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Influence of green manures and NPK fertilizers on fruit quality and economics of banana

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Abstract
An experiment was carried out at Instructional Farm of ASPEE College of Horticulture, Navsari Agricultural University, Navsari (Gujarat) during 2021-22 and 2022-23 to study the influence of green manures and NPK fertilizers on fruit quality and economics of banana. The experiment consisted of green manuring (T_1 - Control, T_2 - Single green manuring, T_3 - Double green manuring and T_4 - Triple green manuring) with dhaincha (*Sesbania aculeata* L.) in main plot and nutrient management practices [N_1 - 100% RDF (FYM: 10 kg plant^{-1}, NPK: 300 : 90 : 200 g plant^{-1} year^{-1}), N_2 - 80% RDF + N 20% from Bio-compost, N_3 - 60% RDF + N 40% from Bio-compost] in sub plot. It was laid out in split plot design along with three replications. Among the various treatments, application of triple green manuring by dhaincha showed the best result for yield, TSS and total sugars as well as shelf life. In nutrient management, the treatment involving 100% RDF (FYM: 10 kg per plant, NPK: 300:90:200 g per plant per year) resulted in the highest values for yield, while a combination of 60% RDF and 40% nitrogen from bio-compost improved TSS and shelf life. It can be concluded that for higher TSS, higher yields and good economic returns, banana cv. Grand Nain should be subjected to triple green manuring with dhaincha along with 100% RDF or 80% RDF combined with 20% nitrogen from bio-compost.

Keywords: GM, Sesbania, NPK, yield, TSS

Introduction
Banana (*Musa paradisiaca* L.) belongs to family Musaceae and is the cheapest, plentiful and most nourishing fruit crop of the world. It is a premier fruit having great socio-economic significance in India. Banana is one of the oldest and most widely consumed fruits, with evidence suggesting it was first domesticated in Papua New Guinea. It is believed to be native to the tropical regions of South East Asia. In many African countries, bananas serve as a staple fruit, consumed either ripe (as table fruit) or raw (for cooking). Beyond being a source of food, bananas provide fodder, fibers, beverages, fermentable sugars, medicines, flavourings, cooked dishes, silage, fragrance, rope, cordage, garlands, shelter, and clothing. They are also used in smoking materials, packaging, house roofs, and wall linings. Additionally, bananas have various religious and industrial applications, such as in the production of resin, gum, glue, latex, dye, and tanning. Due to their diverse uses, bananas are often referred to as "Kalpatharu" (Raghvendra *et al.*, 2021) [22].

Green manuring has long been a traditional agricultural practice involving the incorporation of green manure crops into the soil to enhance its fertility and provide essential nutrients for the primary crop. However, with the widespread adoption of chemical fertilizers, this practice has been somewhat overlooked. Green manure crops, also known as fertility-enhancing or soil-improving crops, play a vital role in maintaining soil health. According to Kumar *et al.* (2021) [12], green manures offer a promising solution for rural communities to address declining land productivity. They provide an alternative to synthetic fertilizers, particularly for resource-limited subsistence farmers. Additionally, green manures contribute to mitigating the impacts of climate change and are an environmentally sustainable option, addressing concerns on both local and global scales. This practice not only extends the duration of soil coverage but also reduces reliance on inorganic fertilizers.

Dhaincha (*Sesbania aculeata* L.) is one of the most important green manure crops for nutrient supply and is gaining momentum in the context of sustainable agriculture. Commonly, it is cultivated as green manure, fodder and as a non perennial temporary shade in crop field. .

It is a root nodulating legume with leaf composition of about 3.50% N, 0.60% P_2O_5, 1.20% K_2O and when it is incorporated into the soil, it adds about 60 to 80 kg nitrogen/ha (Paikary *et al.,* 2001). After decomposition it increases humus, available nitrogen and lower down the C: N ratio of soil. In real sense, this green manure crop improves soil structure, aeration, permeability and also protects the soil from leaching of nutrients. This plant also helps in conservation of soil moisture, prevents the weed growth and reduces the incidence of diseases and residual effects of persistent chemicals. Green manuring also enhances the boron and iron content in to the soil. Decomposed materials of *Sesbania* also serve as chelating compound and help in increasing the availability of nutrients *i.e.* Zn, Cu, Mn *etc*. in succeeding crop (Kumar and Sukul, 2020) [13].

