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Effect of radiation interception and canopy temperature on growth, yield and quality in banana cv. Grande Naine (AAA) under different planting densities

Lanuakum, Graceli I. Yepthomi and C.S. Maiti*
Department of Horticulture
School of Agricultural Sciences & Rural Development
Nagaland University, Medziphema Campus, Medziphema-797 106, India
*E-mail: csmaiti@yahoo.co.in

ABSTRACT

A study was made to test the effect of radiation interception and canopy temperature under different planting densities [T_1- 1.5m x 1.5m (4,444 plants/ha); T_2- 2m x 2m (2500 plants/ha); T_3- 1.5m x 2.5m (2666 plants/ha); T_4- 2m x 2.5m (2000 plants/ha); T_5- 2.5m x 2.5m (1600 plants/ha)] on growth, yield and quality in banana cv. Grande Naine. With an increase in planting density, plant height increased significantly. Pseudostem was tallest in the closest spacing, viz., 1.5m x 1.5m (T_1), and was shortest in the widest spacing, 2.5m x 2.5m (T_5). T_1 treatment (1.5m x 1.5m) recorded the least average-canopy-temperature (25.80^{o}C/day) from the flowering to the harvest. T_5 recorded the maximum average-radiation-interception, with a value of 432.16 lux/8 hr/day; whereas, T_1 recorded minimum average-radiation-interception of 219.58 lux/8 hr/day. Significant influence of spacing was seen on yield /ha. Plants grown under higher density yielded comparatively higher yield (82.65 t/ha) under a spacing of 1.5m x 1.5m (T_1). It is thus seen that growth parameters (pseudostem height and number of leaves) and yield/ha in banana was superior at a higher density (1.5m x 1.5m); whereas, in terms of quality of fruit (TSS and total sugar content) spacing of 2.5m x 2.5m was superior. This indicates a positive influence of radiation interception and canopy temperature in banana production.

Key words: Banana, Grande Naine, radiation interception, canopy temperature, high-density planting

INTRODUCTION

Banana is one of the most common fruit crops in the world. Its production is more highly industrialized than any other fruit crop. It is a fruit that can be planted any time excepting in the winter months (<10^{o}C temperature), with appropriate spacing. However, choice of the right planting density is very important for bridging the gap between actual yield and potential yield per unit area in banana. Effect of planting density on plant canopy temperature and light interception is crucial for vegetative growth, especially during flowering, and up to fruit maturity and harvest. This is so because banana requires abundant solar energy and light; therefore, productivity largely depends on efficient utilization of solar radiation. For optimal harvesting of solar radiation, planting density should be determined judiciously. Similarly, canopy temperature in a plantation has significant effect on growth, development and production of individual plants. Light is an important factor in fruit production. Light plays a role in flower induction and fruit development through carbohydrate synthesis. Robinson (2007) opined that radiation transmission to the floor of a plantation can be used as a good indicator of optimal planting density. However, he also concluded that the criterion for radiation transmission to the orchard floor for determining optimal plant density cannot be universal, and needs to be determined for a particular cultivar under locally prevailent conditions. As such, information is inadequate on banana cultivation under foothill conditions of the far-northeastern states of India. Feasibility of different planting densities in banana needs to be worked out so that economic yield per unit area can be increased. With this view, the present investigation was made to assess the effect of radiation interception, canopy temperature, and planting density on growth, yield and quality in banana cv. Grande Naine.

