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Effect of Inflorescence Types on Fruits Quality of Owari Cultivar of *Satsuma mandarin* (*Citrus unshiu*, Marc.)

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Abstract: Present studies were envisaged to determine the effect of inflorescence pattern on the fruit quality of *Satsuma mandarin* grafted on Troyer Citrange (TR), Sour Orange (SO) and Trifoliate Orange (TF) in the orchard of the Department of Horticulture, Ege University, Izmir Turkey. Physical fruit quality characteristics such as fruit weight, diameter and height of fruits developed from leafy inflorescence were significantly higher as compared with leafless fruits. Fruit peel color (L, a, b and a/b ratio), specific gravity and electrical conductivity percentage (EC%) was significantly higher in leafless fruits than leafy fruits but peel thickness and peel thickness index were higher for leafy fruits than that of leafless ones. Fruit internal quality parameters such as fruit juice percentage and vitamin C contents were significantly higher in leafless fruits as compared with leafy ones.

Key words: Fruit quality, inflorescence leafiness, *Satsuma mandarin*, citrus

INTRODUCTION

Citrus is the most important fruit crop of the world and production of fresh and processed citrus surpasses that of banana, apple, grapes or mangoes. Citrus is also being grown extensively in Turkey and Pakistan due to its medicinal, nutritive and economic values. Citrus is the leading fruit crop of the Turkey as well as Pakistan, oranges and mandarins are main growing species in both countries.

The importance of understanding flowering of citrus is paramount since it is first step in the reproductive process. Physiological differentiation is followed by morphological differentiation during citrus flowering process. Physiological differentiation might start as early as September-October[1] while morphological differentiation of floral organs does not occur until bud sprouting, shortly before flowering. Generally flowering shoots in citrus may either be mixed or generative. Mixed shoots are composed of leafy inflorescence bearing either one terminal flower or many single axillary flowers on a short leafy shoot. Generative shoots are composed of compact, cymose inflorescence bearing one or more flowers without developing leave[2]. In case of *Satsuma mandarin*, four types of flowering shoots may be observed which are; a) single flower leafy shots b) many flowers leafy shoot c) One or more than one flowered leafless shoots d) Vegetative shoot[3]. The flowers without leaves are in abundance, open earlier in the season as compared with leafy ones but fruit set is favoured in case of latters, as it has been noted in case of sweet orange and mandarin, but in contrast to this crop of some species such as 'Tahiti' lime are set primarily on leafless shoots. Various nitrogenous compounds may influence the determination of leafiness or affect growth rate of ovaries on leafy inflorescence since these show a higher polyamine content[4].

Environmental conditions particularly temperature and light may influence carbohydrate supply, translocation rate and sink strength at the stage of fruit development giving rise to seasonal variations in fruit size and composition because it has been observed that elevating canopy air temperature throughout fruit development substantially increased the size and total soluble solids and titratable acidity ratio of fruit at harvest[5].

Rootstocks used affect the fruit set, fruit drop and fruit quality characteristics of the scion variety. For *Satsuma mandarin*, trifoliate is normally used as rootstock which is cold resistant but shallow rooted. So, high temperature during the summer has more adverse effect on fruit quality. Rootstocks significantly influenced the yield, fruit weight, rind thick, rind colour, juice contents, total soluble solids and titrateable acidity of "Owari" *Satsuma mandarin* when grafted on 16 different rootstocks[6]. The rough peel disorder is characterised by

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excessively thick rough peel and large fruit size and was found in Shamouti orange growing under less than optimal conditions such as heavy soils, low relative humidity and on sour orange rootstock[7]. It has also been observed that fruits developed from leafy inflorescence in *Satsuma mandarin* have greater fruit size, thick and rough skin, less juice percentage and late color development. Inflorescence leafiness may also influence total soluble solids and acid contents of fruits. All of these characters are undesirable from quality point of view. In May and June if temperature is higher and relative humidity is lower, (as in Ege region) yield of *Satsuma mandarin* is severely reduced due to heavy drop and this ultimately results in more leafy inflorescence bearing low quality fruit during the next fruiting season, development under warmer condition and low humidity lead to increased proportion of leafy inflorescence[8]. In *Satsuma mandarin* as it has been elaborated earlier, fruits developed from leafy and leafless inflorescence have great difference in respect of quality. Fruit born on leafless inflorescence are of superior quality as compared with those from leafy ones and at the same time later type of inflorescence experience more fruit set than the former ones especially in areas having high temperature and low relative humidity during the early summer but this has not been substantiated by proper research work.

