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Fruit maturity and associated changes in *Khasi* mandarin (*Citrus reticulata*) at different altitudes in humid tropical climate

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ABSTRACT

Fruit maturity and associated changes in terms of physicochemical and sensorial qualities of *Khasi* mandarin (*Citrus reticulat* Blanco) grown at different altitudes, viz. 500-600 m, 700-800 m, 900-1 000 m and 1 300-1 400 m were studied under humid tropical climate of Meghalaya. Rapid increase in fruit growth was recorded from fruit development to colour break stage, however it was slow thereafter at all the altitudes. At 500-600m and 700-800m, juice yield was recorded highest at fruit maturity stage (46.64% and 49.11%) while, it was highest in advanced fruit maturity stage (50.90% and 51.15%) at 900-1 000 m and 1 300-1 400 m. Diurnal variation in climate stimulated drop in chlorophyll (‘a’, ‘b’ and total) and promoted development of yellowish orange colouration on fruit peel at altitude of 500-600 m and 700-800 m while deep orange colouration at 900-1 000 m and 1 300-1 400 m. Significant rise in TSS and TSS: acid ratio with drop in titratable acidity were recorded during maturation. Ascorbic acid content was recorded maximum at 1 300-1 400 m (44.13 mg/100 g) and 900-1 000 m (41.05 mg/100 g) compared with 700-800 m (37.56 mg/ 100 g) and 500-600 m (35.66 mg/100 g) at advanced maturity stage. Duration of 1 and 1 ½ month (fruit development to colour break stage) represents maturation at 500-600 m and 700-800 m considering TSS (10.23 °B and 10.13 °B), TSS: acid ratio (13.22 and 12.60), sweetness (3.93 and 3.67), flavour (8.00 and 7.93) and appearance (8.07 and 7.87) score. While duration of 2 and 2 ½ months (fruit development to fruit maturity stage) required at 900-1 000 m and 1 300-1 400 m considering TSS (10.07 °B and 10.16 °B), TSS: acid ratio (12.40 and 12.02), sweetness (4.07 and 3.93), flavour (7.87 and 7.93) and appearance (7.93 and 8.00) score.

Key words: Altitudes, Fruit maturity, Growth stages, Mandarin, Sensorial attributes, TSS

Mandarins are known for their unique aesthetic, organoleptic and nutritional characteristic in all over the world. Among them, *Khasi* mandarin (*Citrus reticulata* Blanco.) is a widely preferred and commercialised mandarin grown in north eastern region of India, particularly Meghalaya covering an area of 8.60 thousand ha with a production of 40.89 thousand MT (NHB 2014). Under humid tropical climate due to cold winter tree flowers once, i.e. spring blossom (February-April) and crop is ready for harvesting during October-December. In commercial trade the fruits of this crop need to be stored to reduce glut/ extend the availability of fruits in the market. The major production of *Khasi* mandarin in the region is confined to the remote hilly terrains of varying altitudes. In general warm and humid climate is characteristics feature at low altitudes while cooler climate prevails at high altitudes of the region. In Valencia rapid fruits maturity was recorded in hot tropical climate of Cartagena (Colombia), while delayed in cool sub-tropical climate of California (Reuther and Rios-Castano 1969). In mandarin delayed fruit growth period was reported at varying altitudes (Susanto *et al.* 2008). Thus determination of the criteria for fruit maturation is quite complex under varying altitudes as it depends upon the internal changes occurring in the fruit flesh and external colouration takes place on fruit peel. Harvesting of fruits 230-250 days after flowering, TSS (≥ 10ºBrix), juice content (≥ 49.0%) and TSS: acid ratio (≥ 12.0) is suggested as its maturity indices (Deka *et al.* 2006). However, commercial maturity indices incitrus fruit are highly variable and dependent on growing region, market and varieties (Lado *et al.* 2014). Realization of nutritional benefit of citrus fruits in human diet shifted the focus to measured fruit maturity in order to improve nutritional values and sensorial attributes (Obenland *et al.* 2009). Therefore sensorial trials based on trained panels or consumer acceptability is a valuable alternative for fruit quality evaluation (Obenland *et al.* 2009 and Mayuoni-Kirshinbaum *et al.* 2014).

