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Effect of plant density and placement of emitters on yield, post-harvest and quality parameters in Banana *cv.* Grand Naine

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Abstract
An experiment was conducted to study the effect of varied plant densities and different placement of emitters on yield, post harvest and quality parameters in banana *cv.* Grand Naine. The experiment was laid out in factorial RCBD design with three varied plant densities S_1 (1.5 x 1.5 m), S_2 (1.8 x 1.8 m) and S_3 (2 x 2 m) and four different placement of emitters E_1 (placement of emitters at plain), E_2 (placement of emitters at 40 cm), E_3 (placement of emitters at 50 cm) and E_4 (placement of emitters at 60 cm) with three replications. The results of the experiment clearly indicated that the highest yield (79.37, 86.48 tons/ha) was registered in treatment (S_1, E_2 respectively) and the lowest yield (51.35, 54.33 tons/ha) was observed in treatment (S_3, E_1 respectively) in plant crop. Postharvest parameters like pulp weight (82.15 g, 104.53 g), pulp to peel ratio (1.83, 2.50) and shelf life (8.19, 8.52 days) was registered highest and peel weight was found lowest (46.00 g, 42.04 g) in treatment (S_3, E_2 respectively) in plant crop. The highest quality parameters *viz.*, total sugar (19.56, 19.54 %), reducing sugar (16.96, 16.59 %), non reducing sugar (2.70, 2.75 %) and total soluble solid (23.11, 23.37 ^{0}Brix) was recorded highest in treatment (S_3, E_2 respectively) in plant crop. The similar trend of post harvest and quality parameters was found in ratoon crop also. However the lowest postharvest and quality parameter was observed in treatment (S_1, E_1) in plant and ratoon crop respectively.

Keywords: Plant density, placement of emitters, plain (beside the plant), *cv.* grand Naine, post harvest and quality parameters, plant and ratoon crop

Introduction
Banana (Musa spp) has emerged as the major cash – subsistence crop across the world and it is grown in almost all parts of the world especially in the tropical regions. In the world of fruits, banana is a complete food fruit packed with all the necessary energy and health giving elements (Anon, 1969) [3]. On account of these properties combined with delicious taste and flavor, it is in great demand in fresh as well as processed form all over the world and has gained commercial popularity in the international fruit trade (Thomas *et al.* 1968) [18]. Banana is botanically a herb, where training and pruning response is not applicable. Hence, alternative technologies to improve the productivity of banana are main concerns of present researchers. High density planting (HDP) as an intensive system of cultivation in banana not only provides high production and net returns but also facilitates efficient utilization of solar energy, nutrients and water (Apshara and Sathiamoorthy, 2003) [4]. A closer spacing can be adopted under good management conditions using micro irrigation and fertigation techniques. Drip irrigation in banana plantations has helped in saving water and offers a great promise, owing to precise and direct application of water in the root zone of plants (Shashidhara *et al.* 2007) [17]. In addition, due to higher frequency of irrigation, ensuring availability of moisture at critical crop growth stages saves the plants from moisture stress throughout the growing period (Dahiwalkar *et al.* 2004) [8]. The other issue related to drip irrigation is its economic viability and the farmers are often reluctant to adopt this method due to their weak resource base.

Material and Methods

The present study was conducted during 2018-19 and 2019-20 at Horticultural Research Station, University of Agricultural Sciences, Bengaluru. The main objective of the study was to identify the optimum yield, post harvest and quality parameters under varied plant densities and different placement of emitters in banana *cv.* Grand Naine. The investigation was carried out by planting tissue cultured banana plants at 3 varied plant densities *viz.*, S_1 (1.5 x 1.5 m), S_2 (1.8 x 1.8 m) and S_3 (2.0 x 2.0 m) and 4 different placement of emitters E_1 (Placement of emitters at plain), E_2 (Placement of emitters at 40 cm), E_3 (Placement of emitters at 50 cm) and E_4 (Placement of emitters at 60 cm) with 3 replications. The treatments were imposed in the month of September 2018. Fertilizer application schedule followed with a dose of 200:100:300 g NPK (Urea, P_2O_5 and K_2O) per plant as per the package of practice of UAS, Bengaluru recommended for tissue cultured banana (Anon, 2017) [3]. A drip irrigation system was installed at the experimental site with different placement of emitters. The emitters' water discharge rate was 4 liters per hour. The treatment details are furnished as below.

