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PERFORMANCE OF MANDARIN ORANGE GENOTYPES IN NET HOUSE AT JAINTAPUR, SYLHET

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Abstract

A study on performance of seven mandarin genotypes along with BARI Komala-1 as check was carried out at the Citrus Research Station, Bangladesh Agricultural Research Institute (BARI), Jaintapur, Sylhet from January 2016 to December 2018. The average highest number of fruits per plant (37.2), and the maximum fruit yield per plant (6.19 kg) and the maximum fruit yield per hectare (6.87 t) were recorded in the genotype CR Jai-017. The largest fruits (189.67 g) were found in the genotype CR Jai-015 (189.67 g) with the maximum fruit size. Edible portion was found the highest in CR Jai-017 (73.52%) followed by CR Jai-018(72.55%). The genotype CR Jai-016 gave the maximum percent total soluble solids (TSS) (13.58%) and the minimum (9.87) in CR Jai-015, whereas, the titratable acidity (TA) value was the lowest in CR Jai-014 (0.73%) followed by CR Jai-017 (0.75). Maturity index (MI)/sugar acid ratio (17.83) was found in CR Jai-016 followed by CR Jai-017 (15.46). Fruits of CR Jai-017 and CR Jai-018 were dark orange colored. Fruit surface was smooth in BARI Komala-1 and CR Jai-015 whereas other genotypes with pitted skin. The genotype CR Jai-014 has a strong adherence of albedo to pulp, while others were medium to weak. Segment shape of CR Jai-014 and CR Jai-017 were not uniform but the others were uniform. Thickness of segment wall was medium to thick while fruit axis was semi hollow to hollow with light orange to dark orange pulp and pulp firmness was soft to intermediate with medium to high juice content in all the genotypes.

Keywords: Mandarin, Net house, *Citrus reticulata*, titratable acidity, TSS, Sylhet

1. Introduction

Mandarin (*Citrus reticulata* Blanco) locally known as Komala is a popular fruit of Bangladesh. It is a tasty fruit having nutritional and medicinal values, rich in vitamin A, B and C (40 mg l00g^{-1} juice) with recognized immense economic importance (Bhuyan *et al.*, 2016). Mandarin oranges of all kinds are primarily eaten out-of-hand or the sections are utilized in fruit salads, gelatins, puddings or on cakes and very small amounts are canned in syrup (Morton, 1987).

North eastern hilly region of Bangladesh is characterized by small hills and hillocks, wet summer and dry winter, where mandarin is an important crop mostly produced in homesteads along with some commercial fruit crops (Bhuyan

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et al., 2016). However, the productivity is low comparing with other mandarin orange growing countries. One of the main reasons for this low productivity is lack of high yielding varieties. Besides, imbalanced use of nutrients, poor soil management, and lack of irrigation facilities, inadequate management of major pests and diseases as well as low pH of the soil are also responsible to some extent (Nasreen *et al.* 2012).

We conducted the study under net house condition. There are some benefits of net house over the traditional field condition. Previous studies reported that solar radiation and evapotranspiration were 22% and 23.8% lower inside a screen house compared to the open-air, while there was no difference in cumulative rainfall between both production systems (Ferrarezi *et al.*, 2017). On the other hand plants grown inside the enclosed houses had greater canopy area compared to the open-air plots, which is related to higher fruit yield and fruit quality (Schumann *et al.*, 2017). Furthermore, the plants can easily be protected from major pests; therefore, actual potentiality of the plants can be identified without much difficulty. The use of protective netting also prevents yield loss from high temperatures and irradiation, strong wind, and hail (Manja and Aoun, 2019; Mupambi *et al.*, 2018). In addition, protective netting also results in changes in the orchard microclimate that can alter tree physiology and improve tree performance (Manja and Aoun, 2019; Zhou *et al.*, 2018).

Besides, urbanization brings various challenges like increased environmental stressors and massive demand for food.54% of the total world population is urbanized (Pham-Thi *et al.*, 2021). Moreover, many urban residents are facing problems due to lack of space for vegetation. Therefore, rooftop gardening is itself a prodigious idea for pitching a road towards sustainability. The capital city of Bangladesh, the Dhaka is already trying to boost sustainability through urban farming as a possible remedy to these problems (Bhuiyan and Ferdous, 2021; Sultana *et al.*, 2021). Many of the urban farmers are growing different fruits on their rooftops and many of them are trying to produce mandarin orange for getting fresh mandarin oranges on their table. But, still there is a shortage of mandarin variety suitable for rooftop garden, and urban farmers are cheated purchasing mandarin orange seedlings from various nurseries (Islam *et al.*, 2012).

