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INFLUENCE OF THE TREE CANOPY POSITIONS AND DIRECTIONS ON FRUIT MORPHOLOGICAL CHARACTERS AND BIO-CHEMICAL COMPOSITION OF PUMMELO (*CITRUS GRANDIS* OSBECK.)

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ABSTRACT

Investigation revealed that, highest fruit weight was recorded in middle position of tree (793g) and in east canopy direction (769g). Fruit length was maximum (12.52 cm) in middle canopy and in east (12.36 cm) canopy direction. Maximum oil gland density (44/cm^2) was noted in middle position. Thickest rind was recorded on middle position of tree (1.72 cm) and in east canopy direction (1.38 cm). It was also found that maximum fruits were of ellipsoid shaped with necked fruit base. The skin colour was varied from light greenish yellow to yellow, rough surfaced with light pink to pinkish pulp colour. Juice content was recorded maximum on upper position of tree (22.04%) and (21.99%) in east canopy direction. Highest TSS (10.95^{o}brix) was obtained in upper canopy position and in east canopy direction (11.02^{o}brix). Maximum ascorbic acid (47.84 mg/100g of pulp) was noted in upper canopy position and in east canopy direction (56.69 mg/100g of pulp). The significant variation in ascorbic acid was noted in all the positions and directions. The middle canopy and east directional fruits have good morphological as well as chemical content in the matured harvested fruits.

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INTRODUCTION

Citrus (*Citrus sp*.), is one of the world's major fruit crops that are produced in many countries with tropical and sub-tropical climate, which consisting of 140 genera and 1300 species. It is the third most important fruit crop in India, after banana and mango (Mukhim *et al.,* 2015). It accounts for 4% (286.40 Thousand ha) of total area under fruit and 3.20% (2835 Thousand MT) of total fruit production with a productivity of 9.90 MT/ha (Anon., 2015). Botanically pummelo is known as *Citrus maxima* Merr. (*Citrus grandis* Osbeck; *Citrus decumana* L.). In the western world, it is identified mainly as the principal ancestor of grapefruit. Taxonomically pummelo belongs to subgenus *Eucitrus* (commonly cultivated species of citrus) of the family Rutaceae, (2n = 18). It has the biggest fruit among the citrus species (Gaikwad *et al.,* 2015). Pummelo is one of the major monoembryonic species of citrus and its production reached about 6% total citrus production of the world (Ladaniya, 2008). Pummelo is called batabi-lebu in Bengal and chakotra, mahatabi or mahanimbu in others of India. It is considered as an excellent tree for wasteland development in arid and semi-arid region. The fruit is fat, sodium and cholesterol free and this makes a very good source for dieters. The fruit is cheaper than other citrus and is valued for its medicinal properties (Woodford, 2005). In recent years, the pummelo has received much attention because of its nutritional and antioxidant properties, especially flavonoids in Asia *i.e*. Thailand, China, Taiwan and Japan (Xu *et al*., 2008). West Bengal is also endowed with extremely diverse populations of pummelo in her diverse agro- ecological zones and altitudes (Roy *et al*., 2014). In citrus, the harvesting period of fruits vary depending upon the species, variety and purpose of consumption (Singh *et al.,* 2015). The quality of citrus fruits is influenced by many factors, including distribution of sunlight inside the plants, which is influenced by the size of trees, spacing, row orientation, canopy shape and the type of planting system (Detoni *et al*., 2009). The position of the fruit on the tree canopy (Agabbio *et al*., 1999), as well as the geographical quadrants where the fruits lie (Nicolau *et al*., 2014) is important variables that can result in qualitative differences (Cronje *et al*., 2011; Khalida *et al*., 2012). Among several external pre-harvest factors, fruit canopy position and direction play a significant role in final fruit quality. Fruit quality of pummelo is related to the amount of light in the vicinity of the developing fruit. Normally, the amount of light intercepted by a fruit is a function of canopy position, so light level and canopy position are confounded. However, a little information is available about the physico-chemical response of pummelo influenced by the canopy positions and direction for this area. Keeping above in view the present study was conducted to study the influence of the tree canopy positions and directions on fruit morphological characters and bio-chemical composition of Pummelo.

