0.341

Soil pH

N uptake	0.380
P uptake	0.529
Mg uptake	0.458
S uptake	0.445
Cu uptake	0.396

Soil organic carbon

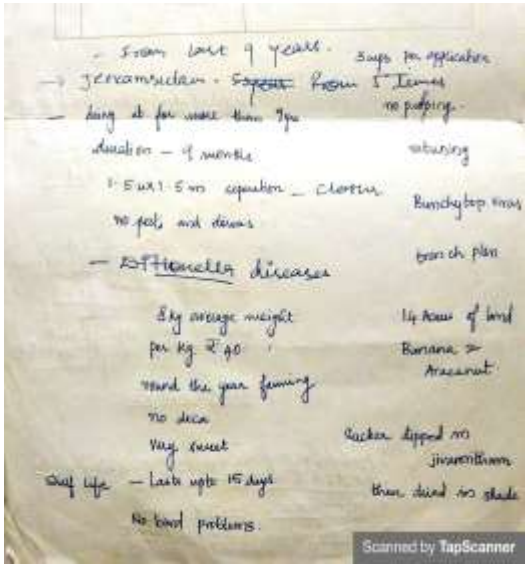
N uptake	0.428
P uptake	0.350
Ca uptake	0.351
Mg uptake	0.424
S uptake	0.437
Zn uptake	0.293
Cu uptake	0.484
B uptake	0280

Appendix –IV Details of inorganic farmers

Inorganic - 2

Quality analysis of fruits of banana Musa (AAB) 'Nendran' from farmers' field
(Questionnaire)

Sl. No	Question	Response
1.	Name and address of the farmer	Binu Varghese
2.	Location (Panchayat and district)	Panchayat - Thrissur
3.	Area under Nendran cultivation	1 Acre - 95000
4.	Land type and season	Red soil
5.	Planting material used	Suckers
6.	Spacing	2m x 2m c/c
7.	Details on manures and fertilisers applied	5 times
8.	Irrigation method and schedule	Sprinkler
9.	Marketing	Thrissur - Market
10.	Total no. of years under the system	12 years
11.	Cost of production	250000
12.	Price obtained	350000
13.	Pest and disease infestation	Leaf spot
14.	Crop protection measures	
15.	Any other information	



Appendix-V Details of organic farmers

Organic -1

Quality analysis of fruits of banana *Musa* (AAB) 'Nendran' from farmers' field
(Questionnaire)

Sl. No	Question	Response
1.	Name and address of the farmer	P S Surendran, Parangyanath (H), Minalur
2.	Location (Panchayat and district)	Minalur, Palakkad
3.	Area under Nendran cultivation	51 cent
4.	Land type and season	Red Soil
5.	Planting material used	Sucker C. changalikodan
6.	Spacing	2m
7.	Details on manures and fertilisers applied	Cowdung 15 kg/plant, Neem cake 4 kg/plant, Jeevamrith
8.	Irrigation method and schedule	Basin irrigation
9.	Marketing	Green Mydhri
10.	Total no. of years under the system	30 years
11.	Cost of production	60000 rs for 800 plants
12.	Price obtained	Rs 800 / Bunch
13.	Pest and disease infestation	Pseudostem weevil, Leafspot, Rhizome rot
14.	Crop protection measures	Vermiwash spray, Jeevamrith spray, [illegible]
15.	Any other information	Pseudostem trap, [illegible]

Organic -2

Quality analysis of fruits of banana *Musa* (AAB) 'Nendran' from farmers' field
(Questionnaire)

Sl. No	Question	Response
1.	Name and address of the farmer	P P Chandran, Pathukulangara (H) Kottekad p o Kuttur
2.	Location (Panchayat and district)	Kolazhy
3.	Area under Nendran cultivation	50 cent
4.	Land type and season	Red Soil, October – August
5.	Planting material used	Sucker
6.	Spacing	2m
7.	Details on manures and fertilisers applied	Cowdung 10 kg/plant, Neemcake 1 kg/plant, vermicompost 4 kg/plant
8.	Irrigation method and schedule	Basin irrigation
9.	Marketing	Kolazhy Market
10.	Total no. of years under the system	8 years
11.	Cost of production	Rs 300 / Plant
12.	Price obtained	Rs 500 / plant
13.	Pest and disease infestation	Pseudostem weevil
14.	Crop protection measures	Neem oil spray & Jeevamrith spray
15.	Any ot[her information]	