Bangladesh Agricultural Research Institute has already released three varieties of mandarin, which are performing better in different regions of Bangladesh. On the other hand Sylhet and Chottagram region are blessed with a considerable bio-diversity of mandarin (Das *et al.*, 2005). Moreover, in recent years, some exotic germplasm are also collected, which are also good resources for developing more modern varieties of mandarin orange. Therefore, our objectives were to find out suitable mandarin orange genotype(s) with higher yield and quality for in-ground as well as rooftop cultivation. Moreover, we conducted our study under controlled net house condition, which facilitated reduced pests infestation as well as provided the genotypes showing the maximum potentiality to yield under suitable condition.

2. Materials & Methods

2.1 Experimental location

The experiment was conducted at Citrus Research Station under Bangladesh Agricultural Research Institute (BARI) located at Jaintapur Upazila of Sylhet district (25.13562º N latitude, 92.13217º E longitude, altitude 36 m from mean sea level), in three consecutive years viz. 2016, 2017 and 2018. The experimental location belongs to the northern and eastern piedmont plains (AEZ 22) having sandy loam textured soil with very low (<4.2) pH (Ahmmed *et al.*, 2018).

2.2 Meteorological variables

Subtropical climate is enjoyed by the experimental location, which is characterized by wet summer March to September) and dry winter (November to February). Annual average rainfall ranges from 4500-6000 mm, the average maximum and minimum temperatures are 36ºC and 6ºC in the month of April and January respectively (Bhuyan *et al.* 2016). The weather data for the experimental location is mentioned in Table 1.

Table 1. Weather data for the experimental period 2016-2018

Month	Temperature(°C)						Precipitation (mm)			Relative humidity (%)		
	2016		2017		2018		2016	2017	2018	2016	2017	2018
	Max.	Min.	Max.	Min.	Max.	Min.						
January	27	14	29	14	27	15	4.29	0.50	13.00	61	59	63
February	31	18	31	16	31	17	33.00	32.70	3.80	55	55	54
March	35	21	31	29	35	20	104.51	296.20	53.43	49	62	51
April	34	24	32	23	36	23	498.09	799.30	175.13	74	78	58
May	34	25	35	25	30	24	460.15	308.60	506.80	77	76	77
June	32	26	32	26	34	26	630.39	976.70	726.11	84	86	81
July	32	25	32	25	33	26	464.95	618.20	490.00	87	86	84
August	33	25	33	25	34	26	360.37	555.90	387.40	83	84	83
September	33	25	33	25	33	25	469.61	560.30	346.14	85	85	81
October	32	23	32	23	32	21	318.80	499.08	83.65	83	83	76
November	29	19	31	19	31	18	185.58	25.10	22.90	81	73	72
December	29	17	29	17	27	16	1.70	79.40	21.10	74	75	69

2.3 Experimental condition

The plants were grown using earthen pots (top diameter 18 inches, bottom diameter 12 inches, height 14 inches and approximate volume of 40.5 L).Seven Mandarin genotypes were included in the study along with BARI Komala-1 as check. The saplings were planted in 2013 to initiate the study. At the beginning the potting soil was prepared by mixing sandy loam nursery soil (pH 6.3) and FYM (1:1) on volume basis. Afterwards chemical fertilizers (20 g of triple super phosphate and 12 g of gypsum) were added with 40 liter of potting mix and the pots were filled followed by watering. The pots were left for 15 days; and afterwards the saplings were planted at the middle of each pot. The saplings were previously prepared using pummelo as the rootstock, and 8 months old grafts were selected for planting. The saplings started flowering at the age of two, but we did not allow any fruit on the year 2014 and 2015 in order to facilitate proper growth of the plants. The plants were around 4 years old when we started data collection and evaluation.

2.4 Cultural Management

Nitrogen (30 g urea) and potassium (20 g MoP) were top dressed in every month in the base of each plant to facilitate proper growth of the plants. Moreover, every year, 5cm top soil of each pot was replaced by new growing media (Soil:FYM=1:1). The plants were irrigated 2-3 times in a week for proper flowering and fruit retention in dry season. Pest management, weeding and other intercultural operations were done when necessary. Fruits were harvested when fruits were fully ripened and the skin color of the fruit turned to deep yellow or orange.