Present study was, therefore, envisaged to find out the effect of inflorescence leafiness on fruit quality of *Satsuma mandarin* grafted on Troyer, Trifoliate and Sour orange root stocks.

MATERIALS AND METHODS

Present studies were carried out during 1997-1998 in Citrus Experimental Garden and Department of Horticulture, Faculty of Agriculture, Ege University, Bornova, Izmir, Turkey. This region has semi-mediterranean type climate. Generally summer is hot and dry with cold and rainy winter.

Plant material: Plant material used in this research work consisted of 25 years old plants of *Satsuma mandarin*, cultivar Owari (*Citrus unshiu*, Marc.) grafted on trifoliate orange (*Poncirus trifoliata*, (L.) Raf.), Sour orange (*Citrus aurantium*, L.) and Troyer citrange (*P. trifoliata* x *C. sinensis*, (L.) Osbeck) rootstocks. Three healthy looking, well bearing and same size plants from each rootstock were selected. During the course of experiment, cultural practices such as weeding, hoeing, irrigation, fertilization and insect pest control were done as recommended. Single plant was considered as one replication.

Inflorescence type: Inflorescence are flowering shoots arising from axillary buds. Inflorescence may be mixed, or generative. Three plants from each of the rootstock cultivar having uniform size were selected and tagged. Four branches one from each of the four sides i.e. south, east, north and west having almost same size at shoulder height were marked before the onset of flowering. On marked branches, number of leafy (LY) and leafless (LS) inflorescence were counted.

Physio-chemical analysis of fruits: Fruits were collected from plants selected for experiment in the 2nd week of November. All the fruits, leafy and leafless were harvested same day. Twenty fruits born on leafy and leafless inflorescence were collected separately in polyethylene bags from shoulder height by walking around the periphery of the tree and taken to laboratory. Fruits brought to laboratory were used for studying various physical and chemical properties.

Average fruit weight, diameter, height and shape index: Fruits samples were weighed and weight per fruit was determined by dividing with the number of fruits.

Fruit diameter was measured at the equator of each fruit while height was measured between stem and stylar end. From these values fruit shape index was calculated.

Fruit shape index = Fruit diameter/Fruit height

Specific gravity: For determining specific gravity, each sample contained 10 fruits. Fruits from each sample were weighed individually. To find the volume of fruit, the lower sieve of the hand citrus press was tied with plastic string and connected with under side of the balance. Its weight was noted inside the beaker filled with distilled water having few drops of detergent. Then each fruit was put in the beaker under sieve connected with balance and thus weight of each fruit was found. The fruit volume was calculated with the help of this formula[9];

$$V = t + (K - Km)$$

Where:
V = Sample volume (cm^3)
t = Sample weight (g)
K = Weight of sieve inside water (g)
Km = Weight of fruit in water under the sieve (g)

The specific gravity was calculated by dividing fruit weight with fruit volume.

Peel color, peel thickness and peel index: Peel color was measured with MINOLTA CR.300 (Japan) colorimeter.

Color values (L, a and b) were measured for 10 fruit sample at the equator from two opposite points and the total values obtained from all fruits measurements were divided by the number of values measured. In this way mean L, a and b values for each sample were determined. where as;

L = Lightness
a = Green-red
b = Blue-yellow

Peel thickness was measured with Vernier Calliper by cutting the fruit into two halves at the equator and peel thickness index was calculated;

Peel thickness index= Peel thickness x 2x100/Fruit diameter

Electrical conductivity: Twenty peel discs (10 mm), two from each of the 10 fruits were taken and weighed. Discs were first dipped in tap and then in distilled water in order to remove dust or any other foreign material. Discs were then put in the flask and added 100 mL of distilled water. Samples were shaken for four hours at 40 revolutions per minute (rpm) with the help of stirrer and Electrical Conductivity (EC) values were measured with EC meter. The samples were then placed in the autoclave at 120°C for 1 h and again EC was measured.

