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Flowering and Fruitset Behaviour of *Satsuma mandarin* (*Citrus unshiu*, Marc.) as Influenced by Environment

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Abstract: Present studies were carried out to determine the effect of environment on inflorescence pattern and fruit set behaviour of *Satsuma mandarin*. Data obtained showed that mean temperature for February, March and April was 9.6°C during 1997 as compared with 11.63°C in 1998. Similarly the mean maximum and minimum temperature during these three months was higher in 1998 than in 1997. Data in respect of flower opening showed that flowering was realized two weeks earlier in 1998 as compared with 1997 due to climate influence. Generaly leafless inflorescence experienced full bloom earlier than leafy ones. Significantly higher leafy inflorescence (27.05%) were noted in 1998 as compared (11.89%) in 1997 and vice versa for leafless inflorescence. There were significant differences among rootstocks in respect of inflorescence leafiness. Leafy inflorescence presented significantly higher ovary weight of 27.75 mg/ovary as compared with 22.07 mg/ovary in leafless inflorescence. Relatively higher fruitset occurred in leafy as compared with leafless inflorescence although differences were non significant. Results obtained have been discussed to establish a relationship of inflorescence leafiness with climatic forces and fruit growth.

Key words: Leafy and leafless inflorescence, *Satsuma mandarin* , fruitset, ovary weight

INTRODUCTION

The importance of understanding flowering of citrus is paramount since it is first step in the reproductive process. Expressed in terms of climatic conditions in the Izmir region, flower development in *Satsuma mandarin* would take place towards the end of February or beginning of March. 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 leaves[1]. 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 flower with leafy shoots d) vegetative shoot[2]. Delgado *et al*.[3] found that when three rates of PP333 active ingredients (2.5, 5.0 and 10 g/tree) were dissolved and applied 5 L of water to individual trees of 'Frost Dancy, mandarin, the primary response was an alteration in the inflorescence structure. The flowering shoots became increasingly leafless as higher levels of growth retardants were applied. Paclobutrazol applied to soil increased flowering in *Satsuma mandarin* dose dependently. At 1000 mg/tree, it markedly increased the number of leafless inflorescence by 66% but reduced new shoot sprouting by 48% and shoot growth by 37%[4].

Interactive effect of air and soil temperature on flowering of 4 and 12 year old Frost Valencia orange budded on trifoliate rootstock were determined in control environment. Quiescent trees were subjected to environmental treatments consisting of 2-day-night air temperature regimes in 2 glass houses and 2 constant soil temperatures in each house. Total bud break was increased by warm soils (25°C) compared with cool soil (15°C). In contrast, the initiation of flowers on the new shoots was mainly influenced by air temperature, with more flowers in cool air (20/15°C, day/night) than at temperature of 30/15°C, lower air temperature, however, resulted in more leafless floral shoots. The greatest number of leafy floral shoots was produced with warmer soil and higher air temperature[5]. Poerwanto and Inoue[6] conducted experiment in growth chamber to observe the effect of air and soil temperature in early and mid winter on flower development and morphology of *Satsuma mandarin* budded on trifoliate orange. There were few flowers at 30/30°C, extremely few at 30/15°C and many at both 15/15 and 15/30°C. The days required to flowering increased and flowering period were longer

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at low air temperature. The trees at the high air temperature developed smaller flowers and ovaries in leafy inflorescence. The trees at 15/30°C produced bigger ovaries than at 15/15°C. Guardiola *et al.*[7] found that dry weight of ovaries in Navelated orange from leafy inflorescence was higher than that of from leafless inflorescence. The size of the ovaries at anthesis is inversely related to flower number and this relation holds for both leafy and leafless inflorescence while fruit set is higher in leafy than leafless ones.

Guardiola and Lazaro[8] observed that in *Satsuma mandarin* sink strength of the fruit is related to the inflorescence type in which it is born which ultimately determines the size of the fruit. Some of these differences in growth rate may be due to bigger assimilates supply to the fruit because of inflorescence leaves, an additional mechanism probably hormonal in nature, seems to be more important[8]. The faster growth in the leafy inflorescence stands when the inflorescence leaves are removed after June drop. Furthermore, the differences in size are clear at flowering when the inflorescence leaves don't contribute to the nutrition of the fruit.

