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Identification of optimum leaf area index (LAI) for high density planting of banana cv. martaman in *Gangetic Alluvium* region of West Bengal

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ABSTRACT

An experiment was conducted under the All India Coordinated Research Project on Fruits, Bidhan Chandra Krishi Viswavidyalaya to identify the optimum leaf area index (LAI) for high density planting of banana cv. Martaman (Musa AAB) in the Gangetic Alluvium region of West Bengal. The experiment was laid out in RBD, replicated four times with four treatment combinations of pit spacings and planting densities viz., T1: 2.0 x 3.0m with 3 suckers pit^{-1} (5000 plants ha^{-1}), T2 : 1.8 × 3.6m with 3 suckers pit^{-1} (4630 plants ha^{-1}), T3 : 1.5 × 2.0m with 2 suckers pit^{-1} (6666 plants ha^{-1}) and T4 : 2 × 2m with 1 sucker pit^{-1} (4444 plants ha^{-1}) as control. Analysis and interpretation of the data observed on plant growth, fruit yield, fruit quality and canopy micro-climate parameters revealed that the LAI gradually increased from 3.36 per pit for 2,500 plant ha^{-1} (T1) to 6.11 per pit for 6,666 plant ha^{-1} (T3), while the bunch weight gradually declined from 15.40 kg (T1) to 13.15 kg (T3). The highest B:C ratio of 2.30 was estimated due to the LAI of 5.50 for a plant population of 5,000 ha^{-1}and bunch weight of 14.95 kg (T1). The light intensity of canopy microclimate drastically reduced in dense population (2.5 thousand Lux in T3), compared with 7.2 thousand Lux under conventional planting density of 2,500 plant ha^{-1} (T4). Incidence of leaf spot diseases increased above plant population of 5000 ha^{-1}. The fruit quality with respect to total soluble sugar, ascorbic acid and total sugar content varied significantly, except for fruit acidity. The identified optimum LAI was 5.50 for high density planting of banana cv. Martaman, corresponding to a plant population of 5000 ha^{-1}with 2 × 3 m spacing of pit and 3 plant pit^{-1} in the Gangetic alluvium region of West Bengal.

***Keywords**: Banana, cv. Martaman, high density planting, optimum leaf area index (LAI)*

One of the major objectives of commercial fruit cultivation is the sustainable increase of productivity to meet per head demand of fruits for human nutrition. Canopy management is one of the successful approaches to achieve high density planting and increased productivity. Training and pruning practices are useful for canopy management of perennial fruit trees but not applicable for crops like banana. Hence, the performance of high density planting for increased productivity of banana depends on the management of optimum leaf area index (LAI). Turner (1998) reported that productivity in bananas is governed by 'source' and 'sink' components of the plant system and LAI could be used as a management tool but it was necessary to distinguish between physiological and agronomic approaches to its use. Sirisena and Senanayake (1997) recorded the significant effects of leaf number and LAI on penetration of photosynthetically active radiation (PAR), crop growth and yield parameters of banana. Higher densities of planting of banana was found to have direct effect on growth and yield parameters including leaf number, LAI, absorption of solar light and productivity (Nalina *et al*., 2000; Thippesha *et al*., 2005). Rodriguez *et al.* (2007) reported that different plant density and spacing gave different canopy structures and affected canopy photosynthesis and yield of cv. Williams in Costa Rica. The LAI was directly proportional to the plant densities (LAI=0.0017* density+0.2178; R2=0.85) and highest densities intercepted the greatest amount of PAR. For high density planting of banana cv. Martaman (AAB) under the Gangetic Alluvium region of West Bengal, it was needed to identify the optimum LAI and accordingly an experiment was designed and conducted under the All India Coordinated Research Project on Fruits, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India.

MATERIAL AND METHODS

The experiment was conducted under the All India Coordinated Research Project on Tropical Fruits of BCKV, Mondouri, Nadia, West Bengal during 2008-13 on banana cv. Martaman. The experiment was laid out in a Randomized Block Design, replicated five times with four treatment combinations of spacings and planting densities *viz*., T1 : 2.0 × 3.0 m with 3 suckers pit^{-1} (5000 plants ha^{-1}), T2 : 1.8 × 3.6 m with 3 suckers pit^{-1} (4630 plants

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ha^{-1}), T3 : 1.5 × 2.0m with 2 suckers pit^{-1} (6666 plants ha^{-1}) and T4 : 2 × 2m with 1 sucker pit^{-1} (2500 plants ha^{-1}) as control. Uniform, healthy sword suckers were used as planting materials and planted in 1m^3 pits in March, 2008 as per spacing treatments. Recommended package of practice (nutrition, irrigation, protection *etc.*) including recommended dose of fertilizer (RDF @ 10kg FYM + 200g N, 50g P_2O_5 & 200g K_2O plant^{-1} year^{-1}) were applied uniformly to all treatments. Observations were recorded on growth characters like pseudostem height (m), girth (cm), leaf number, leaf area per plant (cm^2), leaf area per pit (cm^2), LAI per plant and per pit and crop duration (days). The leaf area per plant was calculated as leaf length (m) × leaf breath (m) × 0.8 × number of leaf per plant and the LAI was calculated by dividing total leaf area per plant by ground covered (m). Light intensity (in thousand lux) under the canopy (1.5 m above ground level) was recorded with a digital lux meter (INS DX-100) at shooting stage. Data were recorded on bunch weight (kg), fruit yield (kg) per pit and productivity (t ha^{-1}). Quality of fruit was analyzed as per A.O.A.C. (1984) methods and B:C ratio was estimated. Three crop cycles' pooled data were analyzed for statistical inference following the statistical method for Randomized Block Design (RBD) described by Gomez and Gomez (1983).