Fruit juice percentage, total soluble solid percentage and total acidity: Every fruit was cut into two halves at the equator and after weighing fruit sample, fruit juice was extracted by the use of Conti Electric Citrus press. The extracted juice was then weighed and fruit juice percentage was calculated.

The extracted juice was filtered by muslin cloth and few drops from the juice were put on hand refractometer. The reading noted was considered as TSS percentage.

For total acidity, five 5 mL from the filtered juice was taken and after adding two drops of phenolphthalein indicator was titrated against 0.1 N NaOH. The amount of total acids was expressed as gr. citric acid/100 mL fruit juice by taking into account the factor of NaOH used.

TSS/TA ratio: Total Soluble Solids Percentage (TSS) was divided by Total Acidity (TA) to obtain this ratio.

Vitamin C contents: For determining the vitamin C contents 1 mL from fruit juice prepared for TSS measurements was taken and added 9 mL of oxalic acid as stabiliser. After this, 1 mL from these samples was taken and after mixing with 0.0012% 2-6 dichlorophenol phthalein indicator was read at 518 nm wave length with spectrophotometer. Same readings were taken with standard ascorbic acid solutions and stabiliser. With the help of standard graph, the amount of ascorbic acid was calculated as mg/100 mL of fruit juice from the absorbance values of the analysed samples. Data was statistically analyzed according to Tarist packet programme.

RESULTS

Fruit weight: It is evident from the Table 1 that differences in relation to types of inflorescence turned out to be significant ($p<0.01$) during both years. A significantly higher fruit weight (145.07 g) was recorded for LY inflorescence as compared with LS ones (110.48 g/fruit) during 1997. Fruit weight for LY and LS inflorescence was 104.98 and 82.70 g, respectively, in 1998. Data regarding rootstocks indicated that non significant differences existed among rootstocks in respect of fruit weight.

Fruit diameter and height: One would visualize from the Table 1 that there were significant difference ($p<0.01$) between two types of inflorescence in respect of fruit diameter in the both years. Fruit diameter was 6.46 and 5.83 cm for LY and LS inflorescence, respectively, in 1997. While a comparatively lower diameter was recorded (6.14 cm) for LY and LS (5.67 cm) fruits during 1998. Significant differences were present regarding fruit diameter among three rootstocks in 1997 but non significant during 1998.

It can be noted from the Table 1 that highly significant ($p<0.01$) differences existed between types of inflorescence in respect of fruit height in 1997 as well as in 1998. Leafy and leafless inflorescence presented 6.56 and 5.62 cm in 1997 and corresponding values for 1998 were 5.54 and 5.01 cm, respectively. The differences among three rootstocks regarding fruit height were found non-significant in 1997 as well as in 1998.

Fruit shape index: It is evident from the data that there was significant difference ($p<0.05$) between two types of inflorescence during 1997 and non significant during 1998. A higher shape index value (1.04) was noted for leafless inflorescence as compared to leafy ones (0.99) during 1997 (Table 1). The comparison of three root stocks among themselves, regarding this parameter spelt out significant differences ($p<0.01$) during both the years.

Specific gravity: Observation of specific gravity values for both years indicated significant differences ($p<0.01$) between two types of inflorescence. The specific gravity which is closely related to puffiness was significantly lower (0.84 g cm^{-3}) in fruits developed from LY inflorescence as compared with LS inflorescence (0.87 g cm^{-3}) in 1997 (Table 1). Comparatively higher values (0.88 and 0.92 g/cm^3) for LY and LS inflorescence were noted in 1998. Data regarding specific gravity in respect of rootstocks showed non significant differences among three rootstocks.