We notice variation in flowering time and corresponding fruit maturity in *Khasi* mandarin with an

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Table 1 Changes in physical characteristics of *Khasi* mandarin during maturation at 500-600m and 700-800m

Growth stages	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Juice yield (%)	Chlorophyll 'a'(mg/g)	Chlorophyll 'b'(mg/g)	Total chlorophyll 'a' (mg/g)
500-600m							
Stage-I	116.87[c]	4.92[c]	5.90[c]	33.06[c]	0.110[a]	0.087[a]	0.196[a]
Stage-II	130.14[b]	5.44[b]	6.10[b]	40.48 [b]	0.081[b]	0.070[b]	0.151[b]
Stage-III	134.20[a]	5.79[a]	6.39[a]	46.34[a]	0.064[c]	0.057[c]	0.121[c]
Stage-IV	136.00[a]	5.82[a]	6.48[a]	46.64[a]	0.052[d]	0.048[d]	0.099[d]
Stage-V	136.45[a]	5.86[a]	6.45[a]	45.68[a]	0.038[e]	0.043[d]	0.081[e]
700-800m							
Stage-I	111.56[c]	5.37[c]	5.86[c]	35.01[c]	0.106[a]	0.084[a]	0.190[a]
Stage-II	129.78[b]	5.81[b]	6.38[b]	41.46[b]	0.084[b]	0.069[b]	0.153[b]
Stage-III	133.99[a]	6.00[a]	6.54[ab]	48.50[a]	0.063[c]	0.054[c]	0.118[c]
Stage-IV	134.22[a]	6.06[a]	6.57[ab]	49.11[a]	0.048[d]	0.050[c]	0.099[d]
Stage-V	135.01[a]	6.10[a]	6.61[a]	48.27[a]	0.034[e]	0.040[d]	0.074[e]

Means with the same letters are non-significantly differed at P ≤ 0.05 (DMRT). Stage-I (fruit development); Stage-II (beginning of colour break); Stage-III (colour break); Stage-IV (fruit maturity) and Stage-V (advanced fruit maturity).

altitudinal variation from 500 to 1 500m under humid tropical climate. There is no information on physico-chemical and sensory attributes (i.e. sourness, sweetness, flavour and appearance) of *Khasi* mandarin fruits growing at different altitudes under humid tropical climate. The information on changes during fruit development and maturity at different altitudes with respect to physico-chemical and sensorial characteristic is necessary to harvest for fresh fruit, storage and processing purpose. Thus looking towards this the present investigation was undertaken to study the changes in fruit maturity and related attributes of *Khasi* mandarin grown at different altitudes under humid tropical climate of Meghalaya.

MATERIALS AND METHODS

Khasi mandarin orchards were selected from four different altitudes, viz. 500-600msl (25°90 N and 91°52' E) 700-800msl (25°75' N and 91°88' E), 900-1 000 msl (25°41' N and 91°55' E) and 1 300-1 400msl (25°76' N and 92°06 E) of Meghalaya during 2013 and 2014. In selected sites soils pH ranged from 5.2 to 6.1, organic carbon (0.5 to 1.2%), nitrogen (100.35-150.33 kg/ha), phosphorus (35.31-38.87 kg/ha) and potassium (336.19-435.12 kg/ha). During the flowering of spring blossom, i.e. at the time of petal fall (fruit set), fruit lets were tagged during 2013 on 27 Feb (500-600 msl), 15 March (700-800 msl), 24 March (900-1000 msl) and 10 April (1 300-1 400 msl). And during year 2014 fruit lets were tagged on 17 Feb (500-600 msl), 09 March (700-800 msl), 20 March (900-1 000 msl) and 05 April (1300-1400 msl). Fifty fruits (ten fruits/tree) were sampled from all the canopy position at 2-3 m height from 180 days after fruit set onwards for recording observation on physical, biochemical and sensorial traits. The sampling was done at five different stages, i.e. Stage-I (fruit development i.e.180 days); Stage-II (beginning of colour break, i.e. 210 days); Stage-III (colour break, i.e. 230 days); Stage-IV (fruit maturity, i.e. 250 days) and Stage-V (advanced fruit maturity, i.e. 260 days)at each altitude. Fruit weight (g) was recorded using weighing balance and fruit length (cm), fruit diameter (cm) were measured with vernier calliper. In biochemical traits, Juice content (%), TSS (^{0}B), titratable acidity (%), TSS: acid ratio, ascorbic acid (mg/100g), reducing sugar (%) and total sugar (%) of fruits were analysed. Total soluble solid (TSS) in juice were measured with the digital refractometer. Titratable acidity were measured by titrating the juice against N/10 NaOH and expressed as per cent citric acid and ascorbic acid content were estimated following titrimetric methods (AOAC 1995). TSS: acidity ratio as a maturity index was calculated. Sugars were estimated by following the method of Lane and Eynon, 1943 as described by Ranganna (2001). The chlorophyll 'a', 'b' and total chlorophyll content were estimated by spectrophotometric method (Sadasivam and Manickam 1996). Sensory characteristics such as flavour and appearance were evaluated by a panel of 15 trained members using nine point hedonic scale rating (Amerine *et al.* 1965). For sweetness and sourness evaluation, scale of 1-5 (score 1, not sweet or not sour; 5 very sweet or very sour) was used. The experiment was conducted in randomized block design using five replications. Data were subjected to analysis of variance (ANOVA) and expressed as mean of duplicate measurement. The means were compared using Duncan's multiple range test (DMRT) using statistical software SPSS version 17.0. Difference were considered statistically significant at $P = 0.05$.

