Plant Archives Vol. 24, No. 2, 2024 pp. 915-920 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.128

IMPACT OF NET HOUSE AND OPEN FIELD CULTIVATION ON QUALITY PARAMETERS OF BANANA (*MUSA* SPP.) VARIETIES

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(Date of Receiving-05-02-2024; Date of Acceptance-13-04-2024)

ABSTRACT

This study investigated the impact of net house and open field cultivation on quality parameters of banana varieties for two consecutive years (plant and ratoon crop) (2021 – 2022 and 2022 – 2023) at M.H.R.E.C., University of Horticultural Sciences, Bagalkot, India. The experiment consisted of six treatments (T_1- G_1V_1 – Ney Poovan under net house condition, T_2 – G_1V_2 – Grand Naine under net house condition, T_3 – G_1V_3 – Rajapuri under net house condition, T_4 – G_2V_1 – Ney Poovan under open field condition, T_5 – G_2V_2 – Grand Naine under open field condition, T_6 – G_2V_3 – Rajapuri under open field condition) laid out in FRCBD with 4 replications. In this present experiment, quality parameters such as TSS (°Brix), titratable acidity (%), TSS to acid ratio, Ascorbic acid content (mg/100mg), pulp weight (g), peel weight (g), peel thickness (mm), pulp to peel ratio, fruit firmness (N) and shelf life (days). Results showed that maximum TSS, TSS to acid ratio, pulp weight and peel weight was recorded in banana variety Grand Naine grown under the net house cultivation. However, the maximum ascorbic acid content and shelf life was highest in Ney Poovan under net house conditions.

Key words : Net house, TSS, Open field, Grand Naine, Ney Poovan, Shelf life.

Introduction

Bananas are native to Southeast Asia. Botanically, banana is a monocotyledonous herbaceous plant belonging to the section Eumusa under the family Musaceae. Banana grows well in warm, humid regions of Asia with tropical climates. The optimal temperature range for banana cultivation is 20–35°C; temperatures below 20°C and above 35°C cause the growth of bananas to be inhibited. High temperature stress alters plant physiological and biochemical responses, lowering crop quality and yield (Ravi and Vaganan, 2016). When the temperature drops below 11.5°C, root growth ceases. The ideal soil temperature for maximal root expansion in bananas is 23.5°C (Bahadur *et al.*, 2020).

Despite being the world's largest banana producer, India's productivity is quite low when compared to other nations for a variety of reasons. Variation in temperature is also affecting the yield and productivity of banana cultivation. Cultivation of banana under open field conditions is affected by various anomalies like wind damage, sunburn, pests, diseases, frost injury and adverse climatic conditions during the growth season, the yield is adversely affected and most of the time whole crop remain damaged. So, to overcome this problem banana cultivation under net house conditions is needed and so far, there no proper work has been done on protected cultivation of banana. This present study aims to evaluate the impact of net house and open field growing conditions on quality parameters of banana varieties.

Material and Methods

The present investigation "Impact of net house and open field cultivation on quality parameters of banana (*Musa* spp.) varieties" was carried out during 2021-2022 and 2022 – 2023 in Main Horticultural Research Station (MHREC), University of Horticultural Sciences, Bagalkot, India. The research centre comes under northern dry zone of Karnataka. It is located at 16º 11´ North latitude, 75 º 42´ East longitudes with an altitude of 537 m above the mean sea level. The soil of the experiment site is red sandy loam with good physical properties and drainage. Nutrient status of the soil is 168.03 kg/ha N, 50.0 kg/ha P_20_5 and 556.34 kg/ha K_2O with alkaline pH (8.05) and EC of 0.15 dS/m.

