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System Intensification for Enhanced Productivity and Water use Efficiency in Banana [*Musa* (AAB) Nendran]

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ABSTRACT

Background: The steady demand for banana due to its varied uses makes banana a high value crop. In Kerala, more than 70 per cent of banana cultivation is done on leased lands and hence obtaining maximum income from a unit area assumes utmost importance. High density planting (HDP) could realize it, but had to be standardised in agro climatic regions of the state using specific cultivars and management level.

Methods: Field experiments were conducted at Agronomic Research Station, Chalakudy, Kerala to assess the water use efficiency and productivity of banana variety Nendran under HDP. The experiment was laid out in factorial RBD with irrigation methods and crop geometry as the factors. Irrigation methods included drip irrigation with 50% pan evaporation compensation (PE) and 75% PE on alternate days (I_1 and I_2) and basin irrigation with 100% PE on alternate days (I_3). Geometry treatments consisted of planting single plants at spacing of 2 m × 2 m (G_1), planting 2 plants/hill at a spacing of 2.6 m × 2.6 m (G_2) and planting 3 plants/hill at spacing of 3.0 m × 3.0 m (G_3) resulting in 2500, 2950 and 3330 plants/ha respectively.

Result: High density planting with 3 plants / hill resulted in increased yield by 21.6% over single plant/pit. Drip irrigation at 75% PE produced comparable yields with basin irrigation at 100% PE and had higher water use efficiency than basin irrigation. In banana HDP with 3 plants/hill under drip irrigation at 75% pan evaporation compensation on alternate days can be recommended to farmers of Kerala.

Key words: Banana, Drip irrigation, High density planting, Water use efficiency.

INTRODUCTION

Bananas are the fourth important staple food and is one of the richest sources of carbohydrates that provide energy (104 calories/100 g) and are also equally rich in vitamins and minerals notably potassium, phosphorus and calcium and thus the crop as a food provides a more balanced diet than other fruits. It is the most important tropical fruit crop of the world with India as the largest producer and consumer. In India among fruit crops, banana ranks first in production and third in area. The steady demand for banana due to its varied uses and wide adaptability to different farming situations makes it a high value crop. In Kerala, the variety Nendran (*Musa* AAB) occupies the first choice and the fruit is in good demand in the State. Its mean yield is very low at 5-6 kg/ plant and management inadequacies alone shall be the cause of this low yield and the situation necessitates a revised formulation of the present production technology of this crop. More than 70 per cent of banana cultivation is done on leased lands by resource-poor farmers, and hence obtaining maximum income from a unit area under cultivation assumes utmost importance. Thus, the emphasis has been on the increase in the productivity by making the best use of vertical and horizontal space per unit time and to harness maximum possible return per unit of inputs. In recent years, there has been considerable emphasis on high-density planting wherein yield of an individual plant cannot be increased beyond a certain limit. However, total yield and net returns can be increased per unit area by adopting closer spacing. Several studies have been conducted in banana to elucidate high density planting (HDP) in banana but the same has to be standardised in different agro climatic regions using different cultivars. Choice of spacing depends upon cultivar and, further, varies from region to region depending upon soil type and fertility, cultural practices of the area and management level (Mustaffa and Kumar, 2012). In HDP, microirrigation and fertigation could be conveniently and successfully practiced. Moreover, the use efficiency of limited and expensive resources like irrigation water and fertiliser can also be improved. Hence the study was taken up to assess the water use efficiency and productivity of banana variety Nendran under modified high density planting in the sandy loam soils of Kerala.

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MATERIALS AND METHODS

Location

The field experiment was conducted during 2010-2013 at Agronomic Research Station, Chalakudy, located at 10° 20'

North latitude and 76° 26' East longitude at an elevation of 3.25 above MSL, Kerala under All India Co-ordinated Programme on Water Management.

Soil and climate

The soil was sandy loam in texture, having a bulk density of 1.3 g cm^{-3} and the depth of 50 cm. Soil was acidic in nature with a pH of 5.5 and the EC was less than 0.5 dSm^{-1}. The surface soil had low content of potassium and nitrogen and medium content of phosphorus. The physicochemical characteristics of soil in the experimental site are detailed in Table 1.