RESULTS AND DISCUSSION

Changes in physical characteristics

Changes in physical characteristics of *Khasi* mandarin fruits were studied during maturation at selected altitudes, i.e. 500-600m; 700-800m; 900-1 000m and 1 300-1 400m. At 500-600m (Table 1) significant increase in fruit weight and size (length and diameter) was recorded from fruit

Table 2 Changes in physical characteristics of *Khasi* mandarin during maturation at 900-1 000m and 1 300-1 400m

Growth stages	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Juice yield (%)	Chlorophyll 'a'(mg/g)	Chlorophyll 'b'(mg/g)	Total chlorophyll 'a' (mg/g)
900-1 000m							
Stage-I	101.14^{d}	4.70^{c}	4.85^{d}	31.11^{c}	0.101^{a}	0.074^{a}	0.175^{a}
Stage-II	118.40^{c}	5.07^{b}	5.74^{c}	42.13^{b}	0.076^{b}	0.060^{b}	0.136^{b}
Stage-III	125.45^{b}	5.30^{a}	6.07^{b}	48.53^{a}	0.051^{c}	0.048^{c}	0.099^{c}
Stage-IV	130.07^{a}	5.42^{a}	6.25^{a}	50.41^{a}	0.039^{d}	0.042^{cd}	0.082^{d}
Stage-V	131.14^{a}	5.43^{a}	6.29^{a}	50.90^{a}	0.029^{d}	0.036^{d}	0.065^{e}
1 300-1 400m							
Stage-I	100.23^{d}	5.01^{c}	5.35^{d}	36.18^{c}	0.098^{a}	0.069^{a}	0.167^{a}
Stage-II	119.13^{c}	5.49^{b}	5.91^{c}	43.64^{b}	0.071^{b}	0.056^{b}	0.127^{b}
Stage-III	127.66^{b}	5.60^{ab}	6.18^{b}	49.79^{a}	0.044^{c}	0.047^{b}	0.091^{c}
Stage-IV	132.11^{a}	5.69^{ab}	6.30^{ab}	51.04^{a}	0.028^{d}	0.035^{c}	0.063^{d}
Stage-V	133.15^{a}	5.71^{a}	6.33^{a}	51.15^{a}	0.022^{d}	0.031^{c}	0.053^{d}

Means with the same letters are non-significantly differed at $P \leq 0.05$ (DMRT). Stage-I (fruit development); Stage-II (beginning of colour break); Stage-III (colour break); Stage-IV (fruit maturity) and Stage-V (advanced fruit maturity).