Integrated Nutrient Management (INM) maintains soil fertility and plant nutrient supply at an optimum level for sustaining desired crop productivity. It enhances farmers' profitability by maximizing the benefits derived from all potential sources of plant nutrients in a holistic and integrated approach (Hazarika *et al.,* 2011) [8]. INM plays a vital role in achieving economic yields and high-quality fruits while preserving soil health. The core principle of INM is to sustain soil fertility and agricultural productivity while enhancing farmers' profitability through the balanced and efficient use of chemical fertilizers, organic manures, green manures, bio-fertilizers and other inputs. Moreover, supplementing Farm Yard Manure (FYM) with green manure crops, bio-compost, vermicompost, bio-fertilizers and other organic materials further boosts fruit yield and improves soil health. Bio-compost is used to maintain soil fertility and enhance crop production because it is rich in sugar and contains appreciable amount of essential plant nutrients *viz.,* organic carbon, nitrogen, phosphorus, potassium, calcium and magnesium along with traces of micronutrients like, Zn, Fe, Cu and Mn (Banulekha, 2007) [3], so the beneficial effect of this bio-compost for enhancing the soil fertility and thereby improving the crop productivity is well established (Laird *et al.,* 2001) [14]. Press-mud, used as bio-compost, is a soft, spongy, amorphous, dark brown material rich in nitrogen, cellulose, lignin, protein, sugar fibers, and coagulated colloids. It also contains cane wax, albuminoids, inorganic salts, soil particles, and various carbon-based components present in the final product. (Yadav, 1992) [30].

The availability of chemical fertilizers is frequently affected by global trade disruptions and security concerns. Additionally, the finite reserves of certain fertilizer components, particularly phosphate, pose significant challenges to fertilizer production in the near future. This underscores the urgent need to explore sustainable alternatives to chemical fertilizers to ensure long-term soil productivity and ecological balance. In light of these considerations, an experiment was designed to study the "Influence of green manures and NPK fertilizers on fruit quality and economics of banana".

Materials and Methods

The present investigation was carried out at the Instructional Farm of ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Taluka-Jalalpore, District-Navsari, during 2021-22 to 2022-23. The experimental plot was prepared through deep ploughing followed by harrowing. Pits size 30 cm^3 were excavated using a tractor-drawn digger, maintaining a spacing of 2.4 m × 1.2 m. Before planting, each pit was filled with 10 kg of well-decomposed Farm Yard Manure (FYM). The twelve treatments of field study were replicated thrice. The trial was conducted using a Split Plot Design, consisting of two main factors: green manuring and nutrient management. The green manuring treatments included single, double and triple applications of dhaincha, while the nutrient management treatments comprised three approaches: 100% RDF (FYM: 10 kg $plant^{-1}$, NPK: 300:90:200 g $plant^{-1}$ $year^{-1}$), 80% RDF + N 20% from bio-compost and 60% RDF + N 40% from bio-compost. The effects of green manuring and nutrient management, individually and in combination, on the yield and quality of bananas were evaluated. Yield data per net plot was recorded and subsequently converted to total yield in tonnes per hectare using a computed area-based multiplication factor. The total soluble solids (TSS) of the fruit were measured using a hand refractometer (0-32 °B). Remaining quality parameters were assessed by Ranganna (1986) [23] methods. The shelf life of the fruits were obtained by keeping fruits at room temperature and recording the number of days from harvesting until the appearance of spoilage symptoms or discoloration. In the economic analysis, the gross income per hectare (in rupees) was determined using the average yield for each treatment and the prevailing market price of banana bunches. The costs of different treatments were worked out by considering the prices of labour employed for the treatments and all treatment cost. The net income was worked out by deducting cultivation cost and the cost required for different treatments from the gross income per hectare for respective treatments and recorded accordingly and BCR was calculated by following formula:

$$\text{Benefit Cost Ratio} = \frac{\text{Net income (Rs ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

Green manuring and nutrient management practices were implemented according to the experimental layout. For green manuring, good quality dhaincha seeds were collected from the Main Rice Research Centre, NAU, Navsari, with a seed rate of approximately 25 kg per hectare. As per treatments seeds were sown between the banana plants. After 45 to 50 days of sowing, the fully green leaves of dhaincha plants were incorporated into the soil using a rotavator machine, corresponding to the single, double and triple green manuring treatments.