MATERIALS AND METHODS

Experimental site and materials

The experiment was conducted at Mondouri Research Station, Bidhan Chandra

Krishi Viswavidyalaya, Nadia, West Bengal, during 2014-2016. Healthy and disease free fully bears pummelo plants were selected for this experiment. The plants were of same age, similar in size and received uniform cultural management.

Experimental details

The fruits were harvested at the proper mature stage from tagged shoots of different positions (Upper, Middle and lower canopy positions) and directions (East, West, North and South directions). The fruits after washing in running tap water dried in the shade for few minutes and then taken for necessary observations. Among the physical parameters, fruit weight, length, diameter, density of oil gland, rind thickness, fruit shape, skin colour, pulp colour, fruit surface texture, number of segments per fruit, albedo colour and number of seeds per fruit were measured. Among the chemical parameters, juice content was expressed in percentage (%) with respect of fruit weight. TSS content of the fruit was recorded with the help of a hand refractometer followed by the method of Mazumder and Majumder, 2003. The acidity of the fruit juice was estimated by titrating against standard alkali solution (0.1 N NaOH) using the phenolphthalein indicator and is expressed in percentage (Rangana, 1977). The total sugar and reducing sugar content were analyzed with the help of copper reducing method followed by A.O.A.C., 1984. pH was measured using pH meter followed by the method of A.O.A.C., 1984. Ascorbic acid content of fruits was estimated based on the oxidation of ascorbic acid to Dehydro Ascorbic Acid and then to Diketo Gluconic acid followed by coupling with 2,4 DNPH and measured colorimetrically by UV/VIS spectrometer (Perkin Elmer, Lambda 25) expressed as mg per 100g fruit pulp (Rangana, 1977). Analysis of variance (one way classified data) for each parameter was performed using op stat software (online version). The statistical analysis was done by following randomized block design (RBD) as per Gomez and Gomez (1984). The significance of different sources of variation was tested by error mean square by Fischer-Snedecor's 'F' test at probability level of 0.05 percent.

RESULTS

Fruit weight

Fruit weight was not significantly influenced by the canopy position in the Pummelo fruits (Table 1a.). Fruit weight was recorded maximum on middle position of tree (793 g); whereas medium weight was noted on lower canopy position (785.80 g) and lowest fruit weight was obtained in the upper canopy position (773.40 g). The data presented in Table 1b showed that fruit weight widely varied in all the directions (744 to 769 g). Fruit weight was recorded maximum in east canopy direction (769 g) followed by south canopy direction (761 g). Lowest weight was obtained in north direction (744 g).

Fruit length

It is evident from the data presented in Table 1a that fruit length of different canopy position varied widely (12.18 to 12.52 cm). Fruit length was maximum (12.52 cm) in middle canopy and minimum (12.18 cm) in upper canopy position. In the present investigation the effect of position significantly influenced the length of fruit. The data presented Table 1b clearly revealed that fruit length varied due to different canopy direction (11.60 to 12.36 cm). Fruit length was recorded maximum (12.36 cm) in east canopy direction. Lowest fruit length was recorded in north canopy direction (11.60 cm).

Fruit diameter

Fruit diameter of different canopy position varied from (12.82 to 13.06 cm). Fruit diameter (13.06 cm) was recorded maximum in middle canopy position. Lowest fruit diameter was recorded in upper canopy position (12.82 cm) [Table 1a]. Fruit diameter was recorded highest (12.92 cm) in east canopy direction as compared with lowest fruit diameter obtained in north direction (12.16 cm). The Significant variation in fruit diameter was noted in the four directions [Table 1b].

Density of oil gland

The data regarding density of oil gland has been presented in Table 1a. Maximum oil gland density (44/cm^2) was noted in the middle position. Lowest (40.60/cm^2) density was recorded in upper canopy position. It was significantly influenced by the canopy position in the tree. The data presented in Table 1b revealed that density of oil gland of different canopy direction widely varied (34 to 43.20 /cm^2). Whereas maximum density was noted in east direction (43.20 /cm^2) followed by west density (42.80/cm^2). Lowest density was (34 /cm^2) recorded in north direction. In the present investigation the effect of direction was found significant.

