Growth and quality of pineapple at different orientations and distances under litchi based agroforestry system

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Abstract: A field experiment was conducted in northern part of Bangladesh to examine the growth, yield and quality of pineapple grown at different orientations and spacing under litchi tree. There were four different orientations (north, south, east, and west) and four different spacings (2.4m, 3.4m, 4.4m, and 5.4m) from the tree base. Yield of pineapple was maximum (35.28 t/ha) at the spacing of 4.4m south and minimum yield (13.14 t/ha) was obtained at the spacing of 5.4m- north from the tree base. Weight of fruit, weight of crown, weight of pulp, weight of peel, pulp:peel, juice content, moisture content, brick percentage, vitamin-C, pH were significantly influenced by the treatment combinations. The highest (16.30) and lowest (13.40) brick percentages were obtained in the treatments where the plants were planted in 3.4m east and 4.4m north from the tree base respectively. The highest (23.79mg/100g) and lowest (17.42mg/100g) vitamin-C were obtained in the treatments where the plants were planted in 2.4m south and 2.4m east from the tree base respectively. Considering orientation, the production of pineapple was found ranked as West>South>East>North and in case of distance from the tree base, the production of pineapple found ranked as 3.4m>2.4m>4.4m>5.4m.
Key words: Pineapple, agroforestry, distance and orientation, yield, quality of pineapple.

Introduction

Pineapple (*Annanas comosus*) is a very popular and one of the major fruits in Bangladesh with a total production of 238360 m. ton per annum in an area of 41935 acres of land and yield per acre is 5684 kg (BBS, 2012). It grows well in partial shade with a pH range of 5.5 to 6.0 and sandy loam soils and the optimum temperature ranges is 15.5 - 32.5°C (Johnson 1935). Pineapple can be a good intercrop with different crops or trees (Rajesekharan and Veerapathran, 2002) and carry a high benefit–cost ratio (Roy *et al*., 2001). Dense planting of pineapple may result in high yields without affecting the quality or size of fruits (Chadha *et al*., 1974). It is a crassulacean acid metabolism plant which opens the stomata of leaves during the cool afternoon and nights and closes them during the hot, dry day (Krauss, 1949).The overlapping of the basal leaves provide partial shade and reduce evaporation loss which is suitable for pineapple growth (Bonner and Bonner, 1948 ; Krauss, 1949).

Pineapple provides a ready source of many food nutrients and minerals. The fruit is nutritious and contains protein and calcium three times higher than apple and grapes. Thailand is the largest pineapple producer country in the world which produces 17.27% of the production while Bangladesh produces 1.28% world production (FAO, 1998). Excess light creates a less favorable micro environment for pineapple. A great crown and less light penetration also help minimize evapo-transpiration loss of water and suppress weed growth, which are favorable for pineapple (Chandha, 1974). On the other hand, a very low percentage of possible sunshine that may be from a high percentage of cloudy days, retards growth and results in small fruits of poor quality, particularly lacking in sugars.

Fruits are very important source of vitamins and minerals but the consumption of fruits in Bangladesh per day per capita is only 30-35 g against the minimum level of 85 g (Siddique, 1995). As a result, fruits are very costly in Bangladesh and majority of people can't afford to buy them and is being suffering from malnutrition. Therefore, production of pineapple in association with litchi tree may be an ideal combination of two high value fruits. Scientific research is needed for investigating interaction effects of Litchi-Pineapple production system.

The litchi (*Litchi chinensis*) is a delicious, juicy fruit of excellent quality. It is a very popular fruit in our country. It is an evergreen tree and a perfect multipurpose tree. It grows well all over Bangladesh especially in the northern part of the country. Total production of litchi is 43767 m. ton and total production area under garden is 5789 acre, average yield per fruit bearing tree is 49 kg (BBS, 2012). Though most of the litchi orchards have the potentiality to allow intercrops (Rahman *et al*., 200) but little works are done in different orientations (Islam and Rahman, 2006) on pineapples grown under the canopy of litchi tree especially in the Northern litchi- grown region of Bangladesh. To introduce pineapples under litchi tree may be the first initiative of litchi-pineapple based systematic practice in the Northern region of Bangladesh. Therefore, the present study was an attempt to evaluate the growth and quality pineapple at different distances and orientations from the litchi tree base.