Design : Factorial RCBD

Factor 1	**Factor 2**
G-Growing conditions	**V- Varieties**
G_1-Net house conditions G_2-Open conditions	V_1-Ney Poovan V_2-Grand Naine V_3- Rajapuri

Treatment combinations : 06

Replications : 04

Spacing : 1.80 m (plant-plant) x 2.10 m (row-row)

Plot size : 34.02 m^2

Treatment details

Treatments	**Code**	**Treatment details**
T_1	G_1V_1	Ney Poovan (AB) under net house condition
T_2	G_1V_2	Grand Naine (AAA) under net house condition
T_3	G_1V_3	Rajapuri (AAB) under net house condition
T_4	G_2V_1	Ney Poovan (AB) under open field condition
T_5	G_2V_2	Grand Naine (AAA)under open field condition
T_6	G_2V_3	Rajapuri (AAB) under open field condition

TSS (ºBrix) : The total soluble solid content was assessed using an Erma digital hand refractometer (0 to 32 %), where in the juice from randomly selected fruit per replication was extracted and strained through muslin cloth. The readings were expressed in degree Brix.

Titratable acidity (%) : The acidity was measured in terms of malic acid by diluting the juice extracted from five grams of sample, which was later titrated against NaOH (0.1 N) with phenolphthalein as an indicator.

TSS to acid ratio : TSS to acid ratio was obtained by dividing TSS (R"Brix) with titratable acidity (%) of corresponding fruits and it is expressed in ratio.

Ascorbic acid content (mg/100g) : Ascorbic acid or vitamin C content of juice was measured using the dye solution (dichlorophenol indo phenol) binding method; the results were represented as mg per 100 g of sample (Anonymous, 1984).

Pulp weight (g) : Pulp weight of representative fruit was weighed by using digital electronic weighing balance and mean weight was recorded and expressed in grams.

Peel weight (g) : Peel weight of ripened fruit was weighed by using digital electronic weighing balance and mean weight was recorded and expressed in grams.

Peel thickness (mm) : The thickness of the peel was measured using vernier callipers, and the average thickness was recorded and reported in millimetres.

Pulp to peel ratio : The fruit weight, pulp weight and peel weight was recorded from ripened fruits and pulp to peel ratio was worked out by dividing the pulp weight of the fruit by the peel weight of the fruit and was expressed in number.

Fruit firmness (N) : The TAXT plus texture analyzer was used to determine the firmness of the banana fruits (Make: Stable Micro System, Model: Texture Export Version 1.22).

Shelf life (days) : The shelf life of fruits was determined by recording the number of days the fruits remained in good condition in storage. The stage where in more than 50 percent of the stored fruits became unfit for consumption was considered as end of shelf life in that particular treatment and expressed as mean number of days (Padmalatha, 1995).

Statistical analysis : Analysis of Variance (ANOVA) was used for the analysis, which was done using the SPSS Software (Statistical Package for Social Science) method by version '20'. Factorial randomised complete block design (FRCBD) with two components is the analysis method employed. The critical difference (C.D. at 5%) and test of significance ('F' test) were read at 0.05 probabilities (Panse and Sukhatme, 1967).

Results and Discussion

The main goal in the fruit production system is to maximize fruit yield without sacrificing fruit quality. The quality parameters of banana varieties were significantly influenced by net house and open field growing conditions in both plant and ratoon crop.

Table 1 : TSS (°Brix), titratable acidity (%), TSS to acid ratio and ascorbic acid content (mg/100g) of banana varieties as influenced by Open field and net house growing conditions.

