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STUDIES ON PHENOLOGY OF CITRUS SPECIES AND THEIR CULTIVARS UNDER SEMI-ARID CONDITIONS OF HISAR

NIDHI SHARMA[1]*, SAVITA DUHAN[2], SHASHANK SINGH[1], H. M. VIJAYA[1] AND SUNEEL SHARMA[1]
*Department of Horticulture, Chaudhary Charan Singh Haryana Agriculture University, Hisar -125 004, Haryana, INDIA
[2]Department of Botany and Plant Physiology,
Chaudhary Charan Singh Haryana Agriculture University, Hisar -125 004, Haryana, INDIA
e-mail: nidhi.nandani@gmail.com

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***Corresponding author**

ABSTRACT

Phenology of three citrus species Sweet orange (*Citrus sinensis* (L.) Osbeck) cv. Jaffa and Pineapple; Mandarin hybrids Pearl Tangelo *(Citrus reticulata* Blanco x *Citrus paradisi* Macf.) and Kinnow *(Citrus nobilis* Lour. x *Citrus deliciosa* Tenore) and Grapefruit (*Citrus paradisi* Macf.) *cv.* Duncan and Ruby Red) in spring flush during 2014 and 2015 were studied. In citrus flowering occurs only once in the year *i.e.* Feb-Mar. It is investigated, that bud initiation took place from 27th Jan to 25th Feb during 2014 and bud break from 8th Feb -28th Feb 2015 utilizing 12.05-49.30°Cd heat units. Flower formation in different cultivars took 16-38 days with 40.0 to 139.1°Cd heat units used up during both the years. Sweet orange cv. Jaffa was earliest to start flowering. Duration of flowering was 10-26 days using 30.5 to 138.5°Cd heat units by different cultivars. Two types of inflorescences i.e. leafy and non-leafy were observed with highest percent of leafy inflorescence in Sweet orange cv. Jaffa *i.e.* 87.83 and 74.46 during both years. Flowering density was highest in grapefruit cv. Ruby Red, however, for fruit set even with least flowering density Kinnow mandarin proved its superiority for growth and yield characteristics with better quality fruits during both the years.

INTRODUCTION

Citrus is a perennial tree crop that exhibits a very peculiar and unusual reproductive biology. It is grown successfully over moderately wide range of environmental conditions, ranged between 40R″ north-south latitudes where minimum temperatures are generally greater than -7ºC. Cognizance of erratic weather fall and rise on citrus phenology, growth and reproductive behavior is a pre-requisite to have optimized production and fruit quality with enhanced nutritional value. It is a rich source of number of carotenoids found in any fruit with an extensive array of secondary compounds such as vitamin-E, provitamin-A, flavonoids, limonoids, polysac charides, lignin, fiber, phenolic compounds and essential oils etc. having pivotal nutritional properties (Iglesias *et al.,* 2007). Citrus belongs to genus of flowering plants in family Rutaceae, sub-family Aurantioideae, tribe Citrae, subtribe- Citrinae (Davies and Albrigo, 1994). Main characteristics of sub-family Aurantioideae, leaves usually possessing transparent schizolysigenous oil glands and flowers with an annular disc; the fruit is a berry (hesperidium) with a leathery rind often with juicy pulp and the seeds without endosperm, sometimes with two or more nucellar embryos (Swingle and Reece, 1967). Citrus is believed to have originated in the part of Southeast Asia bordered by North-eastern India, Myanmar and the Yunnan province of China. However, the most recent research indicates another origin in Australia, New Caledonia and New Guinea (Liu *et al.,* 2012). Sweet orange (*Citrus sinensis* (L.) Osbeck) is believed as originated in southern China or Indo-China border region. Mandarins (*Citrus reticulata* Blanco), might have originated in Philippines and the grapefruit (*Citrus paradisi* Macf.) is of recent origin either as bud mutation of pummelo or as a hybrid between pummelo and sweet orange (Zeven and de Wet, 1982). Citrus flowering is a complex phenological process influenced by a number of interacting factors. Under north Indian conditions, fall in temperature substantially during winter months of due to which buds became dormant. In all citrus species major bloom occurs almost during early spring (February-March) when atmospheric temperature starts rising after the cold winter and soil moisture conditions are suitable (Hayes, 1970). As low temperature causes buds inactive and the release of stress by higher temperature triggers the beginning of reproductive growth. Even the rate of flower bud development is also a temperature dependent phenomenon. As per Mendel (1969) the main temperature ranges for the growth of citrus is minimum of 12.5-13ºC optimum, 23-34ºC and maximum (limiting growth) 37-39ºC. Thus, in central India month of March is found crucial for citrus growth. In this period minimum temperature remains favorable for growth, but maximum exceeds beyond required limit and cause heavy drop of small fruitlets and leads to drastic reduction in yield.