Materials and Methods

The experiment was conducted at the Agroforestry Farm of Hajee Mohammed Danesh Science and Technology University, Dinajpur, Bangladesh during the period of February 2008 to February 2010. This site was located between 25°13′ latitude and 88°23 longitude and about 37.5m above sea level. The climate of the study area is characterized by a heavy rainfall during Kharif season (April to Sep.). While a scanty rainfall during the rest period i.e. during the Rabi season (Oct. to March). The mean maximum temperature in the summer (March to Sep.) was 35°C and the mean minimum temperature in the winter (Nov. to March) was 11.9°C.

The experiment was carried out in concentric row design (satisfying factorial Randomized Complete Block Design) with five replications for each treatment. Two factors were involved in the study. Factor A was four orientations viz. O_1= North, O_2= South, O_3= East and O_4= West, and factor B was four distances (S) viz. S_1= 2.4 m away from tree base, S_2= 3.4 m away from tree base, S_3= 4.4 m away from tree base and S_4= 5.4 m away from tree base. Litchi tree

was 30 years old and its height, basal girth and canopy diameter were 15m, 2.03 m and 10.5 m respectively.

Pineapple's height, fruit length and leaf size were measured by measuring tape. From each sub-plot five plants were measured and averaged at 20, 22 and 24 months after planting (MAP). Plant height was measured from the ground level to the top of leading leaf. Leaf size was calculated as leaf length (cm) x leaf breadth (cm). Weight of fruit in kg/plot was measured by an electric balance. The pineapple yield was later expressed in ton/ha. Crown to fruit ratio, weight of pulp, peel, edible portion of fruit were determined of each treatment and each replication by using electrical balance. Juice of fruit pulp was extracted using blending machine. The percentage of juice content of the fruit pulp was calculated by using the formula: (wt. of Juice/wt. of pulp) x 100. Moisture content of fruit pulp was estimated by sieving the juice. Brick percentage was determined by Abbe Refractometer. The method to determine vitamin-C depends on the stoichiometric reduction of the dye, to a colorless compound by ascorbic acid. The pH of homogenate was measured with a pH meter. One gram fresh pulp was homogenized in 100 ml of distilled and deionized water (pH 7.0).

The data on various growth and yield contributing characters of pineapple were statistically analyzed to determine the significant variation of the result due to different orientations effect of litchi based multistoried production system. The analysis of variance for each of the studied character was done by F (variance ratio) test following Randomized Complete Black Design (RCBD). These data were analyzed statistically following ANOVA technique and means separation were adjusted by Duncan's Multiple Range Test (DMRT) at 1% and 5% level of significance.

Results and Discussion

Effect of orientations and distances on growth of pineapple

Leaf Number: Number of leaf plant^{-1} of pineapple was not significantly influenced by different orientations (Table 1). At 20, 22 and 24 MAP, it ranged from 28.70 to 29.55. The maximum leaf number (29.55) was found in the north orientation (O_1) whereas the minimum leaf number (28.70) was found in the south orientation (O_2). Number of leaf plant^{-1} of pineapple was significantly influenced by different planting spacing (Table 1). Significantly the highest leaf number of pineapple plant^{-1} (29.95) was found at 20 MAP in 4.4m distances from the tree base (S_3) followed by 5.4m distances from the tree base (S_4). On the other hand, the lowest leaf number of pineapple plant^{-1} (27.20) was found at 20 MAP in 2.4 m distance from the tree base (S_1). The leaf numbers recorded at the 22 and 24 MAP were similar to that of the 20 MAP because the pineapple plants were matured. Similar type of results was found by Hossain (1999) and he worked on jackfruit-pineapple based agroforestry system.