development, i.e. Stage-I (116.87 g, 4.92 cm and 5.90 cm), respectively, to colour break, i.e. Stage-III (134.20 g, 5.79 cm and 6.39 cm), respectively, thereafter fruit growth was non-significant (P = 0.05). Similarly at 700-800m rapid increase in fruit weight and size from Stage-I (111.56 g, 5.37 cm and 5.86 cm), respectively, onward to Stage-III (133.99 g, 6.00 cm and 6.54 cm), respectively, with non-significant variation (P = 0.05) thereafter. At an altitude of 900-1 000 m (Table 2) gradual increase in fruit weight and size was recorded from fruit development, i.e. Stage-I (101.14 g, 4.70 cm and 4.85 cm), respectively, onwards to fruit maturity, i.e. Stage-IV (130.07 g, 5.42 cm and 6.25 cm), respectively. And at higher altitude, i.e. 1 300-1 400 m, the rate of increase in fruit weight and size was significant (P = 0.05) during Stage-I (100.23 g, 5.01 cm and 5.35 cm), respectively, to Stage-IV (132.11 g, 5.69 cm and 6.30 cm), respectively. Fruit weight and fruit size are important quality characteristics in fruit trade and marketability. The increase in fruit weight could be attributed to an increase in the size of cell and accumulation of food substances in the intercellular spaces in fruits (Bollard 1970). In Nagpur mandarin, gradual increase in fruit weight from 18.74 g (marble size) to 114.14 (mature fruit) was recorded (Ram and Kumar 2012) and also in Sweet Orange cv. Mosambi (Ladaniya and Mahalle 2011).

The rapid increased in juice yield was recorded during Stage-I to Stage-III with a non-significant (P = 0.05) rise thereafter at all the altitudes. At an altitude of 500-600m and 700-800m (Table 1) the non-significant variation was recorded in juice yield after Stage-III (46.34% and 48.50%), respectively. However, drop in juice yield was recorded at advanced fruit maturity, i.e. Stage-V (45.68% and 48.27%). In citrus juice content increases as fruit matures and reach to maximum value at full maturity and decreases afterwards (Ladaniya 1996 and Lado *et al.* 2014).While at 900-1 000m and 1 300-1 400m (Table 2) juice yield of *Khasi* mandarin fruit was found to be increased at advanced fruit maturity stage, i.e. Stage-V (50.90% and 51.15%), respectively, at par with Stage-IV and Stage-III. The increased in juice yield with delayed harvesting were reported in *Khasi* mandarin (Deka *et al.* 2006) and Kinnow mandarin (Joolka and Awasthi 1982). Changes in chlorophyll content were significant (P = 0.05) during growth stages of *Khasi* mandarin in all the altitudes (Table 1 and 2). The 'a', 'b' and total chlorophyll content were decreased during maturation but loss of chlorophyll 'b' was slower than chlorophyll 'a' with fruit maturity. It may be due to tight bound chlorophyll 'b' with protein and less subject to enzymatic breakdown than chlorophyll 'a' (Jahn and Young 1976). At an altitude of 500-600 m and 700-800 m the total chlorophyll content drop significantly (P = 0.05) from 0.196 mg/g and 0.190 mg/g, respectively, at fruit development, i.e. Stage-I to 0.081 mg/g and 0.074 mg/g, respectively, to advanced fruit maturity i.e. Stage-V. Similarly at 900-1 000 m and 1 300-1 400 m the total chlorophyll drop from 0.175 mg/g and 0.167 mg/g, respectively, at Stage-I to 0.065 mg/g and 0.053 mg/g, respectively, at Stage-V. The 15-20ºC temperature was optimum for production of colour in citrus rind (Wheaton and Stewart 1973). In present investigation, at different altitudes during October to December linear decrease in minimum and maximum temperature may stimulate drop in chlorophyll and promotes development of yellow to orange colouration on fruits at an altitude of 500-600 m and 700-800 m and deep orange colouration on fruit peel at 900-1 000 m and 1 300-1 400 m. The drop in chlorophyll was maximum at higher altitudes, i.e. 900-1 000 m and 1 300-1 400 m may be due to low night temperature stress encourage the production of ethylene in quantities large enough to destroy chlorophyll and promote development of carotenoids (Grierson *et al.*1982). Drop in chlorophyll during maturation was reported in Nagpur mandarin (Ram and Kumar 2012) and in Tangerine (Roongruangsri *et al.* 2013).

Changes in biochemical characteristics

At all the altitudes (Table 3 and 4) as the fruit turning to maturity TSS and TSS: acid ratio increased with

Table 3 Changes in chemical attributes of *Khasi* mandarin during maturation at 500-600m and 700-800m