T_1 (S_1E_1) 1.5 x1.5 m + Emitters Placement at 0 cm (plain) + 100% RDF
T_2 (S_1E_2) 1.5 x1.5 m + Emitters Placement at 40 cm + 100% RDF
T_3 (S_1E_3) 1.5 x 1.5 m + Emitters Placement at 50 cm + 100% RDF
T_4 (S_1E_4) 1.5 x 1.5 m + Emitters Placement at 60 cm + 100% RDF
T_5 (S_2E_1) 1.8 x1.8 m + Emitters Placement at 0 cm (plain) + 100% RDF
T_6 (S_2E_2) 1.8 x1.8 m + Emitters Placement at 40 cm + 100% RDF
T_7 (S_2E_3) 1.8 x1.8 m + Emitters Placement at 50 cm + 100% RDF
T_8 (S_2E_4) 1.8 x1.8 m + Emitters Placement at 60 cm + 100% RDF
T_9 (S_3E_1) 2 x 2 m + Emitters Placement at 0 cm (plain) + 100% RDF
T_{10} (S_3E_2) 2 x 2 m + Emitters Placement at 40 cm + 100% RDF
T_{11} (S_3E_3) 2 x 2 m + Emitters Placement at 50 cm + 100% RDF
T_{12} (S_3E_4) 2 x 2 m + Emitters Placement at 60 cm + 100% RDF
*Plain: Beside the plant

Result and Discussion

Significant difference was registered among the treatments with varied plant densities and different placement of emitters on yield per hectare in both plant and ratoon crop (Table 1).

The highest yield per hectare was registered in high plant density S_1 (1.5 x 1.5 m), while, it was lowest in lower plant density S_3 (2 x 2 m). With regard to placement of emitters the yield was found significantly highest with E_2 (Placement of emitters at 40 cm) and lowest in E_1 (placement of emitters at plain). The highest post harvest parameters *viz.*, pulp weight, peel weight, pulp to peel ratio and shelf life as well the highest quality parameters like total sugars, reducing sugar, non reducing sugar and total soluble solids were registered in S_3 (2 x 2 m) and E_2 (placement of emitters at 40 cm), while the lowest were found in S_1 (1.5 x 1.5 m) and E_1 (placement of emitters at plain) (Table 2 and 3).

The highest yield per hectare was registered in S_1 (1.5 x 1.5 m) and E_2 (placement of emitters at 40 cm) can be attributed to increase in plant population per unit urea (Ahmad and Manan, 1970) [1]. But the highest morphological and physiological characters was registered in low plant density S_3 (2 x 2 m), therefore it was recorded the highest yield in individual levels of plant, but number of plants occupied per hectare area was low. With respect to placement of emitters, increase in fruit yield was due to the improvement in bunch weight of banana under drip irrigation, possibly due to enhanced water utilization through drip, better nutrients uptake and excellent soil-water-air environment in the root zone.

Increase in the pulp weight was observed with decrease in plant density (S_3) and closer placement of emitters (E_2) may be due to high photosynthetic assimilates, better flow of assimilates in to growing fingers and beneficial optimum amount of water and also efficiency of nutrients. The results are in agreement with (Badway *et al.* 2010 [6] and Pawar and Dingre, 2013 [14]) in banana *cv.* Grand Naine.

Decrease in the mean peel weight was observed with lowest plant density (S_3) and closer placement of emitters'(E_2) might be due to high photosynthetic assimilates, better flow of assimilates for developing fingers particularly pulp weight. The results are in conformity by Basavaraj (2014) [7] and Puttana (2016) [15] in banana *cv.* Grand Naine

The highest values obtained with respect to pulp to peel ratio was observed with lower plant density (S_3) and placement of emitters at closer distance (E_2) might be due to the finger development phase; growing fruits act as heavy sink and better assimilates resulted in highest physiological efficiency. The results are in agreements with Ney Poovan (Murugan, 2003) [12] and Grand Naine, (Badway *et al.* 2010) [7].