	TSS (°Brix)			Titratable acidity (%)			TSS to acid ratio			Ascorbic acid content (mg/100g)		
	PC	RC	Pooled	PC	RC	Pooled	PC	RC	Pooled	PC	RC	Pooled
Factor -01	**Growing conditions**											
G_1	24.44	23.52	23.98	0.34	0.31	0.33	73.33	75.63	74.48	5.68	5.78	5.73
G_2	22.45	21.76	22.10	0.36	0.35	0.36	62.97	61.80	62.39	5.27	5.23	5.25
S. Em ±	**0.50**	**0.48**	**0.49**	**0.01**	**0.01**	**0.01**	**0.63**	**0.65**	**0.64**	**0.11**	**0.12**	**0.11**
C.D at 5%	**1.51**	**1.45**	**1.48**	**0.02**	**0.02**	**0.02**	**1.91**	**1.95**	**1.93**	**0.34**	**0.35**	**0.35**
Factor- 02	**Varieties**											
V_1	23.94	22.87	23.40	0.35	0.33	0.34	69.69	70.68	70.18	7.36	7.27	7.31
V_2	25.00	23.87	24.43	0.32	0.32	0.32	78.28	75.48	76.88	5.96	6.37	6.16
V_3	21.41	21.20	21.30	0.38	0.36	0.37	56.49	59.99	58.24	3.12	2.89	3.00
S.Em ±	**0.50**	**0.48**	**0.49**	**0.01**	**0.01**	**0.01**	**0.63**	**0.65**	**0.64**	**0.11**	**0.12**	**0.11**
C.D at 5%	**1.51**	**1.45**	**1.48**	**0.02**	**0.02**	**0.02**	**1.91**	**1.95**	**1.93**	**0.34**	**0.35**	**0.35**
	Interaction effect (GxV)											
G_1V_1	24.74	23.58	24.16	0.33	0.31	0.32	75.12	76.22	75.67	7.70	7.56	7.63
G_1V_2	25.96	24.67	25.32	0.31	0.29	0.30	83.74	85.07	84.41	6.02	6.54	6.28
G_1V_3	22.63	22.32	22.48	0.37	0.34	0.36	61.14	65.62	63.38	3.32	3.25	3.29
G_2V_1	23.13	22.15	22.64	0.36	0.34	0.35	64.25	65.15	64.70	7.02	6.97	7.00
G_2V_2	24.03	23.06	23.55	0.33	0.35	0.34	72.82	65.89	69.35	5.89	6.19	6.04
G_2V_3	20.18	20.07	20.13	0.39	0.37	0.38	51.85	54.36	53.10	2.91	2.53	2.72
S.Em ±	**0.87**	**0.83**	**0.85**	**0.01**	**0.01**	**0.01**	**1.10**	**1.12**	**1.11**	**0.20**	**0.20**	**0.20**
C.D at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

G_1- Net house conditions
G_2- Open field conditions
V_1- Ney Poovan
V_2-Grand Naine
V_3-Rajapuri
PC-Plant crop
RC-Ratoon crop
NS-Non significant

TSS is an important parameter of fruit quality. TSS states the amounts ofsoluble solids in liquid. TSS value affects the taste of the fruit, because it can indicate the level ofsweetness of the fruit.The pooled data showed that highest TSS (23.98 °Brix) was registered in G_1 (net house condition) is presented in Table 1. This may attributed to the high photosynthetic efficiency and fast rate of diversion of sugars from source (leaf) to sink (fruit) under net house. While, G_2 (open field conditions) registered the lowest TSS of (22.10 °Brix). And the lowest TSS was noticed under open field conditions which may be due to increased temperature, which led to increase in respiration rate and as a result, soluble solids decreased under open conditions (Choudhury *et al*., 2023).

With respect to varieties the TSS found significantly influenced. The highest TSS (24.43 °Brix) was found in V_2 (Grand Naine) and it was at par with V_1 (Ney Poovan) (23.40 °Brix). However, the lowest TSS was registered in V_3 (Rajapuri) (21.30 °Brix). This may be due to the genetic makeup and character of the variety. These results are in line with study conducted by Hussain and Reddy (2018), who recorded 24.00 °Brix in Grand Naine. Whereas, in the present investigation interaction effects of different growing conditions and varieties on TSS did not vary significantly in both main and ratoon.