MATERIAL AND METHODS

Planting material used in the present study consisted of tissue culture banana cv. Grande Naine, planted at the four-leaf stage, at Horticultural Experimental Farm of SASRD, Nagaland University. The site is located at

25°45'43''N latitude and 93°53'04''E longitude at an altitude of 310m above MSL at the foothills of Nagaland. It enjoys a humid, subtropical climate, with average rainfall ranging from 200cm to 250cm. Mean summer temperatures range from 20°C to 35°C, and, the temperature ranges from 8°C to 15°C in the winter months. Pits of 60cm^3 size were dug at different spacings as per treatments, viz., T_1- 1.5m x 1.5m (4,444 plants/ha); T_2- 2m'x 2m (2500 plants/ha); T_3- 1.5m x 2.5m (2666 plants/ha); T_4- 2m x 2.5 m (2000 plants/ha); and, T_5- 2.5m x 2.5m (1600 plants/ha). The experiment was laid out in Randomized Block Design, consisting of five treatments with four replications. Five plants from each treatment per replication were selected randomly for observations on various growth parameters. Average canopy temperature was recorded (using a multi-functional infrared thermometer) at intervals of five days. Average radiation intercepted by the plants was recorded using a digital light meter, calibrated at 20,000 x 10Lux, in the morning (10 am) and the afternoon (3 pm) at intervals of five days. Observations on yield attributes (inflorescence emergence, days to first bract-splitting, number of hands/bunch, number of fingers/bunch, number of fingers/hand; fruit weight, length of fruit, breadth of fruit, days to maturity, yield/plant and yield/ha) were recorded using standard methods. Quality attributes of the fruit (Total Soluble Solids, ascorbic acid, titratable acidity and total sugars) were determined as per AOAC, 1984. Mean difference and Analysis Of Variance (ANOVA) for the Randomized Block Design were calculated as per Panse and Sukhatme (1995) to test the level of significance among treatments. All the cultural operations, fertilization, irrigation, etc. were applied as per standard recommendation for banana cultivation.

RESULTS AND DISCUSSION

Growth parameters

Effect of spacing on plant height was significant (Table 1). This is in concordance with findings of Mandal and Sharma (1999). With increase in plant population (density), plant height increased significantly. Pseudostem height was highest in the closest spacing (1.5m x 1.5m) (T_1), and was lowest at the widest spacing (2.5m x 2.5m) (T_5). Results of the present findings are in conformity with observation of several workers (Apshara and Sathiamoorthy, 1999; Nalina *et al*, 2000; Badgujar *et al*, 2004; Kesavan *et al*, 2002). Increase in plant height may primarily be due to mutual shading of plants, resulting in a competitive growth for interception of available light. On the other hand, with increase in plant population (density), pseudostem girth decreased (Table 1). This could be due to a competition between the closely-spaced plants for nutrients, moisture and light. Noticeable, but not significant, effect of different spacings on length of the petiole at flowering was seen. Number of leaves per plant varied significantly under differing planting densities. Maximum number of leaves was recorded at a spacing of 1.5m x 1.5m (T_1), while the minimum was seen at 2.5m x 2.5m (T_5). All high-density treatments resulted in improved vegetative characters such as leaf number (Nalina *et al*, 2000). Spacing had little / minimal influence on number of suckers/plant at flowering. However, a slight increase in the number of suckers trended as the spacing increased. Shading effect under close planting may have reduced the number of suckers produced, and their growth rate.

Effect of planting density on canopy temperature and radiation interception

Average canopy temperature at different densities tended to decrease with higher planting density (Table 2). T_1 (1.5m x 1.5m) recorded the least average canopy-temperature (25.80°C/day) from flowering to the harvest; whereas, T_5 (2.5m x 2.5m) recorded maximum average canopy-temperature (28.35°C/day). A similar trend was observed by Robinson *et al* (1993). This may be due primarily to the development of a dense canopy, thereby altering the microclimate (around the canopy), leading to a