Peel color a/b ratio: This ratio provides information regarding establishing relation of yellow color of fruit peel with green or red color. In this way it is possible to generalize all the color elements. A perusal of the data indicated that significant differences ($p<0.01$) existed between fruits from two types of inflorescence. The LS inflorescence behaved significantly better (0.28) than LY (0.16) inflorescence. Significant differences ($p<0.05$) were also observed among rootstocks (Table 2).

Peel thickness and peel index: Data in relation to peel thickness (Table 2) showed that LY and LS inflorescence differed significantly ($p<0.01$) from each other in 1997 as well as in 1998. The peel thickness for fruits from LY and LS inflorescence was 4.34 and 3.30 mm in 1997 while the corresponding values were 3.47 and 2.56 mm, respectively in 1998.

By calculation of peal index, the effect of fruit weight on peel thickness can be abolished. Results concerning peel thickness index indicated significant differences between LY and LS inflorescence in both the years. The peel thickness index for LY and LS inflorescence was 13.45 and 11.39, respectively in 1997 and 11.33 and 9.08 for LY and LS, respectively in 1998 (Table 2).

Electrical conductivity percentage: It can be visualised from data regarding EC percentage (Table 2) that significantly higher (46.51) value was noted for LS inflorescence as compared with (41.08) LY ones. The results for rootstocks were found non significant.

Juice percentage and total soluble solids percentage: One would visualized from the Table 3 that differences for fruit juice percentage turned out to be significant ($p<0.01$) for both the years. In 1997 fruit juice percentage was 39.62 and 45.85% which indicates the significant superiority of LS inflorescence over LY ones. While in 1998 relatively higher fruit juice values were noted as that of in 1997. The extracted juice percentage was 44.92 and 51.36 for LY and LS inflorescence, respectively. Perusal of results for rootstocks indicated that statistically significant differences existed in 1997 but non-significant in 1998.

It is evident from the data that there were significant differences in 1997 but non significant in 1998 in respect of TSS. The TSS percentage for LY and LS inflorescence was 10.66 and 11.64, respectively in 1997 (Table 3).

Total acidity and TSS/TA ratio: The data showed that there were non significant differences between total acidity for LY and LS inflorescence during both the years but significant differences ($p<0.05$) were found among rootstocks in 1997 as well as in 1998 (Table 3).

Table 1: Effect of leafy and leafless inflorescence on fruit weight, diameter, height, fruit index and specific gravity

Parameters	Year	Fruit type LY	LS	Mean	Rootstocks TR	SO	TF
Fruit weight (g)	1997	145.07a	110.48b	127.78*	122.78ns	124.67	135.89
	1998	104.98a	82.70b	93.84*	91.55	96.33	93.64
Fruit diameter (cm)	1997	6.46a	5.83b	6.15 *	6.54 a	5.67c	6.23b
	1998	6.14a	5.67b	5.90*	5.70	6.01	6.00
Fruit height (cm)	1997	6.56a	5.62b	6.09**	6.12	5.96	6.11
	1998	5.54a	5.01b	5.28**	5.52	5.37	5.23
Fruit Index	1997	0.99b	1.04a	1.01*	1.07 a	0.96c	1.01b
	1998	1.11	1.13	1.12*	1.09bc	1.12ab	1.15a
Specific gravity (g cm^{-3})	1997	0.84b	0.87a	0.85*	0.85	0.85	0.86
	1998	0.88b	0.92a	0.90*	0.89	0.89	0.91

Table 2: Effect of leafy and leafless inflorescence on peel color L, a, b, a/b ratio, peel thickness, peel index and peel EC percentage