Day time high temperature during floral differentiation shortens development time and advances the date of anthesis (Valiente and Albrigo, 2002). Regarding flower intensity, the longer exposer of low temperature increases floral induction, thus, increases the number of flowers per node, per sprouting and the tree (Poerwanto and Inoue, 1990). At higher temperature, citrus trees bloom sooner, fruits mature early, fruit size gets increased and acidity level of fruit juice remains low. The day and night temperature fluctuations result in better fruit coloring and sugar accumulation (Deris *et al.,* 2003).

No work has been done to study the growth and fruiting patterns in Citrus species and cultivars under semi-arid conditions of Haryana. Therefore, present investigation entitled 'Studies on phenology of citrus species and their cultivars under semi-arid conditions of Hisar' with an objective to study Phenology and fruiting pattern in citrus species

MATERIALS AND METHODS

The present investigation entitled 'Studies on phenology of citrus species and their cultivars under semi-arid conditions of Hisar' was carried out at experimental orchard of the Department of Horticulture, CCS Haryana Agriculture University, Hisar, Haryana during January, 2014 to December, 2015. CCS Haryana Agriculture University, Hisar, Haryana is situated at 215.2 m above sea level with co-ordinates of 29 R″10′ N latitude and 75 R″46′ E longitudes. The Hisar is located in the arid and semi-arid north-western region of Haryana state in India and has typical semi-arid climate with cold winter, and hot and dry summers, where, the mean monthly temperature shows wide fluctuations during both winter and summer months. Five trees of each two cultivar taken from every one of the above mentioned three citrus groups having uniform size and vigour were selected for investigation. Thus, all the six cultivars were replicated five times using single plant as a unit arranged in Randomized Block Design (RBD). The recommended standard package of cultural practices and plant protection measures for citrus crop were followed uniformly for all these 30 trees throughout the study period. In citrus the rate of vegetative development is accelerated more by warmer climatic conditions than the cooler one. The mean temperature range affecting growth of citrus species has been noted as minimum of 12.5-13°C, optimum of 23-34ºC and the maximum of 37-39ºC (limiting growth). Fundamentally, in citrus species annually three phases of growth and fruiting occur in India. The first stage being from Feb-May as flowering, fruit set and fruit growth phase, the second stage extends from June-Sept having fruit growth and development period and the third stage begins from October, stretching up to December end and progressing towards fruit maturity and ripening (Fig. 1).

Time of bud initiation: From the day one, the bud appeared on the shoot the date of bud initiation was recorded and used to count the period taken for morphological and developmental changes occurring subsequently. Time of bud break: The day on which the developing buds exhibited the green tips and first leaf tissue appearance the date was recorded. It was the stage of first morphological difference between vegetative and reproductive buds. The period from the date of bud initiation to the date of bud break was counted as the time taken in days for bud break. Duration of flower formation: The period between the bud initiations to flower primordial formation (visual) was regarded as duration of flower formation. The period was counted as the days taken from bud initiation to flower formation. Accordingly, using the daily meteorological data of both seasons taken from Agrimet Observatory, CCS HAU, Hisar the heat units required or accumulated during this period was worked out for the individual citrus species, cultivars/hybrids as per the following formula used by Mendel (1969).

$$\text{GDD/HU (ºCd)} = {}_a\Sigma^b \frac{(\text{T.max} + \text{T.min})}{2} - 12.5$$

Where,

GDD or HU = Growing Degree Days or Heat Units

T.max = maximum temperature

T.min = minimum temperature

a and b = starting date to ending date of a pheno-phase

Base temperature = 12.5°C for citrus species

Type of inflorescence

At flowering, with the contrasting visual differences the following two types of inflorescences appearing on the randomly tagged shoots of selected 30 trees were recorded.