Table 1. Effect of orientation on the growth of pineapple

Treatments		No. of leaf plant^{-1}						Leaf size (cm^2)					
Orientation	Spacing	(20MAP)		(22MAP)		(24MAP)		(20MAP)		(22MAP)		(24MAP)	
(O)	(S)	O	S	O	S	O	S	O	S	O	S	O	S
O_1	S_1	29.55	27.20 b	29.55	27.20 b	29.55	27.20 b	311.20 c	511.90 a	311.20 c	511.90 a	311.20 c	511.90 a
O_2	S_2	28.70	29.45 ab	28.70	29.45 ab	28.70	29.45 ab	438.40 ab	465.10 a	438.40 ab	465.10 a	438.40 ab	465.10 a
O_3	S_3	29.05	29.95 a	29.05	29.95 a	29.05	29.95 a	400.00 b	365.80 b	400.00 b	365.80 b	400.00 b	365.80 b
O_4	S_4	29.10	29.80 a	29.10	29.80 a	29.10	29.80 a	467.20 a	274.00 c	467.20 a	274.00 c	467.20 a	274.00 c
Level of sign.		NS	*	NS	*	NS	*	**	**	**	**	**	**
CV%		13.37	13.37	13.37	13.37	13.37	13.37	19.54	19.54	19.54	19.54	19.54	19.54

** Significant at 1% level; * Significant at 5% level, NS = Not significant, figures having similar letter(s) do not differ significantly where as figure(s) bearing dissimilar letter(s) differ significantly (as per DMRT).

Leaf Size: Leaf size plant^{-1} of pineapple was increased gradually with the increase of shade level. The maximum leaf size plant^{-1}of pineapple (467.20 cm^2) was recorded in west orientation (O_4) followed by south orientation (O_2) (Table 1). On the other hand, the minimum leaf size plant^{-1} of pineapple (311.20 cm^2) was observed in north orientation (O_1). Under shaded condition the cellular expansion and cell division occurred, so the plant which grown under heavy shade gave maximum height. It was collaborating with the findings of Hossain (1999). Similar observation was also found by Uddin (2008). The maximum leaf size plant^{-1}of pineapple (511.90 cm^2) was recorded in 2.4 m distance from the tree base (S_1) followed by 3.4m distances from the tree base (S_2) at different MAP (Table 1). On the other hand, the minimum leaf size plant^{-1} of pineapple (274.00 cm^2) was observed at different MAP in 5.4 m distances from the tree base (S_4). This might be attributed due stimulation of cellular expansion and cell division under shaded condition. It was collaborating with the findings of Hossain (1999) in jackfruit pineapple based agroforestry system. Similar observation was also found in Uddin (2008) in Litchi-pineapple based agroforestry system.

Effect of different orientations and Planting spaces on the quality of pineapple

Weight of Fruit: Weight of pineapple fruit was increased gradually with the increase of shade level (Table 2). Significantly the highest weight of fruit (1043.00 g) was found in west orientation (O_4) followed by east orientation (O_3) which was statistically identical that of south orientation (O_2). On the other hand, the lowest weight of fruit (872.60 g) was found in north orientation (O_1). These findings were also in agreement with Hossain (1999). Significantly the highest weight of fruit (1036.00 g) was found in 3.4 m distances from the tree base (S_2), which was statistically similar to that of 2.4 m distances from the tree base (S_1). On the other hand, the lowest weight of fruit (855.60 g) was found in 5.4 m distances from the tree base (S_4). The pattern of fruit observed was 3.4 m distance > 2.4 m distance > 4.4 m distance > 5.4 m distance from the tree base. These findings were also in agreement with Hossain (1999).

Weight of Crown: Result presented in the Table 2 advocated that the crown weight of pineapple was significantly influenced by different orientations. Significantly the maximum crown weight (388.00 g) was observed in west orientation (O_4) followed by east orientation

(O_3). Otherwise, the minimum crown weight (268.70 g) was observed in north orientation (O_1) which was statistically identical that of south orientation (O_2). The crown weight of pineapple was not significantly influenced by different spacing (Table 3). Numerically the highest crown weight (340.40 g) was observed in 3.4 m distances from the tree base (S_2) and the lowest crown weight (304.00 g) was observed in 5.4 m distances from the tree base (S_4).

C:F Ratio: Among the treatments, it was found that the highest C:F Ratio of 0.38 was recorded from west orientation (O_4) and the lowest C:F ratio of 0.32 was observed in north orientation (O_1). The experiential trend of C:F ratio was as west > east > south > north from the Table 2. Among the treatments, it was found that there was no significant effect of different orientation on C:F ratio of pineapple (Table 3). The maximum C:F ratio (0.37) was observed in 5.4 m distance from the tree base (S_4) and the minimum C:F ratio (0.33) was observed in 2.4 m distance from the tree base (S_1).