Fruit rind thickness

It is evident from the data presented in Table 1a that fruit rind thickness of different canopy position varied (1.66 to 1.72 cm). Rind thickness was recorded maximum on middle position of tree (1.72 cm) and lowest thickness was obtained in the upper and lower canopy position (1.66 cm). The data presented in Table 1b showed that rind thickness widely varied (1.20 to 1.38 cm). Fruit rind thickness was recorded maximum in east canopy direction (1.38 cm); whereas medium thickness was recorded in south direction (1.36 cm). Lowest thickness was obtained in north direction (1.20 cm).

Fruit shape

Fruit shape from different canopy position varied. Fruits harvested from upper canopy position were maximum of spheroid shaped, while fruits from middle and lower canopy were of ellipsoid and pyriform shaped respectively [Table 2a]. Fruit shape was also varied in different directions. Fruits from East and West direction were of ellipsoid shaped. Pyriform and Spheroid shaped fruits were obtained from North and South direction respectively [Table 2b].

Fruit skin colour

The data pertaining to fruit skin colour with canopy position has been presented in Table 2a. Light greenish yellow was obtained from lower canopy and greenish yellow was obtained from upper canopy. Yellow coloured fruits were obtained from middle canopy position. Fruit skin colour was also varied with different canopy direction. Fruits from east and north direction have light greenish yellow skin colour. Greenish yellow and yellow coloured fruits were harvested from west and south direction [Table 2b].

Fruit surface texture

Table 1a: Effect of tree canopy positions on physical characters of fruit in pummelo

Canopy position	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Density of oil gland (per cm^2)	Fruit rind thickness (cm)
Upper	773.40	12.18	12.82	40.60	1.66
Middle	793.00	12.52	13.06	44.00	1.72
Lower	785.80	12.34	12.92	40.80	1.66
SEm(±)	10.94	0.16	0.11	0.85	0.10
C.D. at 0.05	NS	NS	NS	2.82	NS

Table 1b: Effect of tree canopy directions on physical characters of fruit in pummelo

Canopy direction	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Density of oil gland (per cm^2)	Fruit rind thickness (cm)
East	769.00	12.36	12.92	43.20	1.38
West	760.00	12.28	12.36	42.80	1.24
North	744.00	11.60	12.16	34.00	1.20
South	761.00	12.18	12.24	39.80	1.36
SEm(±)	13.04	0.17	0.18	1.36	0.09
C.D. at 0.05	NS	0.53	0.56	4.24	NS

Table 2a: Effect of tree canopy positions on physical characters of fruit in pummelo

Canopy position	Fruit shape	Fruit skin colour	Fruit surface texture	Pulp colour
Upper	Spheroid	Green yellow	Rough	Pink
Middle	Ellipsoid	Yellow	Smooth	Pink
Lower	Pyriform	Light green yellow	Rough	Light Pink

Table 2b: Effect of tree canopy directions on physical characters of fruit in pummelo

Canopy direction	Fruit shape	Fruit skin colour	Fruit surface texture	Pulp colour
East	Ellipsoid	Light green yellow	Rough	Pink
West	Ellipsoid	Green yellow	Rough	Light pink
North	Pyriform	Light green yellow	Smooth	Pink
South	Spheroid	Yellow	Rough	Pink

Table 3a: Effect of tree canopy positions on physical characters of fruit in pummelo

Canopy position	No. of segment/ fruit	Albedo colour	No. of seed/fruit
Upper	14.20	Pinkish white	96.80
Middle	16.00	White	110.80
Lower	14.40	Pinkish white	105.20
SEm(±)	0.85	-	1.96
C.D. at 0.05	NS	-	6.50

Table 3b: Effect of tree canopy directions on physical characters of fruit in pummelo

Canopy direction	No. of segment/ fruit	Albedo colour	No. of seed/fruit
East	15.40	White	113.00
West	14.60	White	104.60
North	13.60	White	99.60
South	13.60	Pinkish white	101.40
SEm(±)	0.48	-	4.25
C.D. at 0.05	NS	-	NS

Table 4a: Effect of tree canopy positions on chemical characters of fruit in pummelo

Canopy position	Juice (%)	TSS (°brix)	Titrable acidity (%)	Total sugar (%)	Reducing sugar (%)	pH	Ascorbic acid (mg/100g)
Upper	22.04	11.02	2.07	9.16	4.52	4.45	47.84
Middle	21.85	10.92	1.59	8.64	4.52	4.32	45.03
Lower	21.76	10.83	2.24	9.08	4.44	4.23	42.18
SEm(±)	0.04	0.03	0.05	0.15	0.02	0.02	0.27
C.D. at 0.05	0.13	0.08	0.18	NS	0.07	0.06	0.90