Growth stages	TSS (^{0}B)	Titratable acidity (%)	TSS: acid ratio	Ascorbic acid (mg/ 100g)	Reducing Sugar (%)	Total sugar (%)
500-600m						
Stage-I	8.07^{c}	1.12^{a}	7.18^{d}	45.12^{a}	3.14^{c}	4.80^{c}
Stage-II	9.07^{b}	0.91^{b}	10.00^{c}	42.65^{a}	3.30^{b}	5.11^{b}
Stage-III	10.23^{a}	0.77^{c}	13.22^{b}	38.10^{b}	3.89^{a}	5.94^{a}
Stage-IV	10.28^{a}	0.73^{c}	14.15^{ab}	36.11^{b}	3.93^{a}	5.98^{a}
Stage-V	10.30^{a}	0.64^{c}	16.01^{a}	35.66^{b}	3.96^{a}	6.01^{a}
700-800m						
Stage-I	7.86^{c}	1.23^{a}	6.39^{d}	43.36^{a}	2.83^{d}	4.52^{c}
Stage-II	8.82^{b}	1.01^{b}	8.72^{c}	40.13^{ab}	3.33^{c}	5.35^{b}
Stage-III	10.13^{a}	0.81^{c}	12.60^{b}	38.22^{b}	3.75^{b}	5.92^{a}
Stage-IV	10.15^{a}	0.77^{cd}	13.22^{b}	38.01^{b}	3.80^{ab}	5.96^{a}
Stage-V	10.17^{a}	0.67^{d}	15.22^{a}	37.56^{b}	3.88^{a}	6.03^{a}

Means with the same letters are non-significantly differed at $P \leq 0.05$ (DMRT). Stage-I (fruit development); Stage-II (beginning of colour break); Stage III (colour break); Stage-IV (fruit maturity) and Stage-V (advanced fruit maturity).

Table 4 Changes in chemical attributes of *Khasi* mandarin during maturation at 900-1000m and 1300-1400m

Growth stages	TSS (^{0}B)	Titratable acidity (%)	TSS: acid ratio	Ascorbic acid (mg/ 100g)	Reducing Sugar (%)	Total sugar (%)
900-1000m						
Stage-I	7.54^{c}	1.41^{a}	5.35^{d}	50.91^{a}	2.54^{d}	4.15^{c}
Stage-II	8.73^{b}	1.16^{b}	7.56^{c}	47.23^{ab}	3.27^{c}	5.27^{b}
Stage-III	9.91^{a}	0.88^{c}	11.30^{b}	44.03^{bc}	3.82^{b}	6.07^{a}
Stage-IV	10.07^{a}	0.82^{c}	12.40^{ab}	42.64^{bc}	3.98^{a}	6.10^{a}
Stage-V	10.10^{a}	0.79^{c}	12.87^{a}	41.05^{c}	4.00^{a}	6.12^{a}
1300-1400m						
Stage-I	7.36^{c}	1.44^{a}	5.13^{d}	54.22^{a}	2.88^{d}	4.65^{c}
Stage-II	8.57^{b}	1.15^{b}	7.46^{c}	51.94^{a}	3.50^{c}	5.55^{b}
Stage-III	10.04^{a}	0.92^{c}	10.98^{b}	46.57^{b}	3.89^{ba}	6.01^{a}
Stage-IV	10.16^{a}	0.85^{c}	12.02^{a}	45.08^{b}	3.90^{a}	6.07^{a}
Stage-V	10.18^{a}	0.83^{c}	12.31^{a}	44.13^{b}	4.03^{a}	6.11^{a}

Means with the same letters are non-significantly differed at $P \leq 0.05$ (DMRT). Stage-I (fruit development); Stage-II (beginning of colour break); Stage III (colour break); Stage-IV (fruit maturity) and Stage-V (advanced fruit maturity).