Pulp Weight: The perusal of data (Table 2) shows that, the pulp weight of pineapple was significantly influenced by different orientations. Significantly the highest pulp weight (807.00 g) was observed in west orientation (O_4), which was statistically identical that of east orientation (O_3) followed by south orientation (O_2). Alternatively, the lowest pulp weight (655.90 g) was observed in north orientation (O_1). The perusal of data (Table 3) shows that the pulp weight of pineapple was significantly influenced by different spacing. Significantly the highest pulp weight (792.20 g) was observed in 3.4 m distance from the tree base (S_2) followed by 2.4 m distance from the tree base (S_1) which was statistically identical that of 4.4 m distance from the tree base (S_3). Alternatively, the lowest pulp weight (654.90 g) was observed in 5.4 m distances from the tree base (S_4).

Peel Weight: Data in Table 2 advocated that there was no significant effect of different orientation on peel weight of pineapple. Numerically the maximum peel weight (236.40 g) was observed in west orientation (O_4) and the minimum peel weight (218.30 g) was observed in north orientation (O_1). The peel weight of pineapple was significantly influenced by different spacing (Table 2). Significantly the maximum peel weight (243.70 g) was observed in 3.4 m distance from the tree base (S_2) which was statistically identical that of 2.4 m distance from the tree base (S_1) and the minimum peel weight (202.30 g) was observed in 5.4 m distance from the tree base (S_4).

Table 2. Effect of orientation on the quality of pineapple

Treatments	Wt. of fruit (g)	Wt. of crown (g)	C:F ratio	Wt. of pulp (g)	Wt. of peel (g)	Pulp: Peel	Juice content (%)	Moisture content (%)	Brick %	Vitamin-C (mg/ 100g)	pH
O_1	872.60 b	268.70 c	0.32 b	655.90 b	218.30	3.04 b	80.34	54.82	14.35 c	21.54 a	4.24 a
O_2	930.70 ab	292.70 c	0.33 b	711.30 ab	219.00	3.27 ab	78.46	55.67	14.88 b	20.89 a	3.88 d
O_3	982.30 ab	335.00 b	0.35 ab	756.50 a	224.80	3.34 a	76.98	53.76	15.38 a	20.94 a	4.07 c
O_4	1043.00 a	388.00 a	0.38 a	807.00 a	236.40	3.41 a	78.06	56.85	14.43 c	18.91 b	4.15 b
Level of sign.	*	**	*	**	NS	*	NS	NS	**	**	**
CV%	18.44%	20.25%	19.16%	20.41%	17.06%	13.26%	7.27%	9.04%	3.86%	6.10%	1.97%

* Significant at 5% level, ** Significant at 1% level; NS = Not significant

Table 3. Effect of spacing on the quality of pineapple

Spacing	Weight of fruit (g)	Weight of crown (g)	C:F ratio	Weight of pulp (g)	Weight of peel (g)	Pulp: Peel	Juice content (%)	Moisture Content (%)	Brick (%)	Vitamin-C (mg/100g)
S_1	979.00 a	313.70	0.33	744.10 ab	232.00 a	3.18	78.50	54.97	15.38 a	20.80 ab
S_2	1036.00 a	340.40	0.33	792.20 a	243.70 a	3.25	78.54	56.23	14.93 b	20.20 b
S_3	957.90 ab	326.30	0.35	739.40 ab	220.60 ab	3.36	78.56	56.12	14.43 c	21.07 a
S_4	855.60 b	304.00	0.37	654.90 b	202.30 b	3.28	78.25	53.78	14.30 c	20.21 b
Level of significance	**	NS	NS	*	**	NS	NS	NS	**	*
CV%	18.44%	20.25%	19.16%	20.41%	17.06%	13.26%	CV%	7.27%	9.04%	3.86%

* Significant at 5% level, ** Significant at 1% level; NS = Not significant

Pulp-Peel ratio: Pulp-Peel ratio of pineapple was also decreased as the increase of light intensity (Table 2). Significantly the highest Pulp: Peel ratio (3.41) was observed in west orientation (O_4) which was statistically identical that of east orientation (O_3). It was followed by south orientation (O_2) and the lowest Pulp: Peel ratio (3.04) was observed in north orientation (O_1). There was no significant effect of different spacing on Pulp: Peel ratio of pineapple (Table 3). The ratio was ranged 3.18 to 3.36. The highest Pulp: Peel ratio (3.36) was observed in 4.4 m distance from the tree base (S_3) and the lowest C:F (3.18) was observed in 2.4 m distance from the tree base (S_1).