2.5 Data Recording

Data were recorded on growth parameters namely, plant height, base girth, canopy spreading (north-south and east-west), fruits per plant, per plant and per hectare yield. Plant height was measured from the base of the plant to the tips of the topmost leaves and expressed in meter, while the base girth was measured 15 centimeter above the soil and expressed in cm. In a similar way the extent of the canopy was measured in both north-south and east-west direction to find out the canopy spreading and expressed in meter. Numbers of fruits per plants were counted and Yield (kg $plant^{-1}$) and yield (t ha^{-1}) was recorded on every commercial harvest.

Every year mature fruits were collected from the plants. Three randomly selected fruits from each plant were harvested for data collection on individual fruit weight, fruit size (length and diameter at equatorial region), segments per fruit, diameter of fruit axis, rind thickness and weight, seeds per fruit, seed weight per fruit, vesicle size, edible portion, total soluble solids (TSS), titratable acidity (TA) and Maturity index.

Total soluble solids content (TSS) was measured with the help of a refractor meter and corrected with temperature factor (Sherwood, 1928). TA was expressed as percent citric acid present in the juice (Hardy and Sanderson, 2010). While, Maturation index (MI) was calculated from the ratio of TSS:TA (Cavalcante *et al.*, 2009).

2.6 Experimental design and Statistical Analysis

The experiment was laid out following completely randomized design (CRD) with three replications. All the recorded data on different parameters were statistically analyzed using Statix10 software and Fisher's LSD Test was performed for mean separations of the studied parameters and interpretation of results (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Height and tree volume

Variation was observed regarding the plant height and tree volume of mandarin variety/accessions (Table2). In 2016, during the first year of study, the plants of CR Jai-015 grows vigorously and reached up to 193.4 cm in height on an average with 2.71 m^3 of tree volume, which was also emulated in both 2017 and 2018 (212.8 cm height and 3.58 $m^3$of tree volume respectively).But in 2018 during the third year of study more vigorosity (235.0 cm height and 3.36 $m^3$of tree volume) was found from the plants of CR Jai-017. While comparatively weak plants were found from CR Jai-014, Jai-016 and Jai-018. In all three years, CR Jai-011, Jai-013 and BARIKomala-1showed intermediate vigor. This might be due to the genetic make-up of the genotypes under study (Neves *et al.*, 2018).

Table 2. Growth characteristics of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Plant height (cm)				Tree volume (m^3)			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	182.6 bc	201.8 b	215.6 bc	200.00 b	2.11 bc	2.29 c	2.63 c	2.34 c
CR Jai-013	188.2 ab	201.6 b	218.8 b	202.87 b	2.15 bc	2.49 c	3.11 b	2.58 bc
CR Jai-014	177.0 c	193.2c	205.6 c	191.93 c	2.20 bc	2.75 b	3.27 ab	2.74 b
CR Jai-015	193.4 a	212.8 a	228.8 a	211.66 a	2.71 a	3.08 a	3.29 a	3.03 a
CR Jai-016	178.0 c	192.8 c	206.6 c	192.45 c	2.22 bc	2.74 b	3.26 ab	2.74 b
CR Jai-017	188.6 ab	211.2 a	235.0 a	211.60 a	2.28 b	2.84 ab	3.36 a	2.83 ab
CR Jai-018	176.2 c	186.4 c	196.4 d	186.33 d	1.89 c	2.22 c	2.27 d	2.13 d
BARI Komala-1	188.4 ab	201.8 b	219.8 b	203.35 b	2.14 bc	2.43 c	3.08 b	2.55 bc
LSD	8.69	8.11	8.63	8.46	0.34	0.25	0.19	0.31
CV%	2.59	02.22	2.18	3.12	8.57	4.55	2.78	8.68

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at $P \leq 0.05$ applying LSD test.

3.2 Yield contributing characters and yield

Significant dissimilarities were observed regarding the yield contributing characters and yield of different variety/accessions studied (Table 3). Throughout the experimental period maximum number of fruits plant^{-1} was observed in CR Jai-017 (31.6, 39.0 and 41.0 respectively), while lowest number of fruits plant^{-1} was observed in CR Jai-017 (12.2, 14.2 and 18.4 respectively). On the other hand, CR Jai-015 performed better regarding individual fruit weight in all the experimental years (185.00 g, 192.00 g and 192.00 g in 2016, 2017 and 2018 respectively), where as the smallest fruit was found from CR Jai-016 (125.67 g, 128.00 g and 122.67 g in 2016, 2017 and 2018 respectively). Moreover, CR-016 bears comparatively small fruits (data not presented) in all the studied year. The number of fruits plant^{-1} is very important for mandarin farmer as they sell each fruit by 20-25 BDT of whether it is sweet or not (Gafor and Choudhury, 2011). Similarly, higher individual fruit weight gave a higher biological yield. Therefore, the accessions boar higher number of fruit might be economically advantageous for the farmers. Talukder *et al.* (2015) also postulated similar results when evaluating some genotypes collected from different locations of Bangladesh.