concomitant decreased in titratable acidity. At 500-600m (Table 3) the rise in TSS (10.23^{0}B), TSS: acid ratio (13.22) and drop in titratable acidity (0.77%) was significant (P = 0.05) up to colour break, i.e. Stage-III. However highest TSS: acid ratio was recorded at advanced fruit maturity, i.e. Stage-V (16.01). Similarly at 700-800m (Table 3) rise in TSS (10.13^{0}B); TSS: acid ratio (12.60) and decreased in titratable acidity (0.81%) was significant up to Stage-III. While lowest titratable acidity (0.67%) and highest TSS: acid ratio (15.22) was recorded at Stage-V. At higher altitudes (Table 4) the highest TSS and lowest acidity was recorded at Stage-V (10.10^{0}B, 10.18^{0}B and 0.79%, 0.83%), respectively, followed by Stage-IV and Stage-III. While, TSS: acid ratio was recorded highest at Stage-V (12.87 and 12.31) at par with Stage-IV (12.40 and 12.02). The increased in TSS during maturity may be due to hydrolysis of acids and deposition of polysaccharides (Ram *et al.* 2003). The decrease in titratable acidity during fruit maturity and ripening was considered to be due to conversion of organic acids into sugars. During fruit development TSS increased from 6.45% (marble stage) to 11.16% (mature fruit) and acidity drop at mature stage (0.69%) in Nagpur Mandarin (Ram and Kumar 2012). The TSS: acid ratio has been used worldwide as the main commercial maturity indicator of citrus fruit internal quality (Lado *et al.* 2014). In present study it was observed that at an altitude of 500-600m and 700-800m high values for above maturity indicators were recorded at colour break and fruit maturity stage while at higher altitudes, i.e. 900-1 000m and 1 300-1 400m it was recorded at fruit maturity and advanced fruit maturity stage. From results, at higher altitudes significantly higher acid was recorded in *Khasi* mandarin fruits compared to lower altitude may be due to environmental and growing condition, differential time of flowering and subsequent fruit maturity. Richardson *et al.* (1997) reported that the relative level of different sugars and acids changes during citrus fruit development appears to be influenced by temperature. At an altitude of 500-600m and 700-800m high minimum and maximum temperature during October may accelerate increase in TSS: acid ratio. While decrease in minimum and maximum temperature in November at 900-1 000m and 1 300-1 400m drop the rate of increase in TSS: acid ratio. Reuther and Rios-Castano (1969) reported that the accumulation solid coupled with late drop in acidity in cool sub-tropical climate of California. i.e. acid remains in the range of 1-1.5% when Valencia fruits matured. In contrast in hot tropical climate of Cartagena (Colombia), rapid fruits maturity coupled with higher rate of sugar accumulation and reduction in acidity was recorded. In mandarin cv. 'Fremont' Susanto *et al.* 2008 recorded higher acid in fruits of tree grown in the higher altitude.

Ascorbic acid content was decreased as the fruit matured from fruit development, i.e. Stage-Iuptocolour break, i.e. Stage-III with a non-significant (P = 0.05) drop thereafter at all the altitude. At an altitude of 500-600m and 700-800m (Table 3) the drop in ascorbic acid was significant up to Stage-III (38.10 mg/100 and 38.22 mg/ 100g). Similarly at higher altitudes, i.e. 900-1 000m and 1 300-1 400m (Table 4) drop was significant up to Stage-III (44.03 mg/100 and 46.57 mg/100g). In analogous findings ascorbic acid content was decreased from 46.08 to 35.74 mg/100g at mature green stage to full ripe stage in *Khasi* mandarin (Deka *et al.* 2006). Singleton and Gortner (1965) reported that the ascorbic acid was influenced by the environmental factors rather than physiological stage of the fruits. In present study also higher retention of ascorbic acid content was recorded in the fruits harvested from higher altitudes (900-1 000m and 1 300-1 400m) compared with lower altitudes (500-600m and 700-800m).

In mandarin cv. 'Fremont' Susanto *et al.* 2008 observed higher vitamin C content in the fruits harvested from higher altitudes. At an altitude of 500-600m and 700-800m (Table 3) reducing sugar (3.89% and 3.75%) and total sugar (5.94% and 5.92%) was found to be increased significantly during fruit development stage up to colour break stage. Similarly at higher altitudes (Table 4) rise in reducing sugar (3.82% and 3.89%) and total sugar (6.07% and 6.01%) was significant up to Stage-III. The increase in sugar during ripening might be due to depolymerisation of polysaccharides and conversion of fruit starch to sugar. Similar trend was also reported in *Khasi* Mandarin (Deka *et al.* 2006) and guava (Patel *et al.* 2013).