Table 1. Effect of plant density on growth and yield in banana

Treatment	Pseudostem height at flowering (cm)	Pseudostem circumference (cm)	Length of petiole at flowering (cm)	No. of leaves	No. of suckers at flowering	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Yield (kg/plant)	Yield (t/ha)
T_1 (1.5m x 1.5m)	87.13	27.93	26.23	11.25	3.25	120.25	15.33	12.05	18.60	82.65
T_2 (2m x 2m)	79.60	30.00	25.75	11.00	3.50	128.00	16.20	12.15	18.90	47.25
T_3 (1.5m x 2.5m)	85.28	28.33	25.98	11.00	3.50	126.25	15.75	12.10	18.65	49.72
T_4 (2m x 2.5m)	76.88	30.08	25.65	10.75	3.50	133.00	16.43	12.25	19.13	38.05
T_5 (2.5m x 2.5m)	74.90	31.70	24.55	10.25	3.75	142.75	16.73	12.65	22.53	36.04
C.D *(P=0.05)*	4.42	1.35	NS	0.38	NS	1.67	0.36	0.24	1.36	3.97

NS= Non-significant

Table 2. Influence of plant density on canopy temperature, radiation interception and flowering in banana

Treatment	Canopy temperature (flowering to harvest) (°C/day)	Radiation interception (flowering to harvest) (Lux/8hr/day)	Days to inflorescence emergence	Days to first bract splitting	No. of hands/ bunch	No. of fingers/ bunch	No. of fingers / hand	Days to maturity
T_1 (1.5m x 1.5m)	25.80	219.58	323.50	6.00	7.75	139.00	16.75	136.50
T_2 (2m x 2m)	27.00	286.89	306.25	5. 25	8.25	147.00	17.25	118.50
T_3 (1.5m x 2.5m)	26.70	266.28	312.00	5.50	8.25	146.75	17.25	129.25
T_4 (2m x 2.5m)	27.90	385.96	297.25	5.25	8.50	154.74	17.25	110.75
T_5 (2.5m x 2.5m)	28.35	432.16	289.75	5.00	8.50	158.25	18.25	101.25
C.D *(P=0.05)*	0.42	13.16	2.32	NS	NS	NS	NS	2.41

NS= Non-significant

decrease in temperature. The negative, significant association between canopy temperature and various yield and quality attributes seen under different plant densities implies that temperature had a significant role in improving the yield in banana. Average radiation-interception by the plant from flowering to harvest was markedly influenced by planting density (Table 2). T_5 recorded maximum average-radiation-interception (432.16 lux/8 hr/day), whereas T_1 recorded the least average-radiation-interception (219.58 lux/8 hr/day). A decrease in average radiation intercepted by the plants may be due to the fact that at closer spacing, light incident at the ground level is low, with increasing size of the plant-canopy and plant age. This finding is also supported by Nalina *et al* (2000) and Ajitpal *et al* (2005). They reported high plant density as having a lower light-transmission-ratio than plants at a wider spacing. On the contrary, Thippesha (2008) reported that solar radiation (in terms of light intensity) below the canopy, and percent light-interception by the crop canopy, were higher at higher planting density. Morphological and yield traits in banana under various plant densities showed good correlation with the incident solar radiation.

Flowering and yield attributes

T_1 resulted in maximum number of days (323.50 days) taken to flowering, compared to T_5 (289 days) (Table 2). T_5 gave maximum fruit weight (142.75g) (Table 1). Reduction in fruit weight under closer spacing may be a consequence of increasing planting density. It was also observed that plants grown under wider spacing resulted in maximum fruit length as well as maximum fruit breadth (16.73cm & 12.65cm, respectively). T_5 also gave the highest yield/plant compared to the other treatments. Significant results were obtained on influence of spacing on yield/ha: plants grown under higher population density yielded comparatively higher (82.65 t/ha) under a spacing 1.5m x1.5m (T_1). Several workers have shown that the highest yield per hectare in banana was obtained at the highest plant density studied (Mustaffa, 1988; Raveendra *et al,* 2004). Increase in yield with increasing plant density can be ascribed to the higher number of fruits, leading to higher yield.