Parameters	Year	Fruit type LY	LS	Mean	Rootstocks TR	SO	TF
Peel color L	1998	62.40b	66.14a	64.27	64.34ns	64.14	64.34
Peel color 'a'	1998	9.86b	18.93a	14.40	16.79a	13.28b	13.15bc
Peel color 'b'	1998	59.95b	66.78a	63.37	64.33	62.70	63.08
Peel color a/b	1998	0.16b	0.28a	0.22	0.26 a	0.21 b	0.20bc
Peel thickness (mm)	1997	4.34a	3.30b	3.82 *	3.81	3.67	3.99
	1998	3.47a	2.56b	3.02 *	3.11	2.97	2.98
Peel index	1997	13.45a	11.39b	12.42 *	11.61	12.89	12.76
	1998	11.33a	9.08b	10.20 *	10.87	9.86	9.88
Peel EC (%)	1998	41.08b	46.51a	43.78	44.78	42.54	44.07

*Any two means not sharing a letter common in a column or row differ significantly, ns (non-significant)

Table 3: Effect of leafy and leafless inflorescence on juice percentage, TSS%, TA, TSS/TA and vitamin C contents

		Fruit type			Rootstocks		
Parameters	Year	LY	LS	Mean	TR	SO	TF
Fruit juice (%)	1997	39.62b	45.85a	42.73*	39.93c	43.64ab	44.63a
	1998	44.92b	51.36a	48.14*	48.71ns	46.47	49.24
TSS (%)	1997	10.66b	11.64a	11.15	11.34	10.83	11.28
	1998	11.41	11.93	11.67	11.50	11.37	12.17
TA (g/100 mL)	1997	1.67	1.81	1.79	1.79ab	1.56bc	1.88a
	1998	1.69	1.68	1.69	1.55bc	1.57b	1.94a
TSS/TA	1997	6.44	6.57	6.51	6.41ab	6.98a	6.13bc
	1998	6.88	7.25	7.06	7.50a	7.35ab	6.34c
Vitamin C (mg/100 mL)	1997	26.01b	29.20a	27.61*	29.72a	29.28ab	23.82c
	1998	22.93b	25.51a	24.22*	24.55	27.34	20.76

*Any two means not sharing a letter common in a column or row differ significantly, ns (non-significant)

A view of the data indicated that non significant differences existed between two types of inflorescence in 1997 as well as in 1998 regarding TSS/TA ratio. The comparison of rootstocks means presented significant differences in both the years (Table 3).

Vitamin c contents: It is evident from the data that significant differences ($p<0.05$) were found between LY and LS inflorescence during both the years. Significantly higher vitamin C contents (29.20) were noted for LS inflorescence as compared with (26.01 mg/100 mL) for LY ones in 1997. While vitamin C contents for LY and LS inflorescence in 1998 were 22.93 and 25.51 mg/100 mL, respectively. Comparison of rootstocks presented significant differences in 1997 whereas non -significant in 1998.

DISCUSSION

Physical fruit characteristics: Significantly higher fruit weight, fruit diameter and fruit height and lower fruit shape index and specific gravity were found in LY inflorescence born fruits as compared with LS ones. Fruit size in general is function of several factors including cultivars, rootstocks, cropload, inflorescence type and cultural practices such as irrigation and nutrition. Difference in fruit size may also result from differences in fruit growth which is determined by the sink strength of the fruit (its capacity to accumulate metabolites) and metabolite supply[10]. Differences in size of LY and LS inflorescence are clear at the time of flowering and increased markedly during post bloom until past June drop, to remain until fruit maturity. While in another study it was reported that cross sectional area of the grapefruit pedicel was highly correlated with final fruit weight, suggesting that transport capacity affects the growth of the fruit[11]. Although no data were collected on pedicel width but on the basis of personal observations it can be said that LY fruits have thicker pedicel as compared with LS ones. The other factor which can play role in determining the size of the fruit is temperature. Because it has been reported that *Satsuma mandarin* in high temperature conditions have greater size as well as pedicel diameter as compared with those grown under lower temperature[5] while Karaçali[12] observed that fruit at the top of the tree have higher fruit weight, diameter and height as compared with other position of the trees. As the LY inflorescence are present normally around the periphery of the tree and the temperature at periphery is thought to be higher than the inside of the tree where LS inflorescence are generally present. So, the high temperature might have contributed to some extent to higher fruit weight, diameter and height in LY inflorescence. Fruit shape index was lower in LY fruits, this indicates that LY born fruits were collard i.e. having more height than diameter while LS were somewhat rounder. Similar trend was noted in Shamout orange that with the progressive increase in roughness the fruit become longer because increasing peel roughness accentuated at the stem end[13].