The experimental site enjoys a typical humid tropical climate. The area received both South West monsoon and North East monsoon and a few summer showers. The South West monsoon contributed to more than 75% of the total rainfall. Average rainfall varied from 3000 to 3500 mm and maximum rain was received during June and July. The average evaporation rate during December to May was 5 $mmday^{-1}$. Maximum temperature ranged from 35 to 37°C and minimum 18 to 24°C.

Experimental treatments

The experiment was laid out in Factorial Randomised Block Design with irrigation methods and crop geometry as the factors.

Irrigation methods (Factor A)

I_1: Irrigation at 50% PE (pan evaporation compensation) through drip on alternate days.
I_2: Irrigation at 75% PE through drip on alternate days.
I_3: Irrigation at 100% PE in basin on alternate days.

Crop geometry (Factor B)

G_1: Single plants at spacing of 2 m × 2 m with 2500 plants ha^{-1}.
G_2: Planting 2 plants / hill at a spacing of 2.6 m × 2.6 m with 2950 plants ha^{-1}.
G_3: Planting 3 plants / hill at a spacing of 3.0 m × 3.0 m with 3330 plants ha^{-1}.

Crop production

Planting was done during the month of November. Healthy sword suckers weighing around 1 kg each of banana cv. Nendran (AAB group) were used for planting. Number of suckers and spacing varied with treatments. Crop Geometry treatments consisted of planting single sucker at spacing of 2 m × 2 m(G_1), planting 2 suckers / hill at a spacing of 2.6 m × 2.6 m (G_2) and planting 3 suckers / hill at a spacing of 3.0 m × 3.0 m(G_3). In G_1, ridges were taken 2 m apart and banana suckers were planted on each ridge, in pits of size 50 cm × 50 cm × 50 cm. The spacing provided for each plant was 2 m within the row, resulting in a plant population of 2500 plants ha^{-1}. In G_2, ridges were taken 2.6 m apart and 2 banana suckers planted side by side in separate pits constituted a hill and a wider spacing of 2.6m was provided for each hill resulting in a plant population of 2950 plants ha^{-1}. Similarly in G_3, 3 suckers planted in pits in a circular manner constituted a hill and a spacing of 3.0 m × 3.0 m was provided holding 3330 plants ha^{-1}.

Irrigation was initiated during the month of December, after the cessation of North East monsoon. The water requirement of banana was computed on the basis of PE, canopy area factor and wetted area factor. Observations on pan evaporation was taken daily from US class A open pan evaporimeter maintained in the research station. In basin irrigation, 100% of pan evaporation was compensated on alternate days through irrigation, while in drip 50 and 75% of pan evaporation was compensated respectively in I_1 and I_2. Two emitters with discharge rate of 8 l h^{-1} were placed for each plant, so that irrigation was provided on both sides of the plant. The total quantity of water provided were 980, 1470 and 1960 litres $plant^{-1}$ respectively for I_1, I_2 and I_3. The treatments were replicated thrice. All other operations, nutrients and plant protection measures were provided on need basis to all the plants uniformly as per Kerala Agricultural University recommendations.

Biometric observations of growth and yield parameters of banana crop as well as water requirement and consumption were recorded and were subjected to ANOVA for factorial RBD. The treatment means were compared at 5% probability level.

RESULTS AND DISCUSSIONS

From the study, it was inferred that the total production per unit area (t ha^{-1}) was significantly increased (Table 2), as the irrigation provided was enhanced from 50 % to 75% through drip. Compensation of 100% PE through basin irrigation was found comparable with drip irrigation at 75% PE resulting in saving of irrigation by 25% through drip. Conventional basin application of water characterized by heavy doses at wider intervals lead to losses and reduced efficiency of irrigation water (Thomas, 2001). For banana, replenishment of evaporation losses up to 80% through drip was found to be optimal for realizing higher yields (Mustaffa and Kumar, 2012). However, increase in irrigation water supplied did not increase the yield per plant significantly though progressive increase in yield per plant was observed.

