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Evaluation of Coorg mandarin (*Citrus reticulata*) clones for yield and quality

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ABSTRACT

Coorg mandarin (*Citrus reticulata* Blanco) is acclaimed for its exquisite taste, quality, distinct flavour and keeping quality. It is predominantly grown, as an intercrop in the coffee-based cropping system in Kodagu region of Karnataka since more than a century. The area of Coorg mandarin was drastically reduced during last two decades due to *Phytophthora,* Citrus Tristeza Virus (CTV) and Citrus Greening Disease (CGD). An extensive field survey was undertaken in different Coorg mandarin growing regions and 20 high yielding diseases - free superior clones were identified. These clones were planted for field evaluation in randomized block design (RBD) during September 2006 at CHES, Chettalli. The growth observations revealed that the average plant height was maximum in Clone -13 (2.72 m) for 9 years followed by Clone - 7 (2.55 m) and Clone -11 (2.55 m). The rootstock and union ratio was between 0.98 to 1.02 while rootstock scion ratio ranged between 0.87 and 0.91. This indicates that there is no incompatibility with rootstock in all selected clones. The maximum rootstock girth (22.77 cm) and scion girth (20.02 cm) was recorded in Clone -7. The tree volume ranged from 3.40 m^3 in Clone-19 to 5.17 m^3 in Clone -4. The Clone - 4, Clone-13, Clone-7, Clone-10 were found vigorous while Clone-19, Clone-18, Clone-6 were found least vigorous. The highest average yield was recorded in Clone –8 (14.82 kg/plant) while lowest yield was recorded in Clone -18 (8.5 kg/plant). The average fruit weight ranged from 96.78 g (Clone-14) to 130.84g (Clone-8). The number of seeds per fruit was lowest in Clone –3 (11.1). TSS was the highest (9.54^{o}B) in Clone -17 and Clone – 8 (9.13 ^{o}B). The pulp per cent was highest in Clone -15 (75.3 %). The fruits of Clone- 1 recorded the highest ascorbic acid content of 38.3 mg/100 ml of juice while Clone-13 registered the minimum (25.69 mg/100 ml). The results revealed Clone-8 and Clone-20 were found better for yield and some of the fruit quality characters. These can be utilized for commercial cultivation while other clones which are superior in one or other traits may be utilized in breeding programmes.

Key words: Coorg mandarin, Clone, Evaluation, Quality, Yield

Citrus is the most important fruit crop in the world, with an annual production of approximately 110 million tonnes. Mandarin (*Citrus reticulata* Blanco), is the second most important species of citrus after orange (*Citrus sinensis* L. Osbeck). Mandarin probably originated in Southern China and Taiwan or possibly in India. Because of their excellent qualities, these mandarins were widely cultivated throughout the world. The mandarin group has several varieties that are especially suited to the tropical climate. Several types of mandarins are known in India and the important ones are Nagpur mandarin, Coorg mandarin and Khasi mandarin. Coorg mandarin is largely grown traditionally under humid sub-tropical conditions in the states of Karnataka, Tamil Nadu and Kerala. It is endemic to Coorg region of Karnataka where its culture is spontaneous dating back to more than a century and characterized predominantly by extensive use of seedlings and mainly grown as an intercrop in the multi-tier coffee-based cropping system. There is large reduction in area of Coorg mandarin during last 30 years which is mainly attributed to *Phytophthora,* Citrus Tristeza Virus (CTV) and Citrus Greening Bacterium (CGB). Approaches to rehabilitate Coorg mandarin cultivation in these areas have primarily considered eradication of affected plants and use of standard disease – free planting materials followed by vector management. Genetically superior, disease-free propagating material is the foundation stone for a successful scientific citrus cultivation. Bud mutations have occurred fairly often in the history of citriculture and instances of their commercial exploitation are well documented (Chakrawar and Rane 1997). In order to pursue this possibility, identification and selection of superior

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clones was undertaken through targeted survey of traditional growing regions. So far clonal selection has been generally used as one of traditional breeding methods because bud mutations arise frequently in *Citrus* (Iwamasa *et al.* 1981, Uzun *et al*. 2004). This offers advantages to select clones suitable for their aims. Yield and fruit quality can be increased via clonal selection of natural mutants. Clonal selection studies, so far, aimed regular production over years, homogeneous fruit weight, and tolerance to biotic and abiotic stresses. In general, selecting main source trees, testing different ecological conditions, and isolating from pathogens are main steps of clonal selection (Ulubelde *et al*. 1986). Thus study was undertaken to determine variations for some selected horticultural traits among 20 Coorg mandarin collections derived from selections.