Present studies were envisaged to determine the effect of environment on inflorescence pattern and fruit set behaviour of *Satsuma mandarin* and their relation with fruit growth.

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. Plant material used in this research work consisted of 25 years old *Satsuma mandarin* plants of Owari cultivar (*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 plants of same size 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 per recommendations. Single plant was considered as one replication and data were analyzed according to Tarist packet programme.

Meteorological observation: This region has semi-mediterranean type climate. Generally summer is hot and dry with cold and rainy winter. The maximum and minimum values regarding temperature and relative humidity along with the precipitation received during the years under study were obtained from the Bornova meteorological station.

Flowering time and inflorescence type: Inflorescences are flowering shoots arising from axillary buds. Inflorescence may be mixed, or generative. Three plants from each of the rootstock cultivars 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 and leafless inflorescence were counted. Then daily observations were recorded for number of flowers opened on leafy and leafless inflorescence from the start of flower opening. When more than 50% flowers had opened, that period was considered as full bloom time for leafy and leafless inflorescence separately.

Weight of ovaries and fruit set percentage: From each of the selected plant, fifteen, about to open flowers from leafy and leafless inflorescence, were collected in polyethylene bags and taken to laboratory. After cutting styles of flowers, weight of ovaries were determined by balance and weight per ovary was calculated for leafy and leafless inflorescence.

Branches selected for determining the percentage of leafy and leafless inflorescence were also utilized for obtaining fruit set data. Data for fruit set was recorded when the petals had fallen and the color of the ovaries turned from light green to dark green i.e. about fifteen days after full bloom and expressed in percentage on the basis of total number of leafy and leafless inflorescence.

RESULTS

Meteorological observation: Generally citrus cultivars grown in semi arid and humid subtropics regions produce high quality fruits as compared with those grown under unsuitable ecological conditions. Factors those directly or indirectly influence the fruit quality were also taken into account during the course of study. Meteorological data for the study period were obtained from Bornova Meteorological station. A perusal of the Table 1 indicated that mean temperature for February, March and April was 9.6°C during 1997 as compared with 11.63 in the year 1998. Like wise the mean maximum and minimum temperature during these three months was higher in 1998 than that of in 1997. In contrast, mean monthly temperature of May and June was higher in 1997 than 1998. The mean relative humidity value for May and June was higher in 1998 as compared with those recorded in 1997.

Table 1: Meteorological data for the year 1997 and 1998

Parameters	Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average	1997	9.10	8.10	9.40	11.40	21.40	26.20	28.20	25.80	21.50	17.10	13.70	10.00
monthly temp.	1998	8.20	9.30	8.80	16.80	19.50	26.20	29.00	28.90	23.00	18.60	14.40	9.40
Maximum	1997	14.20	13.30	15.10	16.60	27.50	32.40	34.50	31.60	28.10	23.00	19.40	14.60
average temp.	1998	13.80	15.30	14.30	23.30	25.40	32.20	35.60	35.40	29.50	25.80	19.50	12.90
Minimum	1997	5.10	3.30	4.30	5.90	13.80	17.80	20.30	19.60	15.30	12.50	9.10	6.00
average temp.	1998	3.80	4.60	3.80	9.70	13.40	19.30	21.90	22.30	17.20	12.80	10.10	6.40
Average relative	1997	65.00	61.00	56.00	68.00	56.00	51.00	45.00	52.00	51.00	63.00	73.00	70.00
humidity%	1998	69.00	64.00	62.00	58.00	62.00	48.00	48.00	53.00	58.00	63.00	69.00	72.00

Table 2: Full bloom time of *Satsuma mandarin* under Izmir conditions during 1997

	Troyer citrange		Sour orange		Trifoliate orange	
	Opened flower %		Opened flower %		Opened flower %	
Observation dates	LY	LS	LY	LS	LY	LS
10.5.97	0.90	15.60	2.40	7.90	1.10	2.80
11.5.97	4.20	31.60	4.70	20.30	2.20	5.90
12.5.97	15.00	55.90	14.50	38.10	4.70	11.20
13.5.97	36.00	70.00	38.40	59.00	9.10	16.40
14.5.97	54.00	84.10	62.70	72.90	17.90	23.50
15.5.97	86.40	93.40	78.00	85.20	53.30	72.30