Plant and ratoon crop extended of highest shelf life in lowest plant density (S_3) and closer placement of emitters (E_2) could be due to antisense properties inhibited ethylene biosynthesis and reduced metabolic activity which will help to extended shelf life. These results are well supported by the previous findings of banana *viz.*, Cavendish banana (Kurien *et al.* 2000) [10] and Nendran (Manivannan, 1994). [11]

The highest total sugar content was registered in lowest plant density (S_3) and closer placement of emitters (E_2) could be due to the fact that, low plant density might have caused increase in light efficiency led to greater photosynthetic activity in the banana plant. With respect to closer placement of emitters, it can provide more precise and uniform amount of the water. These findings are in corroboration with Ney Poovan (Murugan, 2003) [12], Rajapuri (Athani and Hulamani, 2000) [5].

Both the plant and ratoon crop had the highest reducing sugar content in lower plant density (S_3) and closer placement of emitters (E_2). It might me due to allowing proper light distribution in the plants which is a key function in increasing the quality of fruits. Further, the optimum amount of water through more number of emitters improved the nutrient uptake and nutrient mobilization towards growing fruits led to good sugar content as reported by from the work of Ney Poovan (Murugan, 2003) [12], Robusta (Nalina *et al*. 2003) [13].

In the present study, lower plant density (S_3) and closer placement of emitters (E_2) increased TSS. This might be due to light interception of the plant canopy regulation during vegetative growing period and better utilization and efficiency of water. This is in line with the work of Poovan (Sanjay, 2011) [16] and Grand Naine, (Gaonkar, 2018) [9].

Table 1: Effect of different plant densities and placement of emitters on yield (tons/ha) in Banana *cv.* Grand Naine

Treatments	Yield (tons/ha)	
	Plant crop	Ratoon crop
Factor-01	Spacing	
S_1	79.37	77.75

S_2	68.25	60.00
S_3	51.35	46.42
S.Em +	1.45	1.53
C.D.at 5%	4.29	4.53
Factor-02	Placement of Emitters	
E1	54.33	51.43
E2	86.48	73.72
E3	65.86	62.64
E4	58.63	57.77
S.Em +	1.68	1.77
C.D.at 5%	4.96	5.23
Interaction effect (S X F)		
S_1E_1	69.68	66.65
S_1E_2	94.21	90.60
S_1E_3	78.15	77.40
S_1E_4	75.44	76.35
S_2E_1	52.00	47.82
S_2E_2	93.59	77.70
S_2E_3	70.60	62.80
S_2E_4	56.81	51.69
S_3E_1	41.33	39.84
S_3E_2	74.64	52.88
S_3E_3	48.82	47.72
S_3E_4	43.63	45.27
S.Em +	2.91	3.07
C.D.at 5%	NS	NS

NS: Non Significant

Table 2: Post harvest parameters as influenced by different plant densities and placement of emitters in Banana *cv.* Grand Naine

Treatments	Pulp weight (g)		Peel weight (g)		Pulp to peel ratio		Shelf life (Days)	
	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop
Factor-01	**Spacing**							
S_1	70.78	68.02	49.73	47.96	1.45	1.45	6.87	6.74
S_2	79.30	77.67	47.25	45.42	1.75	1.75	7.48	7.38
S_3	82.15	80.45	46.00	43.86	1.83	1.89	8.19	7.71
S.Em +	0.28	0.52	0.66	0.58	0.03	0.02	0.32	0.15
C.D.at 5%	0.83	1.55	1.95	1.713	0.11	0.08	0.94	0.45
Factor-02	**Placement of Emitters**							
E1	59.16	58.07	53.33	51.51	1.15	1.12	6.71	6.7
E2	104.53	101.57	42.04	40.05	2.50	2.54	8.52	7.63
E3	77.50	75.71	46.31	44.71	1.67	1.70	7.69	7.49
E4	68.45	66.17	48.96	46.73	1.39	1.41	7.14	7.21
S.Em +	0.32	0.60	0.76	0.67	0.04	0.03	0.37	0.17
C.D.at 5%	0.96	1.79	2.25	1.97	0.13	0.09	1.09	0.52
Interaction effect (S X F)								
S_1E_1	56.54	55.07	56.00	53.57	1.08	1.02	5.71	6.62
S_1E_2	92.76	88.25	44.00	41.66	2.11	2.11	8.08	6.84
S_1E_3	69.28	67.32	48.93	48.41	1.41	1.38	7.03	6.84
S_1E_4	64.55	61.46	50.03	48.22	1.28	1.27	6.67	6.67
S_2E_1	59.68	58.56	53.00	51.19	1.25	1.14	6.68	6.90
S_2E_2	109.06	107.53	42.04	40.46	2.60	2.66	8.11	7.85
S_2E_3	80.20	78.24	46.04	44.25	1.74	1.77	7.74	7.72
S_2E_4	68.26	66.35	48.07	45.79	1.42	1.44	7.38	7.06
S_3E_1	61.26	60.59	51.07	49.77	1.19	1.21	7.71	6.84
S_3E_2	111.78	108.92	40.12	38.02	2.79	2.86	9.38	8.20
S_3E_3	83.03	81.58	44.00	41.47	1.88	1.96	8.31	7.91
S_3E_4	72.54	70.72	48.88	46.19	1.48	1.52	7.38	7.95
S.Em +	0.56	1.05	1.32	1.16	0.07	0.05	0.64	0.30
C.D.at 5%	1.66	3.11	NS	NS	NS	0.17	NS	NS