MATERIALS AND METHODS

Twenty clones of Coorg mandarin collected from the Coorg mandarin growing regions of Karnataka were used in this study. They were initially selected for agronomical traits by observing for 1-2 years.

Bud woods were taken from selected main source trees and grafted on Rangpur lime (*Citrus limonia* Osbeck) rootstocks. The grafted trees were planted to field in randomized complete block design with 3 replicates and 4 plants each replication in 2006 at Central Horticultural Experiment station, Chettalli, Karnataka. Tree spacing was maintained at 6 m × 6 m. The soil was lateritic with 28.5 % clay content having 652 µg Ca/g soil and a pH of 5.70. The trees were managed according to standard local commercial practices, pruned annually, and watered as needed using a basin irrigation system. Fertilization was managed based on recommended nutrient doses. These plants were fertilized with 60g N, 40g P_20_5 and 60 g K_2O/tree/year of tree age. These doses were divided in two halves and applied in the month of June and October. Foliar sprays of micronutrients (Zn, Mg, Mn, Fe, Ca) were also applied in the month of October and May. Pest populations were kept under control recommended pest management measurements. Characterization for tree performance and fruit quality, selected clones were evaluated as follows.

Tree height, canopy diameter, and scion trunk circumference were recorded annually for 9 years (2007-2015) in the month of January every year. Tree height and canopy diameter were converted into tree spread and tree volume. Tree spread (m^2) was estimated using formula Plant spread (N-S) × Plant spread (E-W))/2. The tree volume (m^3) is calculated using formula: (tree spread × plant height) × 0.85). Scion trunk circumference was measured 10 cm above the bud union and was converted into trunk cross-sectional area (TCSA, cm^2). The trunk cross-sectional area was calculated by using formula (TCSA= $Girth^2/4\pi$) given by Kumar *et al*. (2008).

Yield (kg/tree) were recorded annually during 4 years of production. Tree yield by canopy volume (kg/m^3) and trunk cross-sectional area (kg/cm^2) were also estimated.

In the month of November, which is commercial harvesting season of mandarin in Coorg, 25 fruits per were selected for quality analysis. All fruit samples were assessed for fruit weight (g), rind weight, juice percentage (%) and seed number per fruit for 4 years (2011–14) using standard procedures. Total soluble solids (°Brix), acidity (%) and ascorbic acid (mg/100ml juice) were estimated using procedures described by Ranganna (1986).

For tree and fruit characters, data were analyzed using F-Test procedures as described by Panse and Sukhatme (1995).

RESULTS AND DISCUSSION

Tree growth

The average plant height was maximum in Clone-13 (2.72 m) for 9 years followed by Clone-7 (2.55 m) and Clone-11 (2.54 m). However, significantly higher plant height was recorded in Clone-13, Clone-7 and Clone -14 in seventh, eighth and ninth year of planting and it was 3.37 m, 3.22 m and 3.19 m, respectively, in ninth year. Lower average plant height was recorded in Clone-15 (2.16 mSharma and Tomar) followed by Clone-19(2.26 m) and Clone-20 (2.26 m). The lowest plant height in nine year was recorded in Clone-20 (2.79 m) (Table 1). The average rootstock girth, union girth and scion girth of nine years was highest in Clone-7 which was 22.77 cm, 22.83 cm and 20.02 cm, respectively. But it was statistically at par all other clones except Clone-16, Clone-19 and Clone-6. In ninth year, highest rootstock girth was observed in Clone-7 (31.6 cm) followed by Clone-2 (31.2 cm) and It was lowest in Clone-16 (26.3 cm). The union girth and scion girth exhibited similar trends as of rootstock girth (Table 1). The ratio of root girth and union girth ranged from 0.98 to 1.03 while the ratio of root girth and scion girth ranged between 0.86 and 0.91. This shows that these all clones are compatible with Rangpur lime rootstock. The average trunk cross section area was highest in Clone-7 (3.24 cm^2) followed by Clone -13 (3.15 cm^2) and Clone-8 (305 cm^2). The average tree spread was highest in Clone-4 (1.91 m^2) and Clone-13(1.76 m^2) and Clone-9 (1.71 m^2). In ninth year highest tree spread was observed in Clone-4 (2.70m^2) followed by Clone- 9 (2.57 m^2) and Clone-14 (2.52 m^2). The average tree volume was highest in Clone-4 (5.17 m^3) and Clone-13 (5.17 m^3) and lowest in Clone-6 (3.29 $m^{3)\,cu}$ m). In ninth year highest tree volume was observed in Clone-4 (7.29 m^3) followed by Clone-13 (7.18 m^3) and Clone- 14(6.85 m^3) (Table 1). The results indicated that all the clones showed upright growth and apical dominance. The results indicated that Clone-4, Clone-13 and Clone-14 were vigorous than other clones while Clone-8, Clone-16 and Clone-19 were less vigorous. Clone-20 and Clone-7 showed relatively lower canopy growth with higher stem girth. The possible reason may the intercropping of the Coorg mandarin with coffee and preference of upright tree over spreading trees for centuries may have contributed for this attribute.

