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Effect of fruit size and orchard location on fruit quality and seed traits of mandarin (*Citrus reticulata*) in Sikkim Himalayas

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ABSTRACT

Field experiments were conducted during 2007–10 at ICAR Sikkim Centre, Tadong between 1 000–1 700 m amsl to identify the suitable grade of fruit for raising nucellar nursery and fresh fruit marketing of Sikkim mandarin. Small and large sized fruits were collected from all the four districts of Sikkim. The highest fruit weight (161.3g/fruit), waste index (1.14), TSS: acid ratio (8.0) and number of healthy seeds/fruit (19.0) along with lowest juice (40.9%) was observed in big sized fruits. Maximum juice (53.2%), minimum waste index (0.68) and number of healthy seeds (7.1) were found in small fruits. Negative correlation between specific gravity and number of healthy seeds/fruit (–0.714) was observed. Waste index of fruits revealed significant positive correlation with healthy seeds/fruit (0.727) and total seed weight (0.721) while negative correlation with fruit shape index, specific gravity and juice %. Big sized fruits possessed high number of good quality seeds/fruit which can be used for nursery. raising as well as for fresh fruit marketing purpose whereas small sized fruits with higher percentage of juice can be recommended for juice preparation.

Key words: *Citrus reticulata*, Fruit grade, Fruit quality, Seed quality

Sikkim mandarin (*Citrus reticulata* Blanco) dominates the Citrus family and is the leading cash crop of the mid hills of Sikkim Himalayas with attractive fruit colour, size and good table and processing qualities. Presently 95% of the production is marketed as fresh fruit in India. The remaining 5% of mandarin production only is processed, whereas the post-harvest losses which are an estimated 25–30% can also benefit the growers through creation of state-of-the-art post-harvest and value-addition infrastructure. Thus, in order to appropriately utilize the entire production of mandarin, it is important to process it into juice and other juice-based products. Mandarin fruit is marketed as fresh fruit from October to February while the seeds are used for raising nucellar seedling of mandarin. The world market is continually making higher demand for better quality, uniform grading, presentation, and packaging of fruits. In Florida, 95% of commercial orange production is destined for processing, mainly as orange juice while in California; oranges are mainly produced for fresh consumption with only 21% for processing (Boriss 2006). The fruit industry typically generates large volumes of effluents and solid waste (Senyi 2006). Grading is one of the most important procedures to be followed in post-harvest handling, as it determines the quality, shelf-life and price of the fruit. During grading, the produce is sorted according to the fixed grade standard, taking into consideration various quality factors to make a homogenous lot. Post-harvest grading of mandarin is rarely practised at the producer's level. At the most, the fruits are sorted out, based on physical characteristics like weight, size, colour, shape and degree of damage on fruits.

The grading of fruits as per accepted quality standards helps farmers, marketing functionaries, processors, traders and consumers in efficient marketing (Anonymous 2009). Despite the several advantages of grading growers rarely grade their fruits and vegetables through which farmer's income can increase by 30% (Afshan 1989). Better quality fresh mandarin fruits with higher juice content are preferred while fruit weight and juice percentage reflected negative correlation (Kishore *et al.* 2010). Grading is the final assurance that the fruit going to the extractor is of acceptable quality. Nucellar seedlings of mandarin are raised from mature and large-sized fruits selected from healthy plants (Kumar *et al.* 2008). In order to raise nucellar seedlings, huge

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quantity of seeds is required to get higher number of seedlings. Therefore, the present study was undertaken to identify the most suitable grade of mandarin based on fruit size for raising nucellar nursery in addition to fresh fruit marketing and juice industry of Sikkim Himalayas.

MATERIALS AND METHODS

Experimental site is located at about 27° North and 88° East in the mid hills of Sikkim Himalayas. Fruits were collected from the trees indexed for healthiness and freedom from diseases from all the four district of Sikkim at the altitude variation from 1 000 to 1 700 m amsl in November 2007–09. Five representative orchards were selected from each district for collection of 1 000 numbers of small and large fruits, respectively. Fruits were chosen from 10 randomly selected plants on the basis of fruit size.

The experiment was conducted in randomized block design with three replications and 50 fruits/replication that were categorized as west district small sized fruits (T_1), west district big sized fruits (T_2), east district small sized fruits (T_3), east district big sized fruits (T_4), south district small sized fruits (T_5), south district big sized fruits (T6), north district small sized fruits (T_7) and north district big sized fruits (T_8). Uniform sized small and large-sized fruits were selected for the experiment. Fruits weighing 70–90 g were categorized as small sized fruits while the fruits weighing 135–165 g were categorized as large-sized fruits.

Per cent TSS was measured by hand refractometer. Waste index was calculated as per Russ and Pittroff (2004). Fruit shape index was calculated following Tachibana and Yahata (1998). Acidity, TSS/acid ratio and specific gravity were estimated by standard procedures. Total sugars, reducing and non-reducing sugars were determined by Shaffer-Somogyi micro method (Ranganna 1991).