Titratable acidity (TA) represents the organic acids that greatly affect fruit overall eating quality and flavour (Xu *et al*., 2012). The significant differences were noticed in titratable acidity among the growing conditions, where G_1 (net house condition) recorded minimum titratable acidity (0.33%)is presented in Table 1. While, G_2 (open field conditions) registered the maximum titratable acidity (0.36%). In case of varieties, the minimum titratable acidity (0.32%) was found of V_2 (Grand Naine) and it followed by V_1 (Ney Poovan) (0.34%). However, the maximum titratable acidity was registered in V_3 (Rajapuri) (0.37%). The results of the investigation suggested that the high sugar content and more edible part of the banana may be the cause of the least titratable acidity in the juice obtained from the net house grown banana (Choudhury *et al*., 2022).

Table 2 : Pulp weight (g), peel weight (g) and peel thickness (mm) of banana varieties as influenced by net house and open field growing conditions.

	Pulp weight (g)			Peel weight (g)			Peel thickness (mm)		
	PC	RC	Pooled	PC	RC	Pooled	PC	RC	Pooled
Factor -01	**Growing conditions**								
G_1	92.94	84.89	88.91	22.24	20.07	26.02	1.94	1.74	2.34
G_2	82.83	74.63	78.73	27.52	24.51	21.16	2.58	2.10	1.84
S.Em ±	**0.61**	**0.78**	**0.41**	**0.71**	**0.33**	**0.37**	**0.05**	**0.04**	**0.04**
C.D at 5%	**1.83**	**2.35**	**1.25**	**2.14**	**0.98**	**1.11**	**0.14**	**0.12**	**0.13**
Factor- 02	**Varieties**								
V_1	50.75	50.23	50.49	10.20	8.67	9.44	1.58	1.33	1.45
V_2	131.10	118.78	124.94	39.29	35.17	37.23	2.44	2.08	2.26
V_3	81.80	70.28	76.04	25.15	23.04	24.09	2.76	2.36	2.56
S.Em ±	**0.61**	**0.78**	**0.41**	**0.71**	**0.33**	**0.37**	**0.05**	**0.04**	**0.04**
C.D at 5%	**1.83**	**2.35**	**1.25**	**2.14**	**0.98**	**1.11**	**0.14**	**0.12**	**0.13**
GXV	**Interaction effect (GxV)**								
G_1V_1	54.39	52.10	53.24	9.25	7.93	10.28	1.46	1.23	1.56
G_1V_2	136.74	125.08	130.91	35.02	32.13	40.89	2.13	1.94	2.48
G_1V_3	87.68	77.50	82.59	22.45	20.17	26.88	2.22	2.04	2.99
G_2V_1	47.11	48.36	47.73	11.16	9.40	8.59	1.70	1.42	1.35
G_2V_2	125.46	112.48	118.97	43.56	38.22	33.57	2.75	2.21	2.04
G_2V_3	75.92	63.05	69.48	27.85	25.92	21.31	3.30	2.67	2.13
S.Em ±	**1.05**	**1.35**	**0.72**	**1.23**	**0.57**	**0.64**	**0.08**	**0.07**	**0.07**
C.D at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

G_1- Net house conditions
G_2- Open field conditions
V_1- Ney Poovan
V_2-Grand Naine
V_3-Rajapuri
PC-Plant crop
RC-Ratoon crop
NS-Non significant

However, non-significant differences were recorded with respect to interaction effects in both plant and ratoon crop.

The pooled data showed that highest TSS to acid ratio (74.48) was recorded in G_1 (net house condition)is presented in Table 1. While, G_2 (open field conditions) registered the lowest TSS to acid ratio 62.39, respectively. Regarding banana varieties, the maximum brix to acid ratio of 76.88 was recorded in V_2 (Grand Naine), it was followed by V_1 (Ney Poovan) (70.18). While, the minimum TSS to acid ratio (58.24) was recorded in V_3 (Rajapuri). This might be due to increased TSS and reduced titratable acidity which in turn led to maximum brix to acid ratio under the net house conditions. The non-significant differences were found in all the interactions on TSS to acid ratio content of banana.