Table 1 Growth characters of different clones of Coorg mandarin (average 2007-2015)

Clones	Plant height (m)	Stock girth (cm)	Union girth (cm)	Scion girth (cm)	Ratio		Trunk cross section area (cm^2)	Tree spread (m^2)	Tree volume (m^3)
					Root girth: union girth	Root girth: scion girth			
Clone 1	2.35	20.69	20.35	18.50	0.98	0.89	2.76	1.69	4.14
Clone 2	2.45	21.47	21.56	18.96	1.00	0.88	2.90	1.63	4.12
Clone 3	2.40	20.85	20.69	18.43	0.99	0.88	2.74	1.55	3.80
Clone 4	2.50	21.63	21.47	19.24	0.99	0.89	2.99	1.91	5.17
Clone 5	2.47	20.07	20.03	17.88	1.00	0.89	2.58	1.59	4.08
Clone 6	2.45	19.94	19.73	17.24	0.99	0.86	2.40	1.38	3.29
Clone 7	2.55	22.77	22.83	20.02	1.00	0.88	3.24	1.69	4.58
Clone 8	2.30	22.33	22.39	19.43	1.00	0.87	3.05	1.66	4.14
Clone 9	2.44	21.36	21.41	18.69	1.00	0.88	2.82	1.71	4.34
Clone 10	2.40	20.61	20.47	18.17	0.99	0.88	2.67	1.69	4.81
Clone 11	2.54	20.50	20.19	18.35	0.98	0.90	2.72	1.66	4.19
Clone 12	2.44	20.77	20.93	18.46	1.01	0.89	2.75	1.53	3.79
Clone 13	2.72	22.33	22.42	19.76	1.00	0.88	3.15	1.76	5.14
Clone 14	2.48	20.86	20.78	18.52	1.00	0.89	2.77	1.69	4.36
Clone 15	2.16	20.03	19.73	17.31	0.99	0.86	2.42	1.47	3.68
Clone 16	2.31	18.93	18.81	16.34	0.99	0.86	2.16	1.43	3.94
Clone 17	2.23	20.08	20.07	17.78	1.00	0.89	2.55	1.48	3.55
Clone 18	2.38	20.15	20.29	17.95	1.01	0.89	2.60	1.41	3.48
Clone 19	2.26	18.71	19.33	16.77	1.03	0.90	2.27	1.41	3.40
Clone 20	2.26	20.24	20.64	18.39	1.02	0.91	2.73	1.53	3.58
Average	2.32	20.64	20.63	18.24	1.00	0.88	2.69	1.61	4.07
CD (P=0.05)	0.55	2.16	2.28	2.09			0.04	0.37	0.81

Yield efficiency

The average yield of clones (5 to 8 years) ranged from 10.44 kg/tree to 17.46 kg/tree (Table 2). The highest average yield/tree for 5 to 8 years was observed in Clone-8 (17.46 kg/tree), followed by Clone-20(16.53 kg/tree) and Clone-19(15.21 kg/tree). These clones produced significantly higher yield than most of the clones. The lowest yield per tree was obtained from Clone -12(10.08 kg/tree). In eighth year, higher yield was obtained in Clone - 20 (26.07 kg) followed by Clone -19 (22.29 kg), Clone-13 (22.67 kg) Clone -5(21.81 kg), and Clone -8 (20.48 kg). Clone-8 regularly gave higher yield in all four years (Table 2 and Fig 2). The mean yield of all clones was 9.98 kg, 13.17 kg, 5.58 kg and 18.09 kg in 2011, 2012, 2013 and 2014, respectively. The average yield of all the clones increased over the years except 2013, when immature fruits were damaged by heavy rains during June- August. As far as the yield efficiency per unit trunk cross-sectional area is concerned, it was found highest with Clone-19 (3.29 kg/cm^2). This was followed by Clone-1 (3.02 kg/cm^2) and Clone-8 (3.02 kg/cm^2). The yield in these clones was significantly higher than most of the clones. The lowest yield was obtained from Clone-13 (2.13 kg/cm^2). Since, Clone-1 had lower trunk diameter and higher yield per tree than most of other clones, yield efficiency unit TCSA of this clone was highest. The lower yield efficiency in TCSA in Clone-13 was due to higher vigour than other clones. There were significant differences at $P < 0.05$ among the clones for yield efficiency in term of tree volume. The highest yield unit canopy volume was observed in Clone -8 (3.41 kg/m^3) and Clone-20 (3.33 kg/m^3), whereas the lowest yield in canopy volume was obtained from Clone-10 (1.85 kg/m^3). The results indicated that less vigorous clones produced higher yield in term of trunk cross section area and canopy volume. These clones started bearing early and produced higher yield than the vigorous clones. These may be due to genotypic differences among the clones originated and grown in different locations. Singh (2009) reported that the varied yield levels in selected clones of Nagpur mandarin collected from different Nagpur mandarin growing areas. Kotasias and Vemmos (1998) reported similar results in Satsuma mandarin.