The data were analyzed statistically following the method of Panse and Sukhatme (1985). The correlation between variables was calculated by partial correlation method and the test of significance was considered at 5% and 1% levels of probability.

RESULTS AND DISCUSSION

Effect of fruit grade and location on fruit quality

Observations on various characteristics of Sikkim mandarin showed significant effect of location and fruit size on morphological as well as chemical properties of fruits (Table 1). Fruit weight was significantly different for both small and large fruits at all the locations. The highest fruit weight recorded for big fruits collected from north Sikkim (161.3 g/fruit) was significantly different from all other treatments and at par with the fruits of east district. The lowest fruit weight was observed for small fruits collected from south Sikkim (71.25 g/fruit). Maximum specific gravity was observed in small fruits of south Sikkim (0.95) was at par with T_1, T_2, T_3 and T_7 but significantly different from other treatments. Minimum specific gravity was found in big fruits of south Sikkim (0.73). Large sized fruits exhibited minimum specific gravity was reported by Gill *et al.*, (2002). The fruits of south Sikkim had the maximum fruit shape index (203.8) with the minimum in small fruits of west Sikkim (79.8). The highest fruit hollowness observed in big fruits from south Sikkim (1.91 cm) was at par with big fruits of north Sikkim, however, the lowest fruit hollowness was found in small fruits of north Sikkim (0.88 cm). Amongst all the treatments big fruits from south Sikkim showed the maximum peel thickness (4.6 mm) which significantly differed from all other treatments while the small fruits from south Sikkim only possessed the thinnest peels. Small fruits of north Sikkim contained the maximum juice (53.2%) that was statistically at par with big size fruits of the same location and the small fruits of east Sikkim but significantly different from all other locations. The big sized fruits from east Sikkim recorded the lowest juice percentage (40.9%) and waste index while the big fruits of west and north Sikkim revealed the highest waste index. TSS: acid ratio observed in big size fruits of west Sikkim (8.0) was the highest as compared to all others while the lowest was in big size fruits of south Sikkim. The highest juice content, total soluble solid (TSS): acid ratio and palatability rating were observed for small sized fruits,

Table 1 Effect of fruit grade and orchard location on fruit quality parameters

Treatment	Fruit shape index	Fruit hollowness (cm)	Specific gravity	Fruit weight (g)	Peel thickness (mm)	TSS/ acid ratio	Juice (%)	Waste index	Total sugar (%)	Reducing sugar (%)	Vitamin C (mg/ 100g)
T_1	169.8	1.10	0.93	90.0	2.5	7.63	50.9	0.85	10.06	6.52	40.00
T_2	79.8	1.65	0.92	137.5	3.8	8.00	47.9	1.14	8.57	5.76	36.00
T_3	116.9	1.36	0.92	89.3	2.4	5.66	51.6	0.68	9.09	6.25	44.00
T_4	118.4	1.91	0.82	158.3	3.6	7.57	40.9	1.05	8.57	5.76	42.00
T_5	118.9	1.07	0.95	71.3	2.3	4.56	50.5	0.93	9.37	5.55	50.00
T_6	203.8	1.65	0.73	141.3	4.6	3.92	48.0	1.00	7.50	4.41	40.00
T_7	121.0	0.88	0.91	88.8	2.3	5.42	53.2	0.77	7.50	6.25	42.00
T_8	115.7	1.75	0.84	161.3	3.6	5.45	51.3	1.14	7.50	6.00	40.00
SEm±		0.08	0.02	0.8	0.09		0.9		0.093	0.260	0.497
LSD (*P*=0.05)		0.18	0.04	1.2	0.18		1.9		0.200	0.559	1.065

whereas TSS: acid ratios are not in agreement for small fruits (Gill *et al.*, 2002). The total sugar content of small fruits of west Sikkim was the highest (10.06) which was significantly different from other treatments. The lowest total sugar content was recorded in the small size fruits of south Sikkim (9.37). Reducing sugar was the highest in small size fruits of west Sikkim (6.52%) which was at par with the small fruits of east Sikkim (6.25%) and the fruits of north Sikkim (6.25%) but significantly different from other treatments. Reducing sugar was the lowest in the big sized fruits of south Sikkim (4.41%). The small sized fruits from south Sikkim revealed the maximum vitamin C content (50 mg/100g) which was significantly different from other treatments with minimum in the big size fruits of west Sikkim (36 mg/100g). Similar findings were reported by Arzani *et al.* (2001) and Singh and Singh (2001).

Effect of fruit grade and location on seed quality

The location and fruit size significantly influenced the seed quality. All the seed quality parameters showed significant variation amongst all the treatments (Table 2).