Ascorbic acid, also known as vitamin C, is a vital antioxidant widely found in fruits. Significant differences were reported in ascorbic acid content among the growing conditions. The pooled data showed that the highest ascorbic acid content was registered in G_1 (net house condition) (5.73 mg/100g) is presented in Table 1. While, G_2 (open field conditions) registered the lowest ascorbic acid content (5.25 mg/100g). Net house conditions, characterized by reduced temperature fluctuations and protection from extreme weather conditions (Kumar *et al*., 2017), which provided a controlled environment conducive to optimal conditions for ascorbic acid synthesis and accumulation. Temperature has an enormous effect on vitamin C. During fruit ripening and maturity, low average temperatures lead to more enzymatic activity, this increases the amount of vitamin C and other bioactive chemicals in the fruit (Mditshwa *et al*., 2019). Additionally, controlled environments, such as shade net houses, promote higher chlorophyll content in plants due to optimized light conditions (Hogewoning *et al*., 2010), fostering increased photosynthesis and positively influencing the production of ascorbic acid.

With respect to varieties, the highest ascorbic acid content (7.31 mg/100g) was found in V_1 (Ney Poovan). However, the lowest ascorbic acid content was registered in V_3 (Rajapuri) (3.00 mg/100g). The variation in varieties may be due to genotypic character of the particular variety.

The non-significant differences were observed for

Table 3 : Pulp to peel ratio, fruit firmness (N) and shelf life (days) of banana varieties as influenced by open field and net house growing conditions.

	Pulp to peel ratio			Fruit firmness (N)			Shelf life (days)		
	PC	RC	Pooled	PC	RC	Pooled	PC	RC	Pooled
Factor -01	**Growing conditions**								
G_1	3.74	3.95	3.85	12.90	12.89	12.89	9.85	9.45	9.65
G_2	4.04	4.25	4.15	12.59	12.89	12.74	9.19	8.83	9.01
S.Em ±	**0.10**	**0.09**	**0.06**	**0.25**	**0.26**	**0.25**	**0.20**	**0.19**	**0.19**
C.D at 5%	**0.29**	**0.27**	**0.17**	**NS**	**NS**	**NS**	**0.59**	**0.56**	**0.58**
Factor- 02	**Varieties**								
V_1	5.01	5.85	5.43	12.48	12.52	12.50	12.23	11.93	12.08
V_2	3.38	3.39	3.38	13.18	13.31	13.24	7.28	6.77	7.03
V_3	3.29	3.06	3.18	12.58	12.84	12.71	9.06	8.73	8.89
S.Em ±	**0.10**	**0.09**	**0.06**	**0.25**	**0.26**	**0.25**	**0.20**	**0.19**	**0.19**
C.D at 5%	**0.29**	**0.27**	**0.17**	**NS**	**NS**	**NS**	**0.59**	**0.57**	**0.58**
	Interaction effect (GxV)								
G_1V_1	4.90	5.58	5.24	12.72	12.77	12.75	12.34	12.16	12.25
G_1V_2	3.16	3.27	3.22	13.32	13.16	13.24	7.82	7.12	7.47
G_1V_3	3.17	2.99	3.08	12.65	12.73	12.69	9.40	9.06	9.23
G_2V_1	5.11	6.11	5.61	12.23	12.27	12.25	12.12	11.69	11.91
G_2V_2	3.60	3.51	3.55	13.03	13.45	13.24	6.74	6.42	6.58
G_2V_3	3.41	3.13	3.27	12.52	12.96	12.74	8.71	8.39	8.55
S.Em ±	**0.17**	**0.16**	**0.10**	**0.44**	**0.44**	**0.44**	**0.34**	**0.33**	**0.33**
C.D at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

G_1- Net house conditions
G_2- Open field conditions
V_1- Ney Poovan
V_2-Grand Naine
V_3-Rajapuri
PC-Plant crop
RC-Ratoon crop
NS-Non significant

interaction effects in both plant and ratoon crop on ascorbic acid content of banana.