RESULTS AND DISCUSSION

Data presented in table1 revealed that spacing and density of planting of Martaman banana showed significant variations in crop growth, leaf number, LAI and crop duration. The pseudostem height at shooting stage was maximum (3.21 m) in highest density of 6666 plants ha^{-1} (T_3) and it was minimum (2.65 m) in lowest density of 2500 plants ha^{-1} (T_4). In contrast, the girth of pseudostem at shooting stage was maximum (67.72 cm) in lowest density of 2500 plants ha^{-1} (T_4), which gradually declined due to increase in density and recorded minimum (63.20 cm) in highest density of 6666 plants ha^{-1} (T_3). Hence, it is indicated that banana plant has a tendency of increasing height and decreasing girth due to higher density of plant population per unit area. The lowest density of plant (T_4: 2500 ha^{-1}) recorded highest number of leaf (14.30) and leaf area (13.44 m^2) per plant which declined due to increase in density and recorded lowest (11.60 and 9.16 m^2, respectively) in highest density (T6 : 6666 ha^{-1}). However, leaf area per pit was maximum (34.70 m^2) due to spacing of 1.8 × 3.6m with 3 suckers pit^{-1} (T2 : 4630 plants ha^{-1}) and it was minimum (13.44 m^2) due to conventional spacing of 2 × 2 m with 1 sucker pit^{-1} (T4 : 2500 plants ha^{-1}). The conventional spacing (T4) also recorded highest LAI per plant (3.36) but lowest LAI per pit (3.36) due to planting of only one sucker per pit. LAI per pit gradually increased due to higher density and recorded maximum (6.11) in 1.5 × 2.0m spacing with 2 suckers pit^{-1} (T_3 : 6666 plants ha^{-1}). It was noted that although the size and number of leaf of individual plant under high density planting decreased, the total number of plant and leaf per unit area were much higher and hence the LAI was also much higher. Nalina *et al.* (2000) and Thippesha *et al.* (2005) also reported the effect of high density planting of banana that increased the pseudostem height, leaf number, leaf area and LAI but reduced the pseudostem girth. The crop duration was recorded lowest (406.07 days) in conventional low planting density (2500 plants ha^{-1}), which gradually increased due to higher planting densities and it was recorded maximum (423.28 days) due to the highest planting density (6666 plants ha^{-1}). Rodriguez *et al.* (2007) observed that higher density gave different canopy structures and influenced the morphological and productive variables of the individual plants. That type of influence on morphological and productive variables could be the reason for increasing crop duration in high density planting of present study.

Table 1: Effect of spacings and plant densities on growth attributes at shooting and crop duration of Martaman banana

Treatments	Pseudostem height (m)	Girth (cm)	Leaf number plant^{-1}	Leaf area plant^{-1} (m^2)	Leaf area pit^{-1} (m^2)	LAI plant^{-1}	LAI pit^{-1}	Crop duration (Days)
T1 (5000 plants ha^{-1})	3.13	65.43	13.10	11.00	33.01	1.83	5.50	417.85
T2 (4630 plants ha^{-1})	2.94	65.91	13.45	11.57	34.70	1.79	5.36	411.10
T3 (6666 plants ha^{-1})	3.21	63.20	11.60	9.16	18.33	3.05	6.11	423.28
T4 (2500 plants ha^{-1})	2.65	67.72	14.30	13.44	13.44	3.36	3.36	406.07
SEm (±)	**0.05**	**1.17**	**0.15**	**0.12**	**2.90**	**0.03**	**0.44**	**2.24**
LSD (0.05)	**0.26**	**1.66**	**0.74**	**0.61**	**14.61**	**0.15**	**2.15**	**11.04**

It was evident from table2 that yield and quality of fruit varied significantly due to spacing and high density planting of Martaman banana, except acidity content of fruit. The bunch weight gradually decreased from 15.40 kg in conventional spacing (T4: 2500 plants ha^{-1}) to only 13.15 kg in highest planting density (T3: 6666 plants ha^{-1}). But total bunch weight per pit was much higher under all high density treatments (T2, T1 & T3), due to more than one plant per pit at high density planting. Fruit yield per pit was maximum (45.00 kg) in 4630 plants ha^{-1}, followed by 44.85 kg in 5000 plants ha^{-1}. However, fruit yield was maximum of 87.66 t ha^{-1} corresponding to the highest number of plants ha^{-1} (T3 : 6666), followed by 74.75 t ha^{-1} in T1 treatment (5000 ha^{-1}) and 69.45 t ha^{-1}in T2 treatment (4630 ha^{-1}). It was noted that although the bunch weight of individual plant under high density planting decreased, the total number of plant and bunch per unit area were much higher and hence the productivity was also much higher. Similar effects of planting densities on productivity of banana were also reported by Israeli and Nameri (1988) and Robinson *et al.* (1993).