Table 3. Effect of planting density on fruit quality in banana

Treatment	Total Soluble Solids (°Brix)	Ascorbic acid (mg/100g)	Acidity (%)	Total sugars (%)
T_1 (1.5m x 1.5m)	20.98	87.50	0.16	3.72
T_2 (2m x 2m)	21.28	87.50	0.14	3.81
T_3 (1.5m x 2.5m)	21.25	87.50	0.14	3.75
T_4 (2m x 2.5m)	21.80	62.50	0.08	4.76
T_5 (2.5m x 2.5m)	23.73	50.00	0.06	4.88
C.D *(P=0.05)*	0.17	17.44	0.02	0.07

Fruit quality attributes

Fruit quality (TSS, ascorbic acid, titratable acidity and sugar content) was significantly affected by planting density (Table 3). TSS was significantly influenced by plant density. Plants under wider spacing (2.5x 2.5m) (T_5) had maximum TSS (23.73°B) compared to those grown under a closer spacing (1.5x1.5m) (T_1) showing TSS content of 20.98°B. This is in concordance with findings of Athani and Hulamani (2000), and, Nalina *et al* (2003) who reported TSS content as decreasing with increasing plant density. Experimental evidence confirmed that sugar content and ascorbic acid content in the fruit were significantly affected by plant density (Table 3). A similar trend in increase in ascorbic acid content, with increasing plant density, was obtained by Mustaffa (1988), and Nalina *et al* (2003), respectively.

Correlation coefficient for various variables with mean canopy-temperature and average radiation-interception

Correlation coefficient (Table 4) was higher, and either positive or negatively significant, except for number of suckers, bunch weight and TSS. This indicated a strong

Table 4. Correlation coefficient for various variables with mean canopy temperature and average radiation interception

Variables correlated X	Variables correlated Y	Correlation coefficient
Mean canopy temperature (°C)	Height of the plant (cm)	-0.958**
	Number of leaves	-0.933*
	Number of suckers	0.895*NS
	Days to inflorescence emergence	-0.997**
	Number of fingers/bunch	0.995**
	Bunch weight (g)	0.749NS
	Fruit weight (g)	0.963**
	TSS (°Brix)	-0.487NS
	Acidity (%)	0.951**
	Total sugars (%)	-0.862NS
Average radiation interception (Lux/8 hr/day)	Height of the plant (cm)	-0.944**
	Number of leaves	-0.952**
	Number of suckers	0.854NS
	Days to inflorescence emergence	-0.976**
	Number of fingers/bunch	0.982**
	Bunch weight (g)	0.801NS
	Fruit weight (g)	0.968**
	TSS (°Brix)	-0.547NS
	Acidity (%)	-0.987**
	Total sugars (%)	-0.824NS

NS: Non-significant, *Significant at 5%, **Significant at 1%

association between the various traits studied under the influence of canopy temperature and radiation interception. Canopy temperature was significantly and positively associated with number of fingers per bunch, fruit weight and fruit acidity. Negative, significant association in traits like plant height, number of leaves and days to inflorescence-emergence was observed with canopy temperature and plant density. A negative association between canopy temperature and various yield attributes implies that temperature and plant density influence yield in banana. Most of the economic characters were negatively correlated with the radiation intercepted. For most of the characters studied, the correlation coefficient values were higher, indicating an influence of solar radiation for enhancing various yield and quality attributes, either negatively or positively. Number of fingers per bunch, and fruit weight, had a strong and positive correlation with radiation interception. This positive association suggests that influence of solar radiation can help realize higher yields. Correlation of radiation interception with plant height, number of leaves, days to inflorescence emergence and fruit acidity were negatively significant, indicateing that plant density and solar radiation influence yield and quality attributes in banana cv. Grande Naine.

It may be concluded that growth parameters (pseudostem height and number of leaves) and yield/ha in banana was superior at a higher density of spacing 1.5m x 1.5m (T_1 treatment). In terms of fruit quality, (TSS and total sugar content) a spacing of 2.5m x 2.5m (T_5) was found superior, which indicated a positive influence of radiation-interception and canopy-temperature in banana production.

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