Pulp (88.91 g) and peel weight (26.02 g) was found to be highest under the G_1 (net house) conditions among the growing conditions is given in Table 2. While, G_2 (open field conditions) registered the lowest pulp weight (78.73 g) and peel weight (21.16 g), respectively. With respect to varieties the pulp weight found significantly influenced for both crops. The highest pulp weight (124.94 g) and peel weight (37.23 g) was found of V_2 (Grand Naine). However, the lowest pulp weight (50.49 g) and peel weight ((9.44 g). was registered in V_1 (Ney Poovan). The pooled data showed that the maximum peel thickness of the fruit (2.34 mm) was registered in G_1 (net house condition) is given in Table 2. While, G_2 (open field conditions) registered the minimum peel thickness of the fruit (1.84 mm). With respect to varieties, the peel thickness of the fruit was found significantly influenced. The pooled data showed that the highest peel thickness of the fruit (2.56 mm) was found in V_3 (Rajapuri) and the lowest peel thickness of the fruit were registered in V_1 (Ney Poovan) was (1.45 mm). This may be due to the high chlorophyll content in the leaves, which directly affects the translocation of carbohydrates for increasing the cell division and elongation of the plant (Reddy and Gowda, 2014).

The non-significant differences were observed for interaction effects in both plant and ratoon crop for pulp, peel weight and peel thickness of banana.

Pulp to peel ratio was found to be me in minimum (4.15) under the G_1 (net house condition) among the growing conditionsis given in Table 3. While, G_2 (open field conditions) registered the maximum pulp to peel ratio (3.85). With respect to varieties, the pooled data showed that the highest pulp to peel ratio (5.43) was found in V_1 (Ney Poovan) and it was followed by V_2 (Grand Naine) (3.38). However, the lowest pulp to peel ratio was registered in V_3 (Rajapuri) (3.18). The variation of the parameters among the varieties might be due to varietal character and genotype.

The non-significant differences were noticed for interaction effects in both plant and ratoon crop for pulp to peel ratio of banana.

The present investigation interaction effects of different growing conditions and varieties on fruit firmness

of banana did not vary significantly in both main and ratoon crop and data is presented in Table 3.

Shelf life refers to the length of time a product may be stored without becoming unsuitable for use or consumption. Among the growing conditions, the pooled data showed that the maximum shelf life (9.65 days) was registered in G_1 (net house condition) is presented in Table 3. While, G_2 (open field conditions) registered the minimum shelf life (9.01 days). Higher fruit shelf life under net house is mainly due to the higher fruit peel thickness under this structure as comparative to open field. It is the most important fruit quality trait for shipment of bananas over the longer distance (Gill *et al*., 2018).

With respect to varieties, the pooled data showed that highest shelf life (12.08 days) was found in V_1 (Ney Poovan) and it was followed by V_3 (Rajapuri) (8.89 days). However, the lowest shelf life was registered in V_2 (Grand Naine) (7.03 days). This may be due to the genetic constitution of the variety. All the interaction effect on shelf life in lab conditions was found non significant. The results are in accordance with the findings of Junior *et al.* (2010), Ersoy and Bagci (2011), Gubbuk *et al.* (2018), Kafkas *et al.* (2022). Bodur *et al.* (2023), Choudhury *et al.* (2023) in banana.

Conclusion

The cultivation of banana variety Grand Naine under the net house conditions played a crucial role in enhancing the quality of banana. In the present investigation, quality parameters such as TSS, TSS to acid ratio, pulp weight, peel weight was found to be maximum in Grand Naine cultivated under the net house conditions. Titratable acidity was found to be minimum Grand Naine cultivated under the net house conditions. Whereas, other parameters such as ascorbic acid content and shelf life was found to maximum in Ney Poovan variety under net house cultivation. Thus, growing of these banana varieties under the net house conditions is promising and valuable recommendation for farmers.

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