Table 3: Full bloom time of *Satsuma mandarin* under Izmir conditions during 1998

	Troyer citrange		Sour orange		Trifoliate orange	
	Opened flower %		Opened flower %		Opened flower %	
Observation dates	LY	LS	LY	LS	LY	LS
27.4.98	13.40	8.50	3.50	4.70	0.00	0.00
28.4.98	25.70	24.30	11.80	18.20	1.10	0.50
29.4.98	34.40	33.90	18.20	27.20	5.10	3.80
30.4.98	47.00	51.90	30.60	44.90	9.90	7.40
1.5.98	61.40	73.20	45.30	68.20	14.90	12.10
2.5.98	79.30	85.90	60.20	80.80	24.20	27.70
3.5.98					33.10	41.40
4.5.98					45.70	60.40
5.5.98					64.70	82.60

Table 4: Percentage of leafy and leafless inflorescence under Izmir conditions during 1997 and 1998

	Year		Rootstocks				Rootstocks		
Parameters	1997	1998	TR	SO	TF	Year	TR	SO	TF
LY Infl.	11.89b*	27.05a	14.94bc	17.01ab	26.46a	1997	8.51	10.05	17.11
						1998	21.37	23.97	35.80
LS Infl	88.11a	72.95b	85.06a	82.99b	73.54bc	1997	91.49	89.95	82.89
						1998	78.63	76.03	64.20

*Any two means not sharing a letter(s) common in a column or row differ significantly

Flowering time: Table 2 indicated that full bloom (more than 50% flower opening) in case of Troyer citrange (TR) for leafless inflorescence was attained on 12th May while in case of leafy inflorescence it was two days later. Full bloom in leafless inflorescence of Sour Orange (SO) occurred on 13th May and a day latter in leafy inflorescence. In contrast to TR and SO, full bloom of Trifoliate orange (TF) for both type of inflorescence was observed on same day i.e. 15th May.

It is important to note that during 1998 anthesis started earlier i.e. on 27th April. Examination of the data showed that full bloom of leafless inflorescence in respect of TR occurred on 30th April while in case of leafy ones a day after (Table 3). Data in relation to flower opening for SO exhibited that full bloom of leafless and leafy inflorescence was noted on 1st and 2nd May, respectively. Data in respect of flower opening percentage regarding TF spelt out that full bloom in respect of leafless and leafy inflorescence was attained on 4th and 5th May, respectively.

Leafy and leafless inflorescence percentage: It is evident from the data that significantly higher (27.05%) leafy inflorescence were noted in 1998 as compared with (11.89%) in 1997 (Table 4). On the contrary clearly higher leafless inflorescence percentage was noted in 1997 (88.11) as that of in 1998 (72.95%). The rootstocks affected the inflorescence type percentage. Means for the both

Table 5: Weight of ovaries and fruitset percentage of leafy and leafless inflorescence of *Satsuma mandarin*

		Infl. type		Rootstocks				Rootstocks		
Parameters	Year	LY	LS	TR	SO	TF	Infl. type	TR	SO	TF
Ovary weight mg/ovary	1997	27.75a	22.06b	25.70 ns	24.57	24.44	LY	28.73	28.00	26.52
							LS	22.67	21.13	22.37
Fruit set%	1997	42.47	41.03	42.71	40.95	41.60	LY	43.56	44.96	38.99
							LS	41.86	36.94	44.30
	1998	46.04	41.35	47.07	41.89	42.13	LY	48.71	48.55	40.85
							LS	45.42	35.23	43.40

ns (non-significant)

years presented significant differences (Table 4). The rootstocks means arranged in descending order followed a sequence of TF, SO and TR presenting 26.46, 17.01 and 14.94% leafy inflorescence and 73.54, 82.99 and 85.06% leafless inflorescence, respectively. Year x rootstock interaction for leafy and leafless inflorescence were found non-significant

Weight of ovary: It is clear from the data that leafy inflorescence gave significantly higher weight of ovary as compared to leafless inflorescence giving 27.75 and 22.06 mg/ovary, respectively in 1997(Table 5). The rootstocks mean in relation to ovary weight presented non-significant differences. The means arranged in descending order followed a sequence of TR, SO and TF, respectively. Inflorescence type x rootstock interaction were found non-significant and relatively higher weight of ovaries was noted in case of leafy inflorescence in all the three rootstocks as that of leafless ones.