The other factor, crop geometry had significant influence the bunch yield per plant as well as the production per unit area. When the number of plants per hill increased, the yield per plant decreased significantly, but increased the total production per unit area. On considering the total yield per hectare, high density planting (HDP) with 3 plants/ hill resulted in increased yield by 21.6 per cent over single plant/ hill and was on par with 2 plants/hill Planting of 2-3 plants/ pit resulted in more yield, because of higher number of plants available per hectare in these two treatments. Reports on high density planting conducted in different places showed that HDP could increase banana yield and income of the farmers (Chaudhuri and Baruah, 2010). The establishment of banana crops under high density planting is a management practice that not only optimizes the use of natural resources, but also allows increasing productivity

Table 1: Initial physicochemical properties of the experimental soil.

Particulars	Content	Method used
Sand (%)	79.5	Robinson international pipette method (Piper, 1966)
Silt (%)	9.5	
Clay (%)	11	
Bulk density (g cm^{-3})	1.3	Keen Raczkowski box (Piper, 1966)
pH	5.5	Soil water suspension 1:2.5 and read in a pH meter (Jackson, 1958)
EC (dS/m)	0.4	Soil water suspension 1:2.5 and read in a conductivity meter (Jackson, 1958)
Organic carbon (%)	0.4	Wet digestion method (Walkley and Black, 1934)
Available N (kg ha^{-1})	90	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	11	Bray-I extractant ascorbic acid reductant method (Watanabe and Olsen, 1965)
Available K (kg ha^{-1})	37	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958)

Table 2: Yield of banana as influenced by irrigation levels and crop density pooled over three years.

Treatments	Yield kg $plant^{-1}$				Yield t ha^{-1}			
	I Year	II Year	III Year	Pooled	I Year	II Year	III Year	Pooled
I_1	7.17	7.40	10.45	8.66	20.88	21.79	30.19	24.05
I_2	7.23	8.05	11.46	8.91	20.78	23.47	33.25	25.83
I_3	7.42	8.87	10.44	9.04	21.61	25.94	31.45	24.32
CD (0.05)	NS	1.067	NS	NS	NS	3.392	NS	1.66
G_1	7.74	8.07	11.36	9.06	19.36	20.20	30.20	22.64
G_2	7.27	8.15	11.09	8.84	21.45	24.02	32.73	26.30
G_3	7.11	8.11	9.59	8.27	22.46	27.01	31.97	27.54
CD (0.05)	0.428	NS	1.150	0.58	1.985	3.392	NS	1.66

without affecting fruit quality (Gogoi, 2015; Hanuman *et al*. 2016). However, reduced bunch weight is a frequent result of HDP in the Musaceae. According to Gogoi *et al*. (2015) bunch weight reduction is due to a higher solar radiation intersection, which certainly affected the translocation of assimilates (Thippesha *et al*. 2008).

With increase in plants per hill, the number of hands produced in the bunch decreased, thereby the yield per plant also decreased (Table 3). Swain *et al*. (2020) also stated that HDP treatments resulted in reduced hands per bunch and bunch weight but higher total yield. High planting densities were found to negatively affect assimilation by the last hand (Violet *et al*. 2020). In single planting, the number of hands increased with increase in irrigation from 50 to 75 % but further increase through basin irrigation did not increase the number of hands. This confirms that basin irrigation at 100% recommendation and drip irrigation at 75% recommendation are on par. As the crop density increased, similar trend was not observed and the number of hands produced per plant did not vary with irrigation levels.

Drip irrigation at I_1 and I_2 produced comparable number of fingers but resulted in less number of fingers when compared to irrigation at 100% PE (Table 4). This shows that banana being a succulent water loving plant, responds well to irrigation. The number of fingers did not vary significantly with crop geometry, as water and nutrients were provided for all the plants according to their individual requirements. Crop did not face any scarcity and this resulted in the number of fingers comparable to that of single plant.