Table 3. Fruits plant^{-1} and Individual fruit weight of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Fruitsplant^{-1}(No.)				Individual fruit weight (g)			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	14.5 e	18.3 f	22.7 f	18.4 f	156.33 cd	171.33 cd	174.67 bc	167.44 cd
CR Jai-013	27.0 b	32.0 b	34.7 b	31.2 b	158.67 c	175.33 c	179.00 b	171.00 c
CR Jai-014	12.2 f	14.2 g	18.4 g	15.0 g	172.00 b	184.67 b	192.67 a	183.11 b
CR Jai-015	24.4 c	27.7 c	28.7 cd	26.9 c	185.00 a	192.00 a	192.00 a	189.67 a
CR Jai-016	18.3 d	25.0 d	28.0 d	23.8 d	114.33 f	125.67 g	128.00 f	122.67 g
CR Jai-017	31.6 a	39.0 a	41.0 a	37.2 a	153.67 d	169.33 de	173.00 c	165.33 d
CR Jai-018	23.3 c	26.4 cd	29.7 c	26.4 c	146.33 e	164.67 e	165.00 d	158.67 e
BARI Komala-1	13.7 ef	20.2 e	25.2 e	19.8 e	142.33 e	144.00 f	141.67 e	142.67 f
LSD	1.510	1.371	1.317	1.036	4.92	4.72	4.51	4.12
CV%	4.18	3.09	2.63	2.38	1.83	1.63	1.53	1.45

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at $P \leq 0.05$ applying LSD test.

Yield is the most important factor for getting maximum productivity from any genotypes. As the growth parameters boosted up, there was an opportunity for accumulating more food and dry matter that helps in higher production. In the present experiment yield differed significantly in the studied variety/accessions

(Table 4). In the years 2016 and 2018 less productivity was obtained from the check variety BARI Komala-1 (1.94 and 3.59 kg plant^{-1} respectively), whereas, in 2017 lower productivity was found from CR Jai-014 (2.65 kg plant^{-1}). On the other hand, in three consecutive years CR Jai-17 gave maximum yield (1.86 kg, 6.60 kg and 7.09 kg plant^{-1} and 5.40 t, 7.33 t and 6.87 t ha^{-1} respectively). This was due to the genetic potentiality of each genotype. Moreover, this might be due to faster vegetative growth, progress in photosynthesis rate and improvement of the photosynthates translocation (Talukder *et al.*, 2015). Altaf *et al.*, (2008) also obtained 101g to 287 g fruit weight in Kinnow mandarin. But lowest per ha yield was illustrated by CR Jai-014 in three consecutive years (2.94, 3.92 and 3.07 t ha^{-1} respectively). This result is in conformity with other researchers in banana (Chezhigen *et al.*, 1999).

Table 4. Yield plant^{-1} and yield ha^{-1} of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Yield plant^{-1} (kg)				Yield (t ha^{-1})			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	2.24 e	3.14 e	3.96 e	3.11 e	2.49 e	3.49 e	4.39 e	3.46 e
CR Jai-013	4.28 c	5.61 b	6.21 b	5.37 b	4.75 c	6.23 b	6.89 b	5.96 b
CR Jai-014	2.12 ef	2.65 g	3.53 f	2.77 g	2.35 ef	2.94 g	3.92 f	3.07 g
CR Jai-015	4.50 b	5.31 c	5.51 c	5.11 c	5.00 b	5.90 c	6.11 c	5.67 c
CR Jai-016	2.10 ef	3.14 e	3.58 f	2.94 f	2.33 ef	3.49 e	3.98 f	3.26 f
CR Jai-017	4.86 a	6.60 a	7.09 a	6.19 a	5.40 a	7.33 a	7.87 a	6.87 a
CR Jai-018	3.41 d	4.34 d	4.89 d	4.21 d	3.79 d	4.81 d	5.43 d	4.68 d
BARI Komala-1	1.94 f	2.93 f	3.59 f	2.82 fg	2.16 f	3.25 f	3.98 f	3.13 fg
LSD	0.183	0.165	0.227	0.135	0.203	0.183	0.251	0.150
CV%	3.29	2.24	2.70	1.89	3.29	2.24	2.70	1.89

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at P ≤ 0.05 applying LSD test.