Fruit quality

There were significant differences among the clones for various fruit quality traits. The average fruit weight was highest in Clone-8 (130.64 g) which is agreement in previous study (Sakthivel *et al*. 2012). It means that its fruit weight did not change between the original and present location. The average fruit weight in Clone -8 was higher in all four years, although there was variation over the years. Other clones which recorded higher fruit weight were Clone-20 (122.5 g), Clone-9 (117.74 g) and Clone-14 (117.74 g). The fruit weight in these clones was significantly higher than other clones. Lowest fruit weight was recorded in Clone-12 which was 96.78 g. This clone recorded low weight in all four years (Table 2). The fruit volume and fruit

diameter showed similar trends as of fruit weight. The shape index ranged from 0.89 to 0.97 with no significant difference. This revealed that fruits of all clones were roundish with flat at both the ends. The colour was deep orange or red orange in all the clones. The rind of fruits of all the clones was smooth. The numbers of seeds per fruit is generally higher in Coorg mandarin. Among the clones evaluated, lowest number of seeds/fruits (11.1) were recorded in Clone-3. This is followed by Clone-2 (15.8 seeds/fruit) and Clone-14 (16.7 seeds/fruit). Clone-3 recorded lowest number of seed in all the four years. The highest seed/ fruit were recorded in Clone-10 (21.8). The fruit weight of Clone-3 and Clone-2 was higher than some clones (Table 2). This suggests that there no relationship between number of seed/fruit and fruit weight. This confirmed the earlier results of earlier findings (Sakthivel *et al.* 2012). As far as the per cent seed weight is concerned, it was lowest (1.11%) in Clone-8 followed by Clone-9 (1.12%). The rind weight was lowest in Clone-15(23.22 %). Clone-14 (23.64%), Clone-8 (23.71) and Clone-5 (23.91%) also recorded lower rind weight. Higher pulp weight was recorded in Clone-15(75.3 %), Clone-8(75.18%) and Clone -13(74.8 %). Average Juice per cent was highest (50.15%) in Clone-3. Clone 1(48.62%), Clone-2 (47.35 %) and Clone 11(47.04%) also recorded higher juice percent. Total soluble solids were higher in Clone-17 (9.54 ^{0}Brix), Clone-8 (9.13 ^{0}Brix) and Clone-9 (8.88^{0}Brix).These clones recorded higher total soluble solids during all four years. The lowest total soluble solids (7.84 ^{0}Brix) were recorded in Clone-11 followed by Clone-3(7.88 ^{0}Brix). Titrable acidity was found lowest in Clone-8 and Clone-3 which was 0.28%. Highest titrable acidity (0.40 %) was recorded in Clone-16. The total soluble solid: acid ratio was highest in Clone-8 (32.6). The ascorbic acid content was highest in Clone-1 (38.3 mg/100ml juice) followed by Clone-3 (36.05 mg/100ml juice). The ascorbic acid content was lowest in Clone-18 (23.95 mg/100 ml juice) but it was at par with Clones-20, 15, 13, 14, 11, 10, 6 and 5 (Table 2). The results suggested that there is variability among different clones for various growth and yield attributes. The Clone-13 was found better in terms of vegetative characters while Clone-8 and Clone-20 were found better for yield and some of the fruit quality characters. Some the clones like Clone-3 for less seed and higher juice content and Clone-1 for higher ascorbic acid content were also found superior. The Clone-8 and Clone-20 can be utilized for commercial cultivation while other superior clones may be utilized in breeding programmes. These results demonstrated the importance of the evaluation of natural selections of Coorg mandarin and the results could identify clones with superior characteristics as they were obtained in other *citrus s*pecies (Hearn 1986, Mendel 1981, Robles Gonzales *et al*. 2008). In conclusion, tree growth, yield performance and fruit quality profile of 20 Coorg mandarin clones revealed that clonal