NS: Non Significant

Table 3: Quality parameters as influenced by different plant densities and placement of emitters in Banana *cv.* Grand Naine

Treatments	Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)		TSS (^{0}Brix)	
	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop	Plant crop	Ratoon crop
Factor-01	**Spacing**							
S_1	17.19	15.94	15.10	14.57	2.05	1.37	20.92	20.25
S_2	19.33	18.41	16.91	16.17	2.26	2.21	22.98	22.48
S_3	19.56	19.00	16.96	16.46	2.70	2.54	23.11	22.25

S.Em +	0.11	0.07	0.14	0.05	0.12	0.03	0.04	0.08
C.D.at 5%	0.33	0.21	0.13	0.14	0.37	0.11	0.14	0.24
Factor-02	**Placement of Emitters**							
E1	17.86	17.25	16.14	15.45	1.86	1.79	21.56	20.81
E2	19.54	18.40	16.59	16.04	2.75	2.35	23.37	22.57
E3	18.87	17.93	16.33	15.86	2.54	2.06	22.46	21.80
E4	18.51	17.57	16.22	15.57	2.20	1.95	21.96	21.42
S.Em +	0.13	0.08	0.05	0.05	0.14	0.04	0.05	0.09
C.D.at 5%	0.38	0.25	0.15	0.17	0.42	0.12	0.16	0.28
Interaction effect (S X F)								
S_1E_1	16.60	15.56	14.95	14.15	1.65	1.41	20.24	19.90
S_1E_2	17.70	16.47	15.42	14.99	2.36	1.47	21.28	20.08
S_1E_3	17.32	16.07	15.06	14.75	2.26	1.32	21.23	20.65
S_1E_4	17.16	15.67	14.96	14.37	1.94	1.29	20.95	20.37
S_2E_1	18.46	18.07	16.73	16.07	1.73	1.94	22.28	21.89
S_2E_2	20.22	19.09	17.15	16.32	2.42	2.77	24.31	23.69
S_2E_3	19.52	18.35	16.90	16.19	2.62	2.16	23.03	22.21
S_2E_4	19.14	18.20	16.86	16.11	2.27	1.97	22.31	22.11
S_3E_1	18.52	18.17	16.76	16.14	2.19	2.03	22.16	20.63
S_3E_2	20.70	19.64	17.21	16.82	3.48	2.82	24.51	23.94
S_3E_3	19.77	19.37	17.02	16.65	2.75	2.72	23.15	22.53
S_3E_4	19.24	18.83	16.85	16.24	2.39	2.59	22.62	21.77
S.Em +	0.22	0.14	0.09	0.10	0.25	0.07	0.09	0.16
C.D.at 5%	NS	NS	NS	NS	NS	0.22	0.29	0.49

NS: Non Significant

Conclusion

Application of three varied plant densities and four different placement of emitters influenced on yield, post harvest and quality parameters of banana *cv.* Grand Naine. The yield per hectare was found highest in high plant density (S_1) and closer placement of emitters (E_2) which is due to more plant population per unit area. The highest post harvest and quality parameters were registered highest in low plant density (S_3) and closer placement of emitters (E_2). Whereas the lowest was observed in higher plant density (S_1) and wider placement of emitters (E_1). However, long-term studies are needed to determine the effect of different plant densities and placement of emitters as well as their interaction effect with other factors such as fertilizer, desuckering and management practices.

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