3.3 Quantitative fruit quality attributes

There were no significant differences among the variety/accessions regarding segments per fruit in the second and third year of study but in the first years significant variations were noticed (Table 5). Maximum number of segments per fruit was counted from CR Jai-011 (12.0 in both 2016 and 2018), whereas both CR Jai-013 and CR Jai-016 showed highest number of segments fruit^{-1} in 2017

(Table 5). The number of segment represents the number of carpels within the ovary. Segment adherence to each other was strong in most of the genotypes of Khasi and Nagpuri mandarins (Talukder *et al.*, 2015). Altaf *et al.* (2008) found 8-12 segments per fruit in Kinnow mandarin. Whereas, Singh and Singh (2004) were noted that 11.5 segments exist per fruit in mandarin. Diameter of the fruit axis is also an important factor for mandarin oranges (Table 4). With the increase of the axis diameter the hollow core inside the fruit increased resulted in lowest edible portion. In our study variety BARI Komala-1 showed the maximum fruit axis diameter in all the study years (1.65cm, 1.66cm and 1.65 cm in 2016, 2017 and 2018 respectively) followed by CR Jai-014 (1.64cm, 1.64cm and 1.64 cm in 2016, 2017 and 2018 respectively); while the lowest fruit axis diameter was found from CR Jai-015 (1.09cm, 1.09cm and 1.09 cm in 2016, 2017 and 2018 respectively). Therefore our study corroborates with the previous study of Talukder *et al.*, (2015), who found solid fruit axis in most of the studied mandarin genotypes and the least with hollow and semi-hollow irrespective of Khasi and/or Nagpuri types.

Table 5. Segments fruit $^{-1}$ and diameter of fruit axis of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Segments fruit $^{-1}$(No.)				Diameter of fruit axis (cm)			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	12.0 a	11.3	12.0	11.8 a	1.42 b	1.42 ab	1.42 b	1.42 b
CR Jai-013	10.3 b	10.7	11.3	10.8 c	1.54 ab	1.54 a	1.54 ab	1.54 ab
CR Jai-014	10.7 ab	11.6	12.0	11.4 ab	1.64 a	1.64 a	1.64 a	1.64 a
CR Jai-015	10.6 ab	11.0	11.0	10.9 bc	1.09 c	1.09 cd	1.09 c	1.09 c
CR Jai-016	11.0 ab	11.7	11.7	11.4 ab	0.89 d	0.89 d	0.89 d	0.87 d
CR Jai-017	11.0 ab	11.6	11.7	11.4 ab	1.56 ab	1.56 a	1.57 ab	1.56 a
CR Jai-018	10.6 ab	11.0	11.6	11.1 bc	1.16 c	1.16 bc	1.16 c	1.16 c
BARI Komala-1	11.0 ab	11.0	11.3	11.1 bc	1.65 a	1.66 a	1.65 a	1.66 a
LSD	1.50	1.25	1.05	0.65	0.18	0.27	0.16	0.13
CV%	7.87	6.32	5.16	3.27	7.44	11.16	6.58	5.34

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at $P \leq 0.05$ applying LSD test.

The rind is an important quality attribute of mandarin fruit (Table 6). A thick rind is in most of the cases fragile and creates difficulty to peel off the fruit. Thin peels with low average weight also facilitate higher per cent of edible portion. In all the experimental years, plants of CR Jai-011 showed maximum rind thickness as well as rind weight (3.8 mm, 3.9 mm, 3.9 mm; and 56.39 g, 62.80 g, 64.28 g in 2016, 2017 and 2018 respectively); whereas lowest rind thickness was found from CR Jai-018 (2.3 mm, 2.4 mm and 2.4 mm in 2016, 2017 and 2018 respectively). On the other hand lowest rind weight was found from CR Jai-017 (30.89 g, 32.09 g and 31.50 g in 2016, 2017 and 2018 respectively).Similar result was also found by Altaf *et al.* (2008), who observed 24 to 71 g peel weight in Kinnow mandarin, while rind weight varied from 18.60 to 43.64 g in Khasi type. According to a description given by Mazhar (1959), Kinnow, Feutrell's Early, Coorg and Nagpuri varieties have less percentage of rind.