Results and Discussion

Effect of green manuring on fruit yield and TSS of banana

An analysis of the data in Table 1 indicates that green manuring treatments had a significant effect on fruit yield and TSS. The highest values for fruit yield (108.99 t ha^{-1}) and TSS (21.01 °Brix) were noted in triple green manuring treatment by dhaincha (T_4), which was statistically at par with the double green manuring treatment by dhaincha (T_3). In contrast, the lowest fruit yield (83.02 t ha^{-1}) and TSS (18.48 °Brix) were observed in the control treatment (T_1). The increase in fruit yield, in the triple green manuring treatment could be attributed to the improved chemical and physical properties of the soil resulting from the green manuring process. Green manuring also contributed to a more balanced C/N ratio and greater presence of essential

plant nutrients for physiological processes (Phukan *et al.*, 2016) [21]. Meghwal *et al.* (2021) [15] observed that a combination of FYM (15 kg plant^{-1}), ash (4 kg plant^{-1}) and *insitu* green manuring improved yield and quality of banana cv. Nendran. Highest values of TSS may be attributed to the beneficial effects of triple green manuring, such as nitrogen fixation, production of phytohormones and increased nutrient uptake which not only improved soil biological attributes but also promoted vegetative growth, yield and quality of banana (Patel *et al.*, 2023) [19].

Effect of green manuring on quality parameters and shelf life of banana

The data presented in Table 2 show that nutrient treatments had no significant impact on titrable acidity (%), ascorbic acid (mg/100 g of pulp) and reducing sugar (%) in the pooled analysis. However, green manuring show significant effect on total sugar content and shelf life of banana fruit. Soil application of triple green manuring by dhaincha (T_4) gave the maximum total sugar (16.26) and shelf life (9.53) which was statistically at par with T_3 treatment during pooled analysis. While, minimum total sugar (14.60%) and shelf life (7.80) was noted in control (T_1). This could be attributed to the enhanced nutrient availability, increased hormonal and enzymatic activity facilitated by green manuring, along with improved water absorption and nutrient deposition. These factors collectively contribute to better quality parameters, including a higher total sugar percentage. Hema *et al.* (2016) [9] reported that fruit quality parameters like TSS, total sugars and shelf life were higher in plants treated with organic amendments as compared to inorganic. The extended shelf life in banana fruit might be due to the consequence of reduced weight loss and other physiological process like reduced transpiration and respiration process (Vanilarasu and Balakrishnamurthy, 2014) [29]. Better growth resulted into firm fruits with more pericarp thickness, on account of proper and adequate availability of all macro and micronutrients leading to improved shelf life (Gosavi *et al.* 2010) [7]. Similar finding was also reported by Athani and Hulamani (2000) [1] and Phukan *et al.* (2016) [21] in banana.

Effect of nutrient management on yield and TSS of banana fruits

The data on fruit yield and TSS from Table 1 shows significant effect on nutrient management. The highest fruit yield (103.46 t ha^{-1}) was observed in the N_1 treatment (100% RDF: FYM @ 10 kg plant^{-1} and NPK at 300:90:200 g plant^{-1} year^{-1}), which was statistically comparable to the N_2 treatment (80% RDF + N 20% from bio-compost). In contrast, the lowest fruit yield (89.61 t ha^{-1}) was recorded under the N_3 treatment. Regarding TSS, the highest value (20.44 °Brix) was reported in N_3 treatment (60% RDF + N 40% from bio-compost), while the lowest TSS (19.23 °Brix) in the N_1 treatment. The applied N, P and K were utilized efficiently by the plant, which resulted in production of maximum photosynthates. Translocation of the assimilated material to the developing sink may have resulted in heavier weight of bunch (Pattar *et al.*, 2018) [20]. The increase in bunch weight can also be linked to the enhanced vegetative growth parameters and improved bunch characteristics, such as the number of hands per bunch, the number of fingers per hand and the total number of fingers per bunch, which collectively contributed to a higher fruit yield. (Chattopadhyay *et al.*, 1985) [5]. Higher fruit quality, especially sugar content can be explained on the basis of the role of nutrients, particularly potassium, involved in carbohydrate synthesis, breakdown and translocation of starch, synthesis of protein and in neutralization of physiologically important organic acids (Tisdale and Nelson, 1966) [28]. Athani and Hulamani (2000) [1] in banana reported that increased TSS (°Brix) of fruits is due to the addition of organic manures and amendments to the soil and in turn to plants, which might have enhanced the biosynthesis and translocation of carbohydrates in to the fruits. These findings are in line with the findings of Patel and Naik (2010) [18] in sapota; Talang *et al.* (2017) [26] in mango and Singh *et al.* (2010) [24] in papaya.