Table 2 Yield and fruit quality characters of Coorg mandarin clones (2011 - 2014)

Clones	Yield (kg/tree)	Yield (kg/ canopy vol)	Yield (kg/ TCA)	Fruit wt.(g)	Fruit volume (ml)	Fruit shape index	Pulp weight (%)	Rind wt. (%)	Seed wt. (%)	No. of seeds/ fruit	No. of segments/ Fruit	TSS (^{O}Brix)	% Juice	Titrable acidity (%)	Ascorbic acid (mg/ 100ml)
Clone-1	14.99	2.75	3.02	102.56	104.58	0.95	67.51	30.88	1.61	19.4	11.2	8.35	48.62	0.38	38.30
Clone-2	12.53	2.34	2.19	104.94	101.06	0.90	70.11	28.64	1.25	15.8	10.9	7.92	47.35	0.36	31.98
Clone-3	13.30	2.66	2.67	102.92	101.60	0.94	64.74	33.91	1.35	11.1	11.8	7.88	50.15	0.28	36.05
Clone-4	12.62	1.99	2.40	107.10	107.82	0.91	71.06	27.10	1.84	20.9	11.2	8.48	40.32	0.32	30.38
Clone-5	14.23	2.81	2.95	113.65	118.44	0.93	71.82	26.93	1.25	17.0	11.5	8.58	44.63	0.36	26.05
Clone-6	13.18	3.07	2.99	107.38	111.63	0.92	62.28	35.16	2.56	17.1	11.1	7.91	44.73	0.38	26.18
Clone-7	14.38	2.59	2.40	101.96	107.47	0.95	73.43	25.04	1.53	17.2	10.9	8.29	44.12	0.38	28.01
Clone-8	17.46	3.41	3.01	130.64	132.82	0.97	75.18	23.71	1.11	16.9	10.8	9.13	42.65	0.28	29.83
Clone-9	12.64	2.22	2.45	117.74	121.76	0.90	69.86	29.02	1.12	18.2	12.2	8.88	42.84	0.36	27.90
Clone-10	12.64	1.88	2.43	115.72	114.81	0.97	70.92	27.40	1.68	21.8	11.6	7.76	41.09	0.39	28.07
Clone-11	14.29	2.72	2.83	102.25	105.33	0.98	70.24	28.42	1.34	19.1	10.9	7.84	47.04	0.35	27.27
Clone-12	10.99	2.27	2.14	96.78	100.94	0.89	71.21	26.76	2.03	19.9	11.9	8.63	44.96	0.34	27.58
Clone-13	13.01	1.99	2.13	112.99	113.41	0.91	74.8	23.64	1.56	17.5	11.5	8.69	41.77	0.34	25.69
Clone-14	12.80	2.20	2.51	98.70	100.01	0.95	71.26	27.44	1.30	16.7	10.95	8.40	42.84	0.32	30.38
Clone-15	12.13	2.45	2.56	105.84	108.38	0.95	75.3	23.22	1.48	19.7	11.39	8.78	44.17	0.35	26.83
Clone-16	10.44	1.95	2.50	107.00	104.73	0.86	58.08	40.00	1.92	17.9	11.45	7.95	42.08	0.40	31.18
Clone-17	12.15	2.48	2.24	113.68	115.37	0.97	69.55	29.12	1.33	19.6	11.7	9.54	44.87	0.35	29.14
Clone-18	12.18	2.54	2.20	108.04	109.61	0.92	71.79	26.74	1.47	17.2	11.52	8.30	45.12	0.37	23.95
Clone-19	15.21	3.31	3.29	109.66	112.49	0.90	67.32	30.76	1.92	20.0	11.44	8.04	46.98	0.38	30.05
Clone-20	16.53	3.33	2.85	122.51	123.89	0.94	69.14	29.84	1.02	17.5	12.1	8.08	46.40	0.28	26.98
Average	13.37	2.51	2.58	107.82	109.53	0.93	69.78	28.69	1.53	18.4	11.40	8.39	44.07	0.35	28.84
CD (P=0.05)	2.44			8.33	9.09		3.49	5.01	0.41	2.2	NS	0.48	5.08	0.08	5.39

selection of new genotypes form natural variants from orchards is a potential tool for development of new cultivars in Coorg mandarin.

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