Organic -3

Quality analysis of fruits of banana *Musa* (AAB) 'Nendran' from farmers' field
(Questionnaire)

Sl. No	Question	Response
1.	Name and address of the farmer	Murali Sreenivasan, Arattupuzha, Kakkipalam, Valadkara
2.	Location (Panchayat and district)	Valadkara (Thrissur)
3.	Area under Nendran cultivation	14 Acre
4.	Land type and season	Red soil
5.	Planting material used	Sucker
6.	Spacing	2m × 2m
7.	Details on manures and fertilisers applied	Cowdung (15 kg), Jeevamritham, Groundnut cake (250 g), Neem cake (1 kg), Poultry (1 kg)
8.	Irrigation method and schedule	Chaal irrigation
9.	Marketing	Irinjalakuda Market
10.	Total no. of years under the system	12 years
11.	Cost of production	160000
12.	Price obtained	80000
13.	Pest and disease infestation	Pseudostem weevil, Panama wilt disease
14.	Crop protection measures	Neem oil spray
15.	Any other information	Pseudostem trap, Jeevamritham spray

Organic-4

Quality analysis of fruits of banana *Musa* (AAB) 'Nendran' from farmers' field
(Questionnaire)

Sl. No	Question	Response
1.	Name and address of the farmer	Stephen P Paul, Puthenpurackal house, Mulluthara corporation, Thrissur
2.	Location (Panchayat and district)	Thrissur, Thrissur corporation
3.	Area under Nendran cultivation	1 Acre, 650 plants
4.	Land type and season	Red soil
5.	Planting material used	Suckers
6.	Spacing	6 feet
7.	Details on manures and fertilisers applied	5 times, steamed – 1 kg, [illegible], Poultry manure – 3 kg
8.	Irrigation method and schedule	Basin irrigation
9.	Marketing	Thrissur
10.	Total no. of years under the system	15 years
11.	Cost of production	35000
12.	Price obtained	30000
13.	Pest and disease infestation	Pseudostem weevil
14.	Crop protection measures	Neem oil spraying
15.	Any other information	

Organic -5

Quality analysis of fruits of banana *Musa* (AAB) 'Nendran' from farmers' field
(Questionnaire)

Sl. No	Question	Response
1.	Name and address of the farmer	Sathyan P K, [illegible] madakkathara, PO Kuttikkad
2.	Location (Panchayat and district)	madakkathara
3.	Area under Nendran cultivation	–
4.	Land type and season	December
5.	Planting material used	Suckers
6.	Spacing	2 × 2
7.	Details on manures and fertilisers applied	FYM – 25 kg/plant, two times application
8.	Irrigation method and schedule	Manual irri
9.	Marketing	–
10.	Total no. of years under the system	
11.	Cost of production	
12.	Price obtained	
13.	Pest and disease infestation	
14.	Crop protection measures	3 spray [illegible] Neem oil &
15.	Any other information	the control of Pseudostem weevil

RESPONSE OF BANANA *Musa* (AAB) 'NENDRAN' TO NUTRIENT SOURCES

By

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ABSTRACT

Submitted in the partial fulfillment of the requirement for the degree of

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Abstract

Banana is the leading tropical fruit in the world market today with a highly organized and developed industry. Banana having a root system spread in the top 60 cm soil, is heavy feeder of nutrients and requires large quantities of nutrients for its growth, development and yield. Nutrient removal from soil by crops must be replenished. Under good management conditions and adequate supply of biofertilizers and organic manures, the nutrient removal can be replenished and soil physical, chemical and biological properties can be improved. Organic and inorganic sources of nutrients have significant influence on fruit quality and soil characteristics. The current agricultural policy emphasize a shift towards safe agricultural practices for which organic management is the best option. However the crop behaviour under organic and inorganic management needs elaborate studies. Hence the research entitled ‘Response of banana *Musa* (AAB) 'Nendran' to nutrient sources was formulated to elucidate response of banana in terms of growth, yield and quality to nutrient sources and to compare the fruit quality of banana grown under organic and conventional systems in farmer’s field.