Table 6. Rind thickness and Rind weight of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Rind thickness (mm)				Rind weight (g)			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	3.8 a	3.9 a	3.9 a	3.9 a	56.39 a	62.80 a	64.28 a	61.15 a
CR Jai-013	3.2bc	3.3 cd	3.3 bc	3.2 cd	43.56 c	43.22 c	44.01 c	43.59 c
CR Jai-014	3.4 b	3.5 bc	3.5 ab	3.5 bc	40.27 d	39.110 d	39.11 d	39.50 d
CR Jai-015	3.57 ab	3. 7 ab	3. 7 ab	3.6 ab	46.86 b	50.60 b	51.52 b	49.66 b
CR Jai-016	2.7 d	2.8 e	2.7 de	2.7 ef	34.14 e	34.4 e	35.01 e	34.51 e
CR Jai-017	3.0 cd	3.1 d	3.03 cd	3.0 de	30.89 e	31.52 f	32.09 f	31.50 f
CR Jai-018	2.3 e	2.4 f	2.4 e	2.4 g	41.43 cd	42.88 c	43.66 c	42.66 c
BARI Komala-1	2.6 de	2.6 ef	2.6 e	2.6 fg	27.05 f	29.54 f	29.75 f	28.78 g
LSD	0.37	0.32	0.40	0.36	3.26	2.54	2.55	1.93
CV%	6.86	5.89	7.33	6.60	4.65	3.47	3.43	2.66

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at $P \leq 0.05$ applying LSD test.

Seed weight also varied considerably among the treatments exhibiting the genotypic effect of different variety/accessions (Table 7). In three consecutive years–2016, 2017 and 2018 highest average numbers of seeds fruit^{-1} was counted from CR Jai-15 (17.67, 17.67 and 18.00 respectively), followed by CR Jai-011 (17.67, 17.33 and 18.00 respectively), where as lowest number of seeds fruit^{-1} was counted from CR Jai-014 (2.33, 2.67 and 2.33 respectively). Similarly, lowest seed weight fruit^{-1} was found from CR Jai-014 (0.07, 0.07 and 0.11 in 2016, 2017 and 2018 respectively). Contrary highest seed weight fruit^{-1}was measured in CR Jai-016 (0.35, 0.36 and 0.35 in 2016, 2017 and 2018 respectively), followed by CR Jai-017 (0.35, 0.33 and 0.34 in 2016, 2017 and 2018 respectively).

Table 7. Seeds fruit $^{-1}$ and seed weight of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Seeds fruit $^{-1}$(No.)				Seed weight (g)			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	17.67 a	17.33 a	18.00 a	17.67 a	0.17 bc	0.18 bc	0.17 bc	0.17 bc
CR Jai-013	7.67 e	7.33 e	7.67 e	7.56 e	0.14 bc	0.15 bc	0.14 b-d	0.14 bc
CR Jai-014	2.33 f	2.67 f	2.33 f	2.44 f	0.07 d	0.07 d	0.11 d	0.08 d
CR Jai-015	17.67 a	17.67 a	18.00 a	17.78 a	0.12 cd	0.12 cd	0.12 cd	0.12 cd
CR Jai-016	11.00 d	11.00 d	11.00 d	11.00 d	0.33 a	0.35 a	0.33 a	0.34 a
CR Jai-017	13.33 c	13.00 c	13.33 c	13.22 c	0.35 a	0.36 a	0.35 a	0.35 a
CR Jai-018	15.00 b	15.00 b	15.00 b	15.00 b	0.14 bc	0.15 bc	0.14 b-d	0.14 bc
BARI Komala-1	11.00 d	11.33 d	11.67 d	11.33 d	0.18 b	0.19 b	0.18 b	0.19 b
LSD	1.53	1.34	1.51	1.40	0.05	0.06	0.06	0.05
CV%	7.33	6.44	7.11	6.68	15.32	16.27	17.69	15.67

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at $P \leq 0.05$ applying LSD test.