Fruit Set

After full bloom, fruit set in each cultivar was recorded and the percentage of fruit set was worked out on the basis of number of buds tagged and number of fruits that had set.

$$\text{Fruit set (\%)} = \frac{\text{Total number of fruits set}}{\text{Number of flowers tagged}} \times 100$$

RESULTS

Time of bud initiation and bud break

The shoot growth in most of citrus species and cultivars also occurs in several well defined flushes (Fig. 1). It has been observed that spring flush (March- April in northern hemisphere) usually being far more intense affects more growing points than the summer flush. Spring flush contains both vegetative and reproductive shoots. As the trees get older, the spring flush mainly comprises of short reproductive shoots (leafy/non-leafy inflorescences). New growth originates from the axillary buds close to the top and, held at slight angle to the previous one. The ensuing sympodial zigzag pattern gets obscured as the shoot diameter increases. The pattern and time taken for bud initiation in different citrus cultivars shown in Table 1 revealed that the three citrus groups included in the study required different duration for transition from bud initiation (Plate 1) to bud break (Plate 1). The bud initiation was observed earliest in sweet orange cv. Jaffa that took place on 27th January and 2nd February during 2014 and 2015, respectively. While, in Pineapple during spring flush the buds initiated on 5th and 6th February in consequent years. It appeared that low temperature in February resulted in delayed bud initiation. A similar trend was observed in the mandarin hybrids and grapefruits. Pearl Tangelo as an early cultivar required less heat units (12.55 and 21.65°Cd) for subsequent growth. However, in comparison to all other cultivars investigated, the mandarin hybrid Kinnow was most early for bud initiation and bud break period utilizing heat units 34.15 and 49.30°Cd, respectively during 2014 and 2015. A perusal

Table 1: Time of bud initiation, bud break and heat units (°Cd) required in different citrus species and cultivars during 2014 and 2015

Citrus species	Cultivars	2014 Date of bud initiation	Date of bud break	Bud break period*	Heat units accumulated
Sweet orange(*Citrus sinensis*)	Jaffa	27th Jan	8th Feb	13	35.45
	Pineapple	5th Feb	17th Feb	12	12.05
Mandarin hybrids	Pearl Tangelo	9th Feb	22nd Feb	13	12.55
	Kinnow	25th Feb	7th Mar	10	34.15
Grapefruit(*Citrus paradisi*)	Duncan	9th Feb	28th Feb	20	25.05
	Ruby Red	10th Feb	26th Feb	17	19.05
Citrus species	Cultivars	2015 Date of bud initiation	Date of break	Bud break period*	Heat units accumulated
Sweet orange(*Citrus sinensis*)	Jaffa	2nd Feb	16th Feb	15	35.85
	Pineapple	6th Feb	15th Feb	11	16.85
Mandarin hybrids	Pearl Tangelo	9th Feb	16th Feb	12	21.65
	Kinnow	15th Feb	21st Feb	7	49.30
Grapefruit(*Citrus paradisi*)	Duncan	13th Feb	17th Feb	5	25.00
	Ruby Red	13th Feb	16th Feb	6	17.70

Table 2: Days taken to flower formation in different citrus species and cultivars during 2014 and 2015

Citrus species	Cultivars	2014	2015	2014	2015
		Days to flower formation*		Heat units utilized (°Cd)	
Sweet orange(*Citrus sinensis*)	Jaffa	33	21	60.1	95.0
	Pineapple	38	34	104.1	139.1
Mandarin hybrids	Pearl Tangelo	25	20	40.1	88.6
	Kinnow	28	23	89.9	100.1
Grapefruit(*Citrus paradisi*)	Duncan	31	21	74.4	135.5
	Ruby Red	28	16	69.2	120.1

Table 3: Percentages of the type of inflorescences in different citrus species and their cultivars during 2014 and 2015

Citrus species	Cultivars	Type of inflorescence (%) 2014 Leafy	Non-leafy	2015 Leafy	Non-leafy
Sweet orange(*Citrus sinensis*)	Jaffa	87.83	12.17	74.46	25.54
	Pineapple	84.34	15.66	63.41	36.60
Mandarin hybrids	Pearl Tangelo	61.24	38.16	58.99	21.01
	Kinnow	87.02	12.99	73.67	26.33
Grapefruit(*Citrus paradisi*)	Duncan	30.17	69.84	34.08	65.93
	Ruby Red	44.60	55.40	39.92	60.08
Mean		65.87	34.04	57.42	39.25
SE(m) ±		4.62	2.72	4.77	3.23
CD at 5%		13.22	7.76	13.62	9.23

of data given in Table1. showed that time taken in days for bud break was more but almost similar for cv. Jaffa, Pineapple and the hybrid Pearl Tangelo.

Foremost bud break in sweet orange cv. Jaffa was recorded on 8th Feb, 2014 taking a total of 13 days, but during 2015 the bud break occurred on 16th Feb, 2015 within 15 days of bud initiation and its period for bud beak was not at par with rest of cultivars of other species. The reason behind this was the accumulation of heat units that cv. Jaffa required heat units 35.45°Cd in 2014 and heat units 35.85°Cd during 2015, whereas cv. Pineapple required less heat unit accumulation of 12.05 and 16.85°Cd in these years.The change in the weather pattern here might have resulted in change in duration of bud break. It revealed that number of days taken for bud break might be in relation with accumulated heat units. Bud break period was noted shorter during both the years for Kinnow, but for grapefruit cv. Duncan and Ruby Red it was longest in 2014 and shortest during 2015 exhibiting almost a reverse trend. Comparatively in 2015 the time span for transition from bud initiation to bud beak was numerically less than in 2014 in almost all the species and their cultivars.