Table 4b: Effect of canopy directions on chemical characters of fruit in pummel

Canopy direction	Juice (%)	TSS (°brix)	Titrable acidity (%)	Total sugar (%)	Reducing sugar (%)	pH	Ascorbic acid (mg/100g)
East	21.99	10.95	1.28	9.42	4.29	4.45	48.79
West	18.69	10.05	2.14	8.64	4.12	4.18	40.87
North	17.84	9.28	2.24	8.58	4.00	4.10	46.69
South	19.73	10.50	1.60	8.80	4.22	4.30	45.39
SEm(±)	0.09	0.03	0.08	0.20	0.03	0.02	0.60
C.D. at 0.05	0.28	0.09	0.25	0.62	0.09	0.06	1.88

Fruits produced in upper and lower canopy position have rough surface texture, while fruits in middle position have smooth texture (Table 2a). Considering the effect of canopy direction on this parameter, all the direction had rough texture except in north direction, where the surface was smooth (Table 2b).

Pulp colour

Canopy position had impact on pulp colour of pummelo fruits. Pink pulp colour was obtained from upper and middle positioned fruits but fruits from lower position had light pink coloured pulp (Table 2a). In case of the effect of canopy direction, all the direction had pink coloured pulp in fruits except in west direction, where the colour was light pink (Table 2b).

Number of segment per fruit

It is evident from the data presented in Table 3a that segment number of different canopy position varied widely (14.20 to 16.00). Segment number was maximum (16.00) in middle canopy and minimum (14.20) in upper canopy position. In the present investigation the effect of position had no significant effect on number of segment per fruit. The data presented in Table 3b clearly revealed that the number was varied due to different canopy direction (13.60 to 15.40). Segment number was recorded maximum (13.60) in east canopy direction. Lowest number (15.40) was recorded in north and south canopy direction.

Number of seed/fruit

Seed number of different canopy position varied from (96.80 to 110.80). Seed number (110.80) was recorded maximum in middle canopy position. Lowest number was recorded in upper canopy position (96.80). The Significant variation in seed number was noted in the tree positions [Table 3a]. Seed number was recorded highest (113.00) in east canopy direction as compared with lowest fruit diameter obtained in north direction (99.60) [Table 3b].

Albedo colour

Canopy position had impact on albedo colour of pummelo fruits. Pinkish white colour was obtained from upper and lower positioned fruits but fruits from lower position had white coloured albedo (Table 3a). In case of the effect of canopy direction, all the direction had white coloured pulp in fruits except in south direction, where the colour was pinkish white (Table 3b).

Juice content

It is evident from the data presented in Table 4a that juice content of different canopy position varied widely (21.76 to 22.04%). Juice content was recorded maximum on upper position of tree (22.04%); whereas medium juice was noted on middle canopy position of both varieties (21.85%) and lowest content was obtained in the lower canopy position (21.76%). In the present investigation the effect of position significantly influenced the juice content of fruit. In Pummelo fruits juice content was significantly influenced by the different canopy direction. The data presented in Table 4b showed that juice content widely varied (17.84 to 21.99%). Juice quantity was recorded maximum (21.99%) in east canopy direction. Lowest content (17.84%) was obtained in north direction.

Total soluble solids (TSS)

TSS content of different canopy position varied from (10.83 to 11.02°brix) [Table 4a]. Whereas, maximum TSS (11.02°brix) was obtained in upper canopy position. Lowest amount of TSS recorded in lower position (10.83°brix). In pummelo fruits, TSS was significantly influenced by the different canopy direction. TSS varied between 9.28 to 10.95°brix [Table 4b]. Maximum TSS was recorded in east canopy direction (10.95°brix). Lowest TSS (9.28°brix) was recorded in north canopy direction.

Titrable acidity

It is clear from the data presented in Table 4a that titrable acidity of different canopy position varied prominently from (1.59 to 2.24%). Fruit acidity was maximum (2.24%) in lower canopy position. Whereas, lowest acidity was recorded in middle canopy position (1.59%). Fruit acidity was significantly influenced in Pummelo fruit due to canopy position differences. It is evident from Table 4b that titratable acidity varied from (1.28 to 2.24%). Whereas, maximum acidity (2.24%) was recorded in north canopy direction. Acidity was lowest (1.28%) in east canopy direction.