Table 2: Yield and quality of fruit and benefit cost ratio of Martaman banana due to spacing and high density planting

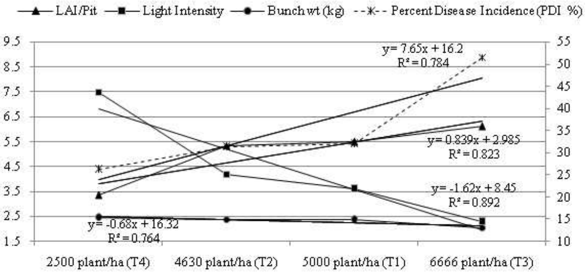
Treatments	Fruit yield			Fruit quality				Benefit : cost
	Bunch wt. (kg)	Yield (kg pit^{-1})	Yield (t ha^{-1})	TSS (^{0}Brix)	Acidity (%)	Ascorbic acid (mg 100^{-1} g)	Total sugar (%)	
T1 (5000 plants ha^{-1})	14.95	44.85	74.75	23.40	0.25	18.55	22.00	2.30 : 1
T2 (4630 plants ha^{-1})	15.00	45.00	69.45	23.60	0.24	18.20	22.10	2.21 : 1
T3 (6666 plants ha^{-1})	13.15	26.30	87.66	22.10	0.27	19.10	21.40	2.02 : 1
T4 (2500 plants ha^{-1})	15.40	15.40	38.50	24.20	0.22	17.50	22.05	2.11 : 1
SEm (±)	**0.13**	**1.49**	**1.35**	**0.11**	**0.01**	**0.13**	**0.07**	**-**
LSD (0.05)	**0.65**	**7.36**	**6.65**	**0.53**	**NS**	**0.66**	**0.37**	**-**

Data presented in table- 3 revealed that spacing and density of planting caused significant variations in LAI per pit, bunch weight, light intensity of micro-climate and incidence of leaf spot diseases of Martaman banana. The line diagrams with regression equations and R-square values of those parameters as displayed in fig.- 1, showed that LAI per pit and percent disease incidence (PDI %) were positively correlated with density of planting, while bunch weight per plant and light intensity of micro-climate of plant canopy were negatively correlated. It was also evident from table 3 and fig. 1 that the density of planting more 5000 plants ha^{-1} caused LAI per pit to be more than 5.50, which showed adverse effect on the micro-climate of plant canopy by reducing its light intensity and resulting in increased incidence of leaf spot diseases.

Table 3: Effect of LAI on bunch weight, light intensity of micro-climate and incidence of leaf spot diseases of Martaman banana due to varied planting density

Treatments	LAI pit^{-1}	Bunch weight (kg)	Light intensity of canopy micro-climate (000' Lux)	PDI (0-4 scale) (%)
T1 (5000 plants ha^{-1})	5.50	14.95	3.60	32.0
T2 (4630 plants ha^{-1})	5.36	15.00	4.20	31.4
T3 (6666 plants ha^{-1})	6.11	13.15	2.30	51.6
T4 (2500 plants ha^{-1})	3.36	15.40	7.50	26.3
SEm (±)	**0.44**	**0.13**	**0.25**	**0.97**
LSD (0.05)	**2.15**	**0.65**	**1.24**	**4.81**

Note: PDI= Percent disease intensity (%) was recorded on a scale of 0 to 4 as described by Stover (1971), where 0 =< 10 disease spots leaf^{-1}, 1 => 5% leaf area affected, 2 = 5-15% leaf area affected, 3 = 16-33% leaf area affected and 4 => 33% leaf area affected.



Note: Y1: LAIpit^{-1}, Light intensity (000' Lux); Y2: Bunch weight (Kg), PDI (%)

Fig.1 : Effect of LAI on bunch weight, light intensity of micro-climate and incidence of leaf spot diseases of Martaman banana due to density of planting

The additional costs of management of leaf spot diseases and removal of suckers due to planting density of 6666 plants ha^{-1} resulted in lower benefit : cost ratio of 2.02: 1, compared with higher benefit : cost ratio of 2.30 : 1 due to planting density of 5000 plants ha^{-1}. The LAI less than 5.50, as estimated due to plant population of less than 5000 ha^{-1}, also recorded lower benefit - cost ratio of 2.21: 1 and was uneconomical as compared that of the LAI of 5.50. Findings of the experiment on planting densities (2381, 3571 and 4762 plants ha^{-1}) conducted by Israeli and Nameri (1988) also confirmed the feasibility of high density planting (4762 plants ha^{-1}) of banana.

Hence, the optimum LAI was identified to be 5.50 for high density planting of Martaman banana accommodating 5000 plants ha^{-1} planted in 2.0 × 3.0m spacing with 3 suckers pit^{-1} in *Gangetic Alluvium* region of West Bengal.

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