Total soluble solids (TSS) and titratable acidity (TA) significantly differed among the variety/accession tested (Table 8). Among the variety/accessions CR Jai-016 showed highest TSS in three consecutive years (13.50%, 13.60%, and 13.63% in 2016, 2017 and 2018 respectively), where as lowest TSS was found from CR Jai-015 (9.77%, 9.83%, and 9.87% in 2016, 2017 and 2018 respectively). On the other hand highest percent TA was obtained from CR Jai-018 (0.96%, 0.96%, and 0.97% in 2016, 2017 and 2018 respectively) followed by CR Jai-015 (0.95%, 0.95%, and 0.96% in 2016, 2017 and 2018 respectively), while minimum TA was found from CR Jai-014 (0.73%, 0.73%, and 0.72% in 2016, 2017 and 2018 respectively) followed by CR Jai-017 (0.75%, 0.76%, and 0.75% in 2016, 2017 and 2018 respectively). A total soluble solid along with the TA is important for measuring the fruit quality. The organoleptic sourness of fruit increased with the increasing TA although TSS of that particular fruit is high. Our study unfolded the genotypic effect of different variety/accessions regarding percent TSS, TA and maturity index badly. Babu and Yadav (2002) obtained that 10.48% TSS in Khasi mandarin genotypes and reported that the TSS found from the Khasi mandarin was more than the released variety BARI Komala-1 (8.66%). But in our study the TSS (%) was much higher than the reports of Babu and Yadav (2002). This might be due to the cultural condition of the two studies. As we cultivated the plants under net house condition which facilitated more intensive care and reduced pest infestation, given ultimate quality of the fruit. Ladaniya (1996) also reported that Nagpur mandarins grown near Nagpur developed minimum 10% TSS after 270-280 days from fruit set, which supported our study.

Table 8. TSS and TA of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	TSS				TA			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	12.60 ab	12.70 ab	12.71 ab	12.67 ab	0.81 c	0.83 b	0.84 b	0.82 c
CR Jai-013	11.13 b-d	11.24 b-d	11.25 b-d	11.21 b-d	0.94 a	0.94 a	0.96 a	0.95 a
CR Jai-014	11.23 b-d	11.34 b-d	11.35 b-d	11.31 b-d	0.73 d	0.73 c	0.72 d	0.73 d
CR Jai-015	9.77 d	9.83 d	9.87 d	9.82 d	0.95 a	0.95 a	0.96 a	0.95 a
CR Jai-016	13.50 a	13.60 a	13.63 a	13.58 a	0.76 d	0.77 c	0.76 c	0.76 d
CR Jai-017	11.50 bc	11.60 bc	11.60 bc	11.57 bc	0.74 d	0.75 c	0.76 cd	0.75 d
CR Jai-018	10.30 cd	10.37 cd	10.41 cd	10.36 cd	0.96 a	0.96 a	0.97 a	0.96 a
BARI Komala-1	11.43 bc	11.54 bc	11.55 bc	11.51 bc	0.88 b	0.88 b	0.86 b	0.87 b
LSD	1.58	1.59	1.59	1.58	0.044	0.048	0.038	0.041
CV%	7.88	7.88	7.88	7.88	3.00	3.21	2.57	2.74

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at $P \leq 0.05$ applying LSD test.

Fruit quality attributes were significantly varied among the variety/accessions studied (Table 4). Edible portion were statistically indifferent among variety/accessions CR Jai-017, CR Jai-018, CR Jai-014 and BARI Komala-1 during 2016, but maximum edible portion was found from CR Jai-017 (73.93%). On the other hand, in the year 2017 and 2018, CR Jai-017, CR Jai-018 and BARI Komala-1 showed statistically similar percentage of edible portion, where CR Jai-017 showed the maximum (72.92% and 73.52% in the year 2017 and 2018 respectively). Regarding maturity index (MI) CR Jai-016 performed better in all the tested year (17.86, 17.76 and 17.83 in 2016, 2017 and 2018 respectively), whereas, the lowest MI were found from CR Jai-015 (10.29, 10.39 and 10.32 in 2016, 2017 and 2018 respectively).This might be due to proper cultural and nutrient management to the genotypes, which gave the genotypes to show their potentiality under controlled condition. Bhuyan *et al.* (2016) found similar result with integrated nutrient management in mandarin orange with higher TSS/TA ratio and better quality. Talukder *et al.* (2015) found more than 70% edible portion in all the studied genotype.

Table 9. Edible portion and MI (TSS/TA) of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	(%)				MI (TSS/TA)			
	2016	2017	2018	Mean	2016	2017	2018	Mean
CR Jai-011	61.52 b	62.80 bc	62.39 c	62.23 e	15.71 ab	15.29 bc	15.20 bc	15.40 b
CR Jai-013	63.94 b	62.59 bc	63.73 bc	63.42 de	11.90 de	11.96 de	11.73 de	11.87 cd
CR Jai-014	72.73 a	63.67 bc	63.12 bc	66.51 c	15.39 bc	15.55 ab	15.69 b	15.54 b
CR Jai-015	64.54 b	64.07 b	64.07 b	64.22 d	10.29 e	10.39 e	10.28 e	10.32 d
CR Jai-016	63.06 b	62.09 c	62.84 bc	62.66 e	17.86 a	17.76 a	17.87 a	17.83 a
CR Jai-017	73.93 a	72.92 a	73.52 a	73.45 a	15.64 ab	15.40 b	15.33 bc	15.46 b
CR Jai-018	72.85 a	72.50 a	72.23 a	72.55 ab	10.77 de	10.84 e	10.74 e	10.78 d
BARI Komala-1	71.04 a	72.03 a	72.61 a	71.89 b	13.06 cd	13.12 cd	13.39cd	13.19 c
LSD	3.29	1.73	1.43	1.29	2.36	2.23	2.00	2.18
CV%	2.76	1.49	1.22	1.10	9.75	9.25	8.31	9.03