Effect of nutrient management on quality parameters and shelf life of banana

The effect of nutrients was found non-significant in respect to titrable acidity (%), ascorbic acid (mg/100 g of pulp), reducing sugar (%) and total sugar content (%) in pooled analysis. Table 2 indicated that an application of nutrient management had significant effect on shelf life of banana fruit. Soil application of 60% RDF + N 40% from bio-compost (N_3) gave maximum shelf life of banana fruit in pooled analysis (9.13 days) which was reported at par with N_2 treatment while minimum shelf life of banana fruit was recorded in N_1 treatment (8.47 days). Shelf life extension was more in the treatments receiving 60% RDF + N 40% from bio-compost indicating their effectiveness in controlling weight loss, which might be due to presence of higher calcium content, reduced rate of respiration and transpiration from fruit surfaces. The decrease in respiration could be further attributed to lowering of succinate and malate dehydrogenase activities associated with TCA cycle. Presence of epicuticular wax on the fruit skin also reduces respiration and transpiration during post harvest period by partially blocking the lenticels, cuticle and consequently retards the moisture loss caused by transpiration. Higher availability of secondary nutrients, metabolites like GA and reduced gaseous exchange effects delay in ripening, senescence, less tissue break down and softening of tissue which increases firmness and extends storage life. These results are in conformity with the findings reported by Singh *et al.* (2010) [24] and Tandel *et al.* (2017) [27] in papaya.

Interaction effect of green manuring and nutrient management on fruit yield and TSS of banana

Green manuring and nutrient management had a significant impact on both fruit yield and TSS. Treatment T_4N_1 *i.e.* triple green manuring by dhaincha and 100% RDF (FYM: 10 kg plant^{-1}, NPK: 300:90:200 g plant^{-1} year^{-1}) resulted in the highest fruit yield (121.74 t ha^{-1}) whereas T_4N_3 *i.e* triple green manuring by dhaincha and 60% RDF + N 40% from bio-compost noted maximum TSS (21.92 °Brix) which was at par with T_4N_2 (Table 1). The use of triple green manuring combined with nutrient management likely supplied additional nutrients to the plants, enhancing their physiological and biochemical activities, which contributed to an increase in bunch weight. The relatively higher carbohydrate availability may have further supported an accelerated growth rate, larger bunch size and consequently, greater bunch weight (Hazarika *et al.*, 2011) [8]. This is in agreement with earlier results reported by Kanamadi *et al.* (2004) [10] in banana using 25% RDN as farm yard manure +

green manuring with sunhemp + 75% RDN as an inorganic source. This could also be attributed to the combined effect of triple green manuring with dhaincha and 100% RDF, which facilitated the efficient translocation of nutrients from the vegetative parts to the fruits, ultimately boosting the yield (Athani *et al.*, 2009) [2]. Similar findings were also reported by Bhalerao *et al.* (2009) [4], Patel *et al.* (2012) [17] and Phukan *et al.* (2016) [21] in banana. Improvement in TSS of fruits might be due to increased continuous supply of nutrients, higher concentration of soil enzymes, soil microorganism, rapid mineralization and transformation of plant nutrients in soil and also growth promoting substances produced by microorganisms (Tandel *et al.*, 2017) [27]. This is in line with earlier findings of Soorianathasundaram *et al.* (2001) [25] and Ganapathi *et al.* (2018) [6] in banana and Kumar (2010) [11] in papaya.

Interaction effect of green manuring and nutrient management on quality parameters and shelf life of banana

The interaction effect between green manuring and nutrient management (T x N) failed to show any significant effect on titrable acidity (%), ascorbic acid (mg/100 g of pulp), reducing sugar (%), total sugar content (%) and shelf life of banana fruits in pooled analysis (Table 2).

Interaction effect of green manuring and nutrient management on economics of banana

Economics is a major consideration for the farmers while taking a decision regarding adoption of new technology, hence the cost of cultivation, maximum net realization and benefit cost ratio were computed according to different green manuring and nutrients, which was indicated in Table 3. Taking into account economics of both the years, the maximum net realization 1554789 Rs ha^{-1} was obtained with triple green manuring by dhaincha and 100% RDF treatment (T_4N_1) followed by 80% RDF in combination with N 20% from bio-compost (T_4N_2) with 1444195 Rs ha-^{1}. The above treatments gave maximum yield in present investigation which fetched more returns as compared to other treatments. Consequently, the highest benefit cost ratio (5.73) was also noted in these treatments.