The study revealed that vegetative growth of *Musa* Nendran banana was not influenced by different sources of nutrients in early stage in both the years but later differences were recorded between the treatments. Plant height, number of leaves and pseudostem girth showed significant differences from 90 DAP.

At bunching stage plant height and pseudostem girth were higher in organic treatments. There was significant difference in pseudostem girth between the treatments throughout the growth stage of Nendran banana. Among the treatments, T_8 resulted in better growth of plants.

Leaf characters like number of leaves and leaf area index were not influenced significantly between organic and integrated nutrient management. Early leaf production was also noticed in treatment T_8 as indicated by the

observations on phyllocron. Growth was delayed in control where no manures and fertilizers. In general more number of leaves per plant and lesser duration for leaf emergence was recorded in both the years in organic treatments.

Chlorophyll production in the index leaf of banana was influenced with organic and inorganic nutrition. Chlorophyll a, b and total chlorophyll in the index leaf were distinctly higher in treatment T_8 (fertigation with FYM) which was on par with treatments T_3 and T_5 where organic manures alone were applied.

Early flowering and early harvesting were observed in organic treatments. Higher total biomass production was recorded in organic treatments. Yield and yield attributing characters like bunch weight, number of finger, finger weight were highest in treatments with organic sources of nutrients. The mean bunch weight was influenced significantly by organic and inorganic sources of nutrients. Fertigation with organic sources of nutrients resulted in the production of heavier bunches in both years. Maximum bunch weight was recorded from treatment T_8 which was on par with other organic treatments as well as integrated management with fertilisers applied as fertigation as well as based on soil test results.

No significant variation was observed between treatments on number of hands per bunch and finger characters like finger length and girth. Peel thickness of fruits were not significantly influenced but the pulp to peel ratio was significantly influenced by the treatments. Pulp to peel ratio was higher in all treatments other than T_1 and control where T_1 is the POP recommendation for TC banana under integrated nutrient management.

Yield per plant was positively correlated with available N, P, K, Calcium, magnesium, sulphur, Zn, Cu, B, content of the soil. Yield was also positively correlated with soil properties like pH, organic carbon content, CEC, Bulk density, and Dehydrogenase enzyme activity.

Higher biomass production was recorded in plants that received nutrients from organic sources compared to integrated nutrient management and control.

Shelf life of fruits were improved in organic treatments. Fruit quality parameters like TSS, Total sugars, ascorbic acid and β carotene of ripe banana fruits were improved in organic treatments compare to inorganic system. Sensory score of ripe fruits and fruit chips were maximum in organic treatments. The taste of ripe banana fruits was improved in plants grown under organic treatments. Fertigation with organic manures (T_8) resulted in improved fruit quality of Nendran banana in both the years.

Different soil physical and chemical properties also improved when nutrients were supplied through organic sources.

Soil pH, electrical conductivity, organic carbon content, cation exchange capacity, available, N, P, K, Mg, Iron, Copper, Zinc, Mn and boron were better in soils receiving organic manures alone. Similarly the soil biological properties like dehydrogenase activity, nitrogenase activity, microbial biomass carbon, and viable counts of total fungi, bacteria and actinomycetes were better in organic treatments. Bulk density of soil was low in soils receiving organic manures alone compared to integrated nutrients.

Total uptake of nutrients in organic and integrated nutrient management system was compared. Uptake of N, Ca, S, Fe, Mn, Zn and Cu was higher in organic system of cultivation of banana compared to integrated system.

Higher benefit cost ratio was recorded banana grown in organic system.

The study revealed that organic sources of nutrients improved soil properties and thereby improved growth, yield and quality of banana.