Water being a scarce resource, its efficient use is imperative and under conditions of limited water supply, drip irrigation can be adopted. Drip at 50 and 75 % PE had higher water use efficiency than basin irrigation at 100% PE, but drip at 75% PE was on par with basin at 100% (Table 5). The results showed that water can be saved by 25% when drip irrigation 75% was practiced instead of traditional basin irrigation. Further decrease in water reduced yield significantly. As the population per unit area increased from single planting to 2 plants per hill, WUE also increased. Two plants and three plants per hill had comparable WUE. Kumar *et al*. (2012) also reported that in banana, high density planting combined with drip resulted in better input use efficiency and saving of 30-40% irrigation water as compared to conventional method. This resulted in increased production, productivity and fruit quality with reduction of cost of cultivation. Drip irrigation gave 3-14.5% increase in banana fruit yield and 52% water saving over surface irrigation and the quality of banana fruits was not affected significantly (Pawar *et al*. 2017).

The analysis of BC ratio of different irrigation methods showed that BC ratio of 2.47 could be obtained with drip irrigation at 75% PE, while the BC ratio of basin irrigation was 2.70 (Table 6). Drip requires high installation charges, though it avoids the highly expensive labour component.

Table 3: Number of hands produced under different treatments (Nos./ Plant).

Treatments	G_1	G_2	G_3	Mean
I_1	5.00	5.23	4.97	5.06
I_2	5.50	4.72	4.63	4.95
I_3	5.42	4.80	4.99	5.07
Mean	5.31	4.92	4.86	
CD (0.05%)	G- 0.20;	I- NS;	I × G-0.346.	

Table 4: Number of fingers produced under different treatments pooled over three years (Nos./Plant).

Treatments	G_1	G_2	G_3	Mean
I_1	44.60	45.54	45.16	45.09
I_2	46.74	45.73	44.37	45.61
I_3	51.00	48.9	49.0	49.67
Mean	47.45	46.74	46.19	
CD (0.05%)	G- NS;	I- 2.319 ;	I×G – NS	

Table 5: WUE of banana under different treatments pooled over three years (kg/ha cm).

Treatments	WUE(kg/ha cm)			
	G_1	G_2	G_3	Mean
I_1	981.63	896.57	759.33	879.17
I_2	606.8	606.48	558.52	590.6
I_3	496.33	470.77	437.12	468.07
Mean	694.92	657.94	584.99	
CD-(0.05%)	I-104.086;	G-104.086;	I × G-180.282.	

Table 6: Economics of production of banana under different treatments.

Treatments	B:C Ratio			
	G_1	G_2	G_3	Mean
I_1	1.70	2.41	2.58	2.23
I_2	2.03	2.47	2.92	2.47
I_3	2.23	2.69	3.18	2.70
Mean	1.98	2.52	2.89	

Among the different crop geometries tried planting of three plants per hill registered the highest BC ratio (2.89) as it yielded more and avoided additional expenses on cost of standards or props and labour. Two plants per hill also resulted in a BC ratio of 2.52. Thus high density planting (3 plants/ hill) and drip irrigation at 75% PE were more beneficial in terms of income (B:C ratio 2.92) and water use efficiency. Kumar *et al.* (2012) reported that under the modified HDP technology demonstrated in Nendran banana, the cost of production per plant was significantly reduced to Rs. 50 per plant as against a cost of Rs. 80 per plant under conventional system of cultivation. During last four decades, the importance of high density planting for higher productivity of fruit crops have been realized and now it has become one of the most successful tools of the Hi-Tech horticulture ensuring efficient use of land, water, nutrients and solar radiation with higher production per unit area. HDP offers early cropping and higher yields, improved fruit quality, reduced labour costs, enhanced mechanization in production with efficient use of different production resources leading to higher income per unit area (Tripathi *et al.* 2020).

CONCLUSION

Basin irrigation at 100 per cent PE significantly increased the bunch yield /plant and yield per unit area and was on par with drip irrigation at 75% PE. Water saving up to 25% could be obtained by following drip irrigation at 75% PE. High density planting with 3 plants/hill increased the yield by 21.6% over single plant/pit on per hectare basis. HDP (3 plants/hill) and irrigation at 75% PE were more promising for better income and water use efficiency. The study conclusively proved that high density planting with 3 plants per hill under drip irrigation at 75% pan evaporation compensation on alternate days is a viable practice for banana cultivation in Kerala.

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Conflict of interest: None.

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