Table 2 Effect of fruit grade and orchard location on seed quality parameters

Treatment	Total no. of healthy seeds	No. of aborted seed	Total seed weight (g)	Seed shape index
T_1	7.1	1.75	2.10	54.55
T_2	19.0	4.50	3.09	50.00
T_3	12.0	2.50	1.42	46.77
T_4	17.0	3.52	2.29	50.41
T_5	7.0	13.00	0.68	42.98
T_6	19.5	4.50	2.37	47.97
T_7	8.5	8.00	1.65	53.76
T_8	19.0	6.50	3.14	60.83
SEm±	0.57	0.53	0.11	
LSD (P=0.05)	1.23	1.13	0.23	

The big sized fruits of north Sikkim exhibited the best seed shape index (60.83) while the small sized fruits of south Sikkim had the lowest (42.98). Aborted seeds were lowest in small fruits of west Sikkim (1.75) with the highest recorded in small size fruits of south Sikkim (13). Maximum number of healthy seeds per fruit was found in big size fruits of south Sikkim which was at par with the big size fruits of south, west and north Sikkim but significantly different from the other fruits. The big size fruits of north Sikkim had the heaviest seeds (3.14 g) which was at par with big size fruits of west Sikkim (3.09 g) and significantly different from the other fruits. The lightest seed weights were observed in small size fruits of south Sikkim (0.68 g). Number of seeds per fruit was significantly correlated with fruit size, fruit weight and peel thickness (Demirkeser *et al.*, 2009). Large fruit size may be related to local climatic conditions coupled with higher number of seed, cytokinin and gibberellins levels in the relevant tissues. The size of seeded fruits was larger but less soluble solids content was reported by Zhang (2003). Findings of our present study are in agreement with Zhang (2003) for the fruit size and seed numbers but differed for the soluble solid content.

Correlation between fruit and seed qualities

The correlation co-efficient (Table 3) between different variables of Sikkim mandarin revealed that fruit hollowness was positively correlated with waste index (0.723*), number of healthy seed/fruit (0.909**), total seed weight (0.693*) and negatively to specific gravity of fruits (–0.650*) which showed hollowness as an important contributor towards waste index. Data also indicated that there was negative correlation between specific gravity and number of healthy seeds/fruit (–0.714*). Waste index of fruits recorded significant positive correlation with healthy seeds per fruit (0.727*) and total seed weight (0.721*) which showed that seeds and total seed weight contributed significantly to waste index. Total number of seeds/fruit was also positively correlated with total seed

Table 3 Correlation studies between fruit and seed qualities

	Fruit shape index	Fruit hollowness (cm)	Specific gravity	TSS/ acid ratio	Juice (%)	Waste index	Total healthy seeds	No. of aborted seed	Total seed weight (g)
Fruit shape index									
Fruit hollowness (cm)	–0.082								
Specific gravity	–0.567	–0.650*							
TSS/ acid ratio	–0.425	0.222	0.338						
Juice (%)	–0.073	–0.423	0.168	–0.433					
Waste index	–0.183	0.723*	–0.409	0.217	–0.510				
Total healthy seeds	–0.048	0.909**	–0.714*	0.054	–0.500	0.727*			
Number of aborted seed	–0.236	–0.389	0.253	–0.540	0.277	0.079	–0.321		
Total seed weight (g)	–0.081	0.693*	–0.445	0.415	–0.282	0.721*	0.795*	–0.488	
Seed shape index	–0.031	0.172	–0.145	0.260	0.186	0.296	0.234	–0.279	0.669*

*Correlation is significant at P=0.05 and ** at P=0.01

weight/fruit (0.795*). Total seed weight/fruit was positively correlated with seed shape index (0.669*). Highest juice content, total soluble solid (TSS): acid ratio and palatability rating for large sized fruits has been reported by Gill *et al.* (2002). This data showed the role of seed numbers in controlling the final size of fruit. Developing seeds are active sites of auxin, cytokinin and gibberellins synthesis. The physiological role of endogenous hormones produced in developing seeds are able to pass out of the seed either along the vascular system or by diffusion through the testa which in turn directly stimulate the growth of surrounding tissues of the fruit and indirectly by directing the metabolic transport of photosynthates required for fruit growth. Ovaries contain a greater number of fertilized ovules hence; greater seed number may automatically accompany larger fruit size. Similarly, there is direct relationship between seed number and peel thickness of Sikkim mandarin. The role of endogenous hormones in normal and abnormal (rough) thickness of mandarin fruits has been extensively reviewed. There is close agreement between the development of rough peel and the presence of higher cytokinin and gibberellins levels in the relevant tissues.

The fruit and seed quality revealed significant variation in all the four districts of Sikkim. However, the big sized fruits that possessed good fruit quality and high number of good quality seeds can be recommended for raising mandarin nursery and fresh fruit market while the smaller fruits with higher juice content and low waste index may be processed for value-addition fetching higher returns to the resource-poor farmers of Sikkim, since they are normally sold in market at very low price.

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