Changes in sensorial characteristics

At an altitudes of 500-600 m and 700-800 m (Fig 1) the significant variation (P = 0.05) was recorded in sourness (1.87 and 2.00), sweetness (3.93 and 3.67), flavour (8.00 and 7.93) and appearance (8.07 and 7.87) score up to colour break stage. The increased in appearance score was attributed to the development of yellowish orange colour on fruit peel. However, at advanced fruit maturity stage flavour and appearance score dwindled at both these altitudes. At 900-1 000 m and 1 300-1 400 m (Fig 2) difference in sourness (1.73 and 1.67), sweetness (4.07 and 3.93), flavour (7.87 and 7.93) and appearance (7.93 and 8.00) score were found significant up to fruit maturity stage.The increased in appearance score at higher altitudes attributed to the development deep orange colouration on fruit peel. The sensorial test indicated that consumers did not like sour fruits. The flavour intensity depends on the ethanol and ethyl acetate content and increase their content decreases the flavour intensity. In present study low flavour score at altitudes of 500-600 m and 700-800 m on advanced fruit maturity stage may be due to synthesis of metabolic compounds like ethanol and ethyl acetate due to respiratory metabolism (Marcilla *et al.* 2006 and Kishor *et al.* 2010). For *Khasi* mandarin juice minimum standard for TSS is ≥ 10 ^{0}B and TSS: acid ratio is ≥ 12.0 (Deka *et al.* 2006). In present study at 500-600 m and 700-800 m, TSS (10.23°B and 10.13°B), TSS: acid ratio (13.22 and 12.60) coupled with desired sweetness (3.93 and 3.67), flavour

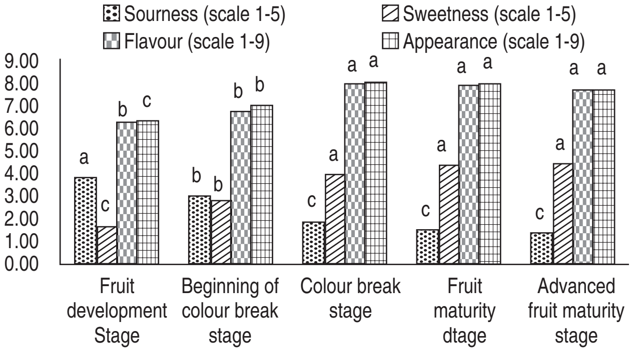

Fig 1 Changes in sensorial characteristics at 50-600m and 700-800m. Means with the same letters are non-significantly differed at P ≤ 0.05 (DMRT)

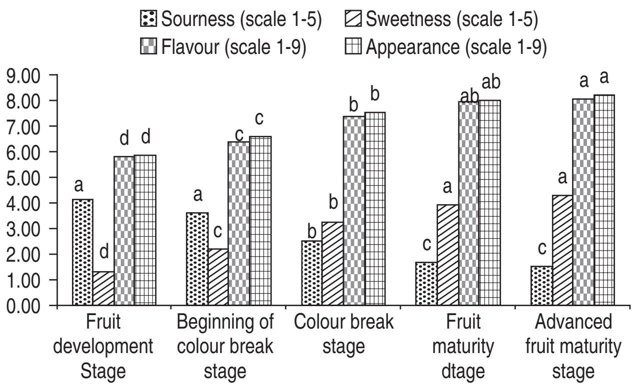

Fig 2 Changes in sensorial characteristics at 900-1 000m and 1 300-1 400m. Means with the same letters are non-significantly differed at P ≤ 0.05 (DMRT)

(8.00 and 7.93) and appearance (8.07 and 7.87) score resulted into good palatability and acceptability at colour break stage. While at 900-1 000 m and 1 300-1 400 mTSS (10.07 °B and 10.16°B), TSS:acid ratio (12.40 and 12.02) coupled with desired sweetness (4.07 and 3.93), flavour (7.87 and 7.93) and appearance (7.93 and 8.00) score at fruit maturity stageresulted into good palatability and acceptability of fruits.

Duration of 1 and 1 ½ months (fruit development to colour break stage) represents the maturation of *Khasi* mandarin fruits at an altitude of 500-600 m and 700-800 m while 2 and 2 ½ months (fruit development to fruit maturity stage) required at an altitude of 900-1 000 m and 1 300-1 400 m under humid tropical climate. During that period fruit growth coincided with increase in soluble solid and sensorial characteristics with drop in acidity. Similar findings were reported by Reuther and Rios-Castano (1969), Susanto *et al.* (2008) and Kishor *et al.* (2010).

Thus considering the fruit growth, TSS, TSS: acid ratio and sensory characteristics, it was concluded that *Khasi* mandarin fruits planned for storage and fresh market can be harvested at colour break stage (230 days) and for processing purpose at fruit maturity stage (250 days) at an altitude of 500-600m and 700-800m. While at an altitudes of 900-1 000m and 1 300-1 400m for storage and fresh market fruits can be harvested at fruit maturity stage (250 days) and for processing purpose at advanced fruit maturity stage (260 days) under humid tropical climate.

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