Means were calculated from three replications (n = 3) for each treatment. Values with different letters are significantly different at $P \leq 0.05$ applying LSD test.

3.4 Qualitative fruit quality attributes

In case of other qualitative fruit characters (Table 5), fruits of CR Jai-017 and CR Jai-018 were found dark orange color in all the experimental period, while greenish yellow color was found in CR Jai-013 and CR Jai-015, but light orange was found in CR Jai-016and CR Jai 011, whereas orange and greenish color fruits were recorded in BARI Komala-1 and the genotype CR Jai-014. Obloid shaped fruits were recorded in all the consecutive years in all genotypes. Fruit surface was found smooth in BARI Komala-1 and CR Jai-015, while other with pitted skin. Strong adherence of albedo to pulp was found in CR Jai-014, while others were medium to weak in every study year. Furthermore, a strong attachment of fruits with stalk was found in CR Jai-013 and CR Jai-016, while others were weak in all the studied year. Rind color of citrus is considered to be one of the most important external factors of fruit quality, as the appearance of fruit greatly influences consumer choice (Olmo *et al.*, 2000). Chahidi *et al.* (2008) also reported various rind colors in Clementine mandarin.

Table 10. Fruit color, fruit shape, fruit surface texture, adherence of albedo to pulp, fruit attachment to stalk of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Fruit color	Fruit Shape	Fruit surface texture	Adherence of albedo to pulp	Fruit attachment to stalk
CR Jai-011	Light Orange	Obloid	Pitted	Weak	Medium
CR Jai-013	Greenish Yellow	Obloid	Pitted	Medium	Strong
CR Jai-014	Greenish	Obloid	Pitted	Strong	Medium
CR Jai-015	Greenish Yellow	Obloid	Smooth	Weak	Medium
CR Jai-016	Light Orange	Obloid	Pitted	Weak	Strong
CR Jai-017	Dark Orange	Obloid	Pitted	Medium	Medium
CR Jai-018	Dark Orange	Obloid	Pitted	Medium	Medium
BARI Komala-1	Orange	Obloid	Smooth	Medium	Medium

Uniform shape of segments was found in all the genotypes except CR Jai-014 and CR Jai-017 (Table 11). Thickness of segment wall was found medium to thick in all the genotypes except CR Jai 018, which was comparatively thin. Fruit axis was found semi hollow to hollow and pulp color was recorded light orange to dark orange in all the genotypes. Pulp firmness and juice content were recorded soft to intermediate and medium to high respectively in all the genotypes in all the experimental year.

Table 11. Segment shape uniformity, thickness of segment wall, Fruit axis, pulp color, pulp firmness, juice content of mandarin genotypes in net house condition under north eastern hilly region of Bangladesh

Variety/ Accession	Segment shape uniformity	Thickness of segment wall	Fruit axis	Pulp color	Pulp firmness	Juice content
CR Jai-011	Yes	Medium	Semi-hollow	Dark Orange	Soft	High
CR Jai-013	Yes	Thick	Hollow	Light Orange	Intermediate	Medium
CR Jai-014	No	Thick	Semi-hollow	Light Orange	Intermediate	Medium
CR Jai-015	Yes	Medium	Semi-hollow	Light Orange	Intermediate	Medium
CR Jai-016	Yes	Thick	Semi-hollow	Dark Orange	Soft	High
CR Jai-017	No	Medium	Hollow	Dark Orange	Soft	High
CR Jai-018	Yes	Thin	Semi-hollow	Dark Orange	Soft	High
BARI Komala-1	Yes	Medium	Hollow	Dark Orange	Soft	High

Conclusion

From the study, it can be concluded that the genotypes CR Jai-017 and CR Jai-016 were found superior in terms of yield and fruit quality attributes. The genotype CR Jai-016 also may be released as a variety and the both genotypes may be recommended for net house cultivation and roof gardening in controlled condition under north eastern hilly region of Bangladesh.

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