Table 1: Effect of green manuring and nutrient management on fruit yield and TSS of banana cv. Grand Nain

Treatments	Fruit yield (t ha^{-1})	TSS (°Brix)
Green manuring (T)		
T_1	83.02	18.48
T_2	95.83	19.47
T_3	102.27	20.50
T_4	108.99	21.01
S.Em. ±	1.98	0.20
C.D. at 5%	6.10	0.63
C.V.%	8.61	4.36
Nutrient management (N)		
N_1	103.46	19.23
N_2	99.51	19.93
N_3	89.61	20.44
S.Em. ±	1.43	0.09
C.D. at 5%	4.11	0.26
Interaction T x N		
T_1N_1	83.21	18.61
T_1N_2	82.98	18.09
T_1N_3	82.87	18.75
T_2N_1	99.07	18.83
T_2N_2	98.14	19.52
T_2N_3	90.27	20.05
T_3N_1	109.83	20.01
T_3N_2	102.89	20.47
T_3N_3	94.09	21.03
T_4N_1	121.74	19.47
T_4N_2	114.03	21.64
T_4N_3	91.20	21.92
S.Em. ±	2.86	0.18
C.D. at 5%	8.23	0.51
C.V.%	7.17	2.20

Note: Mean of two years (2021-22 and 2022-23)

Table 2: Effect of green manuring and nutrient management on different quality parameters and shelf life of banana cv. Grand Nain

Treatments	Titrable acidity (%)	Ascorbic acid (mg/100 g of pulp)	Reducing sugar (%)	Total sugar content (%)	Shelf life (days)
Green manuring (T)					
T_1	0.109	4.25	6.57	14.60	7.80
T_2	0.109	4.33	6.70	15.64	8.97
T_3	0.107	4.41	6.75	15.84	9.21
T_4	0.104	4.48	6.99	16.26	9.53
S.Em. ±	0.002	0.05	0.16	0.19	0.20
C.D. at 5%	NS	NS	NS	0.60	0.62
C.V.%	6.86	5.24	10.07	5.30	9.56
Nutrient management (N)					
N_1	0.109	4.29	6.63	15.34	8.47
N_2	0.107	4.40	6.79	15.69	9.03
N_3	0.105	4.41	6.83	15.73	9.13
S.Em. ±	0.001	0.04	0.07	0.15	0.14
C.D. at 5%	NS	NS	NS	NS	0.41
Interaction T x N					
S.Em. ±	0.003	0.07	0.16	0.30	0.28
C.D. at 5%	NS	NS	NS	NS	NS
C.V.%	5.71	4.04	5.15	4.69	7.86

Note: Mean of two years (2021-22 and 2022-23)

Table 3: Effect of green manuring and nutrient management on economics of banana cv. Grand Nain

Treatments	Yield (kg ha^{-1})	Fixed cost (Rs ha^{-1})	Treatment cost (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})	Gross Realization (Rs ha^{-1})	Net Realization (Rs ha^{-1})	BCR
T_1 N_1	83.21	140620	121241	261861	1248150	986289	3.77
T_1 N_2	82.98	140620	116185	256805	1244700	987895	3.85
T_1 N_3	82.87	140620	111120	251740	1243050	991310	3.94
T_2 N_1	99.07	140620	124391	265011	1486050	1221039	4.61
T_2 N_2	98.14	140620	119335	259955	1472100	1212145	4.66
T_2 N_3	90.27	140620	114270	254890	1354050	1099160	4.31
T_3 N_1	109.83	140620	127541	268161	1647450	1379289	5.14
T_3 N_2	102.89	140620	122485	263105	1543350	1280245	4.87
T_3 N_3	94.09	140620	117420	258040	1411350	1153310	4.47
T_4 N_1	121.74	140620	130691	271311	1826100	1554789	5.73
T_4 N_2	114.03	140620	125635	266255	1710450	1444195	5.42
T_4 N_3	91.20	140620	120570	261190	1368000	1106810	4.24

* Banana selling price - 15 Rs kg^{-1}

Conclusion

Based on the two-year average data, it can be concluded that the soil management practice of triple green manuring with dhaincha, combined with 100% RDF, produced the highest yield, net income and benefit-cost ratio (BCR). This was closely followed by the combination of triple green manuring with dhaincha and 80% RDF with N 20% from bio-compost. The best fruit quality in terms of TSS and shelf life was recorded in triple green manuring by dhaincha along with 60% RDF in combination with N 40% from bio-compost. The above treatment was at par through triple green manuring by dhaincha with 80% RDF in combination with N 20% from bio-compost. The present investigation emphasizes the potential of incorporating triple green manuring with dhaincha, along with either 100% RDF or 80% RDF in combination with N 20% from bio-compost, to achieve higher banana production. This approach also enhances the quality of the bananas and improves soil health.

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