The specific gravity of fruit which is closely related with puffiness was significantly lower in LY in comparison with LS fruits. As the specific gravity of the fruit indicates the largeness of the cavity inside the fruit, so, factors those increase the fruit volume and peel growth, decrease and factors those increase uptake of water increase specific gravity[14]. In this context it can be said that LY fruits having less specific gravity are low quality fruits.

External fruit quality: The a/b ratio which provides information regarding establishing relation of yellow color of fruit with green or red color, was also higher in LS fruits than in LY ones. This indicated that LS fruits attained better peel color than LY fruits. Peel roughness in orange fruit was due to increased Gibberellin and Cytokinin of the flavedo and albedo tissues[15], and our findings also indicated that LY fruits have more gibberellins contents as compared with LS ones. The external application of Gibberellins also delay color development by delaying chlorophyll degradation and senescence in citrus[16]. The other hormone which accounts in color development is the amount of ABA in the flavedo. Abcissic acid contents increase throughout the course of color development and reached a maximum at the time of color break. A decline in the ABA concentration occurred concomitantly with the full expression of color[17], so it may be assumed that LS fruits have attained ABA peak earlier than the LY ones and showed better color development.

Significantly higher peel thickness and peel index was noted in LY as compared with LS fruits (Table 2). The peel thickness is directly related with fruit weight[12,18]. Leafy fruits were bigger in size and hence presented thicker peel and higher peel index. Significantly higher peel thickness in 1997 may also have resulted from higher fruit weight in 1997 than that of in 1998.

Significantly higher electrical conductivity percentage noted in LS fruits as compared with LY fruits was independent of rootstocks (Table 2). A typical behavior of senescence is the increase in electrolyte leakage[19]. As it has been elaborated earlier, that rough developed fruit have higher flavedo Gibberellin content[15]. Secondly, GA_3 improved the viability of mechanically isolated protoplast and in the excised mesocarp tissue of pummelo, the electrolyte leakage and K+ efflux was significantly reduced in the presence of GA_3. So, the less electrical conductivity of leafy fruits can be explained in this context.

Internal fruit quality: Data regarding juice percentage indicated that significantly higher juice percentage was obtained from LS as compared with LY fruits during the both year (Table 3). Fruit weight is negatively related with juice percentage[12,20]. The leafy fruits were bigger in size with less juice percentage than the LS ones those were smaller in size but juice yield was higher.

Significantly lower TSS percentage in LY fruits compared with LS may also be explained (Table 3) with reference to the fruit weight because TSS is also negatively related with fruit weight, so the higher fruit weight in LY fruits was responsible for lower TSS. Differences between LY and LS fruits regarding total acidity were found non-significant during both the year (Table 3) but differences among rootstocks were found significant. It has been reported that Sour orange rootstock for *Satsuma mandarin* gave maximum acidity while Trifoliate and Troyer citrange stood at par with each other[21] while Mendilcioglu[22] obtained different results with the same rootstocks. This indicated that various factors such as microclimate, cultural practices and nutrition may also influence the total acidity of the fruit. The total acidity is positively related with total soluble solids[20] but this cannot be verified by our results.

Total soluble solids/total acid ratio presented non-significant differences for LY and LS fruits but significant for rootstocks. No proper pattern was followed by different rootstocks regarding TSS/TA ratio during both the year. Others workers also reported different results[21,22]. Significantly higher vitamin C contents were found in LS as compared with LY fruits during both the year. Significantly lower vitamin C contents were found in 1998 as compared with in 1997. High temperature of May, September, October increases vitamin C contents[23] but our results do not substantiate these findings because during these months temperature was higher in 1998 but vitamin C contents were higher in 1997. The vitamin C contents were positively related with TSS percentage. So, the LS fruits have comparatively higher TSS percentage as well as in vitamin C contents[20].

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