Duration of flower formation and heat unit accumulation

Among all species studied, mandarin hybrid Pearl Tangelo during 2014 and grapefruit cv. Ruby Red during 2015 formed flowers the earliest (Table 2). Pearl Tangelo was also the next earlier during 2015. Sweet orange cv. Pineapple was the latest taking 38 and 34 days in flower formation while, Kinnow and Ruby Red took minimum of 28 days in both the years. Heat units accumulated during the period from initiation of buds to the formation of flowers by different species and their cultivars were different. This is evident from the accumulation of heat units as shown in this data Table 2. The results are in close conformity with the findings of Sulochana *et al.* (2015) and Meena *et al.* (2013).

There was differential requirement of heat units by different species and cultivars within the group for flower formation, initiation of flowering and to complete the flowering. The cv. Pineapple accumulated maximum number of heat units (104.1 and 139.1°Cd) for flower formation during respective years. It was followed by Kinnow in 2014 and Duncan during 2015. Similarly, the cv. Jaffa and Ruby Red were at par for heat units utilized in flower formation during both the years. The mandarin hybrid Pearl Tangelo accumulated minimum heat units (40.1°Cd) in 25 days and sweet orange cv. Jaffa utilized less heat units (60.1°Cd) for flower formation in 33 days, both recording lowest heat units among all the cultivars during 2014.

Type of inflorescence

There were mainly, two types of inflorescences *viz.* leafy and non-leafy inflorescences was observed in citrus species and cultivars (Plate 2). There were significant differences in the production of leafy and non-leafy inflorescences in the various species investigated (Table 3).

The percentage of bearing leafy inflorescences on shoots was observed highest in sweet orange cv. Jaffa followed by mandarin hybrid Kinnow and the lowest was recorded in cvs. Duncan and Ruby Red thereby, which produced the highest percentage of non-leafy inflorescences during both the years. Nevertheless, the cv. Pineapple and hybrid Pearl Tangelo also produced high proportions of leafy inflorescences during both the years of investigation.

Flowering density and fruit set (%)

The data on flowering density along with the fruit set recorded in the material under investigation has been mentioned in Table 4. Significantly higher flower density was recorded in cultivar Ruby Red (3.86, 6.23%) followed by cultivar Duncan (2.63%) in 2014 and Pineapple (3.18%) and Pearl Tangelo (2.57%) during 2015. However, the lowest flowering density was observed in mandarin hybrid Kinnow (1.07 and 1.72%) during both the years. The flowering density might have some positive effect on fruit set in respective citrus fruit crop varieties that varied significantly with the environmental and field growing conditions. However, in the present study the impact of flowering density on the level of fruit set in different species and their varieties was not clearly visible, rather a very weak association appeared in this regard. The data pertaining to the fruit setting in citrus species and their cultivars have also been included in Table 4.

The per cent fruit set observed significantly higher in mandarin hybrids Kinnow (56.2 and 72.6%) was followed by cv. Jaffa (46.9 and 57.5%) during 2014 and 2015, respectively. The grapefruit cv. Duncan exhibited lowest fruit set (13.4 and 18.2%) while, other genotypes had average fruit set during both the years of investigation. Thus, the patterns of flowering density and fruit set were not identical. These variations were quite visible with respect to the fruit size, rind thickness, flesh thickness and flesh colour development in respective cultivars investigated during the course of study in both the years.

DISCUSSION

Earliest bud initiation was recorded in sweet orange cv. Jaffa on 27th January with bud break on 8th February with (35.45 and 35.85) heat units (Table 1). On the other hand Pineapple required less heat unit accumulation (12.05 and 16.85 in subsequent years) to initiate bud break in both the years. It revealed that number of days taken for bud break was in relation with accumulated heat units. The same trend was observed in mandarins and grapefruits. It also revealed that low temperature during February results in delayed bud initiation. These results are supported by findings of Srivastava *et al.* (2000) and Rikhande *et al.* (2013).

Foremost bud break was recorded in sweet orange cv. Jaffa on 8th Feb, 2014 after 13 days of bud initiation, but in 2015 it takes 15 days from bud initiation to reach bud break stage (Table 1). The reason