Total sugar

It is clear from the data presented in Table 4a that total sugar varied prominently from 8.64 to 9.16%. Total sugar was maximum (9.16%) in upper canopy position. Lowest total sugar (8.64%) was recorded in lower canopy position. Total sugar was significantly influenced by canopy position. Total sugar of different canopy direction varied from 8.58 to 9.42%. Total sugar 9.42% was recorded in east canopy direction. Lowest total sugar was recorded in north direction (8.58%). Total sugar was significantly influenced by canopy direction (Table 4b).

Reducing sugar

It is evident from Table 4a that reducing sugar of different canopy position varied from 4.44 to 4.52%. Maximum amount

of reducing sugar showed in middle and upper canopy position (4.52%). Lowest reducing sugar was obtained in lower canopy position (4.44%).The significant variation in reducing sugar was noted in different directions. Reducing sugar was varied from (4.00 to 4.29%). Reducing sugar was maximum (4.29%) in east canopy direction. Lowest amount of reducing sugar (4.00%) was recorded in north canopy [Table 4b].

pH content of fruit juice

Table 4a clearly revealed that pH content varied from 4.23 to 4.45. pH was recorded highest (4.45) in upper as compared with lowest pH obtained in lower canopy position (4.23). pH was recorded highest (4.45) in east direction as compared with lowest pH obtained in north (4.10). The significant variation in pH was noted in all the directions [Table 4b].

Ascorbic acid

It is clear from the data presented in Table 4a that ascorbic acid was ranged from (42.18 to 47.84mg/100g of pulp). Maximum Ascorbic acid (47.84mg/100g of pulp) was noted in upper canopy position. Lowest ascorbic acid was recorded in lower canopy position (42.18mg/100g of pulp).Ascorbic acid was recorded highest in east canopy direction (48.79mg/100g of pulp) as compared with lowest ascorbic acid obtained in west canopy direction (40.87mg/100g of pulp). The significant variation in ascorbic acid was noted in all the directions (Table 4b).

DISCUSSION

Microclimatic differences within the fruit tree canopy might cause differences in appearance and eating quality between inner and outer canopy fruit. Fruits were produced throughout the canopy and were therefore exposed to varying irradiance and temperatures that might affect postharvest fruit quality characteristics and influence consumer preference regarding eating quality and appearance (Hamadziripi, 2012). Leaves exposed to high irradiance had increased photosynthesis and this resulted in an increased supply of assimilates to outer canopy fruit (Johnson and Lakso, 1986). Fruits that were supplied by light-exposed leaves would have more soluble sugars and total carbohydrates (Woolf and Ferguson, 2000). TSS was a good indicator of the concentration of sugar and therefore the perceived proper sugar-acid balance (Hoehn *et al*., 2003). Fruits that received adequate light normally had higher TSS concentrations and were consequently perceived as being sweeter while Dussi *et al*., (2005) found that shading decreased TSS in pears. Nilsson and Gustavsson (2007) found that outer canopy apple fruit had a higher TSS and a lower TA. Canopy position affected the external quality of fruit. Appearance provided the first impression of the fruit that would either attract or repel the consumer (Kays, 1998). The synthesis of carotenoids might be responsible for deep pink coloration in pummelo, which was enhanced by better light penetration within the canopies. Similar results were also reported in pears by Steyn *et al*., 2005. Previous study of Jawanda *et al*., (1973) confirmed that fruits from the inner part of the canopy were heavier than from other sides of tree canopy. Higher fruit weight and peel thickness of fruits form internal canopies than from external canopies were determined in Red Blush grape fruit, Valencia orange and Lisbon lemon (Fallahi *et al*., 1989). Jawanda *et al*., (1973) observed the higher amount of juice weight in the fruit harvested from the top outer position of the tree. Grapefruit harvested from the sunlit canopy positions were heavier with more juice content than fruit from shaded positions (Syvertsen and Albrigo, 1980).

From the above experiments it may be concluded that, both positions and directions have a great influence on the morphological and chemical content of pummelo fruits. The middle canopy and east directional fruits have good morphological as well as chemical content in the matured harvested fruits.

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