Juice percentage: It was found that there was no significant effect of different orientation and spacing on juice percentage of pine apple (Table 2). The juice percentage ranged from 76.98-80.34%. The maximum juice percentage (80.34%) was observed in north orientation (O_1) and the minimum juice percentage (76.98%) was observed in east orientation (O_3). The juice percentage of pineapple ranged from 78.25% to 78.56%. The maximum juice percentage (78.56%) was observed in 4.4 m distance from the tree base (S_3) and the minimum juice percentage (78.25%) was observed in 5.4 m distance from the tree base (S_4).

Moisture Percentage: Moisture percentage of pineapple was not significantly influenced by different orientations (Table 2). Numerically the maximum moisture percentage (56.85%) was observed in west orientation (O_4) and the minimum moisture percentage (53.76%) was observed in east orientation (O_3). Moisture percentage of pineapple was not significantly influenced by different spacing (Table 3). Numerically the maximum moisture percentage (56.23%) was observed in 3.4 m distance from the tree base (S_2) and the minimum moisture percentage (53.78%) was observed in 5.4 m distance from the tree base (S_4).

Brick Percentage: Careful study of data (Table 2) reveals that east orientation (O_3) produced significantly higher

percentages of brick (15.38 %) followed by south orientation (O_2). Lower brick percentage (14.35%) was observed in north orientation (O_1), which was statistically similar to that of west orientation (O_4). It was collaborating with the findings of Hossain (1999) in jackfruit pineapple based agroforestry system. The data (Table 3) reveals that 2.4 m distance from the tree base (S_1) produced significantly higher percentages of brick (15.38%) followed by 3.4 m distance from the tree base (S_2). Lower brick percentage (14.30%) was observed in 5.4 m distance from the tree base (S_4), which was statistically similar to that of 4.4 m distance from the tree base (S_3). It was collaborating with the findings of Hossain (1999) in jackfruit pineapple based agroforestry system.

Vitamin-C: Vitamin-C of pineapple was significantly influenced by different orientations (Table 2). Significantly the maximum vitamin-C (21.54 mg/100g pulp) was observed in north orientation (O_1), which was statistically similar to that of south orientation (O_2) and east orientation (20.94 mg/100 g pulp). On the other hand, the minimum vitamin-C (18.91 mg/100 g pulp) was observed in west orientation (O_4). Hossain (1999) conducted an experiment of pineapple with jackfruit, which showed similar type of results. Vitamin-C of pineapple was significantly influenced by different spacing (Table 3). Significantly the maximum vitamin-C (21.07 mg/100 g pulp) was observed in 4.4 m distances from the tree base (S_3) followed by 2.4 m distances from the tree base (S_1). On the other hand, the minimum vitamin-C (20.20 mg/100 g pulp) was observed in 3.4 m distance from the tree base (S_2), which was statistically similar to that of 5.4 m distance from the tree base (S_4). Hossain (1999) conducted an experiment of pineapple with jackfruit, which showed similar type of results.

pH: A significant variation in pH of pineapple due to grown different orientations was observed (Table 2). Significantly the highest pH (4.24) was observed in north orientation (O_1) and the lowest pH (3.88) was observed in south orientation (O_2). The pattern of pH observed was north > west > east > south. These findings were also in agreement with Hossain (1999). A significant variation in pH of pineapple due to grown different spacing was observed (Table 3). Significantly the highest pH (4.18) was observed in 5.4 m distances from the tree base (S_4) and the lowest pH (3.96) was observed in 2.4 m distances from the tree base (S_1). The pattern of pH observed was 5.4 m > 4.4 m > 3.4 m > 2.4 m distance from the tree base. These findings were also partially in agreement with Hossain (1999).

Based on the present study, it is concluded that in litchi-pineapple association, the yield and quality of pineapple was increased. Among four orientations, west orientation is finest for the maximization of pineapple. Again in case of spacing 3.4 m distance from the tree base was best. However, best yield of pineapple was obtained in 4.3 m distance from the tree base at south orientation. The results guided us that the litchi orchard in northern part of Bangladesh has the potentiality to produce pineapple.

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