Fruit set percentage: Relatively higher fruit set occurred in LY as compared to LS inflorescence in both the years, although differences were found non-significant. Fruit set was 42.47 and 41.03 in 1997 while 46.04 and 41.35% in LY and LS inflorescence, respectively, in 1998 (Table 5). Non-significant differences regarding fruit set percentage were present among rootstocks during both years. The rootstock means arranged in descending order followed a sequence of TR, TF and SO presenting 42.71, 41.60 and 40.95% fruit set in 1997, while, 47.07, 42.13 and 41.89% fruit set was experienced by TR, TF and SO, respectively, in 1998. Data regarding inflorescence x rootstocks interaction were also found non significant.

DISCUSSION

Flowering time in citrus like fruits is dependent on the temperature before flowering. Keeping in view the Izmir climatic conditions, the first step towards flowering i.e. initiation takes place towards the end of February[9]. The antheses period may be slightly shifted from year to year at the same location depending upon the climate and especially temperature[10]. Because of the differing climatic conditions (from February-April) of the two years (Table 1) flowering started about two weeks earlier in 1998 than in 1997. Brammeier[2] also observed that high temperature during the months before flowering was responsible for 23 days earlier flowering. Results regarding flower opening indicated that leafless inflorescence opened earlier as compared with leafy inflorescence (Table 2 and 3). Generally leafless inflorescence attained full bloom (50% of the flower opening) one day before the leafy ones. When compared all the three rootstocks in respect of time of flowering then in both years, Troyer citrange attained full bloom earlier and this was followed by Sour orange and Trifoliate orange with one-day difference. The unfolding of citrus flowering is associated with substantial increase in the production of ethylene and the concentration of its precursor 1-aminocyclopropane-1-carboxylic acid[11]. The earlier opening of leafless inflorescence may also be attributed to greater production of ethylene by LS inflorescence as compared with (LY) inflorescence.

Result obtained indicated that percentage of LS and LY inflorescence varied during both the years under study (Table 4). Comparatively lower (11.89) percentage of LY inflorescence was recorded in 1997 as compared with (27.05) in 1998. Many factors such as pruning, high soil and air temperature may be responsible for more LY inflorescence[5,12]. Pruning was done before the start of flowering in 1998 and high air temperature might have contributed towards more LY inflorescence. In contrast to this, lower air temperature resulted in more LS inflorescence in 1997 than 1998. Besides this, various nitrogenous compounds such as foliar application of urea increased inflorescence leafiness[13], while application of PP333 (a growth retardant) and ringing increased the formation of LS inflorescence[3,14] in mandarin. Leafy inflorescence have significantly higher weight of ovaries as compared with leafless inflorescence (Table 5). Comparatively higher dry ovary weight at anthesis in Novelette orange and fresh ovary weight in *Satsuma mandarin* at petal fall was noted in LY as compared with LS inflorescence. Weight of ovaries at anthesis is inversely related to flower number and this relation holds for flowers both from LY and LS inflorescence[2,7].

A view of the data regarding fruit set in LY and LS inflorescence indicated that although higher fruit set occurred in LY as compared with LS inflorescence but differences were non significant (Table 5). Various mechanisms have been supposed for greater set in LY inflorescence involving increased supply by inflorescence leaves to developing ovaries of carbohydrates[15], phytohormones or nitrogenous compounds[13] and higher sink strength of LY inflorescence[16]. In our view, fruit retention is more important than initial set because most of the fruits born on LS inflorescence drop during post set period. Our view can be substantiated by the findings that 30 days after full bloom weight of LY fruit lets were greater than the leafless fruit lets and LY fruit lets showed considerably greater tree retention after 10 weeks (12.70%) than LS fruit lets (1.20%)[17]. The other factor, which can play role in fruitset and tree retention, is the difference in the vascular system of the LY and LS inflorescence. The vascular system of the LY inflorescence contains distinct central xylem cylinder and the vascular area of the LS inflorescence is only about ¼ th of that of the LY ones[18]. So, the well-developed vascular system of LY inflorescence may be responsible for higher set and lower fruit let drop. Both the abscission and ethylene production was higher in LS inflorescence than LY ones and presence of leaves reduce the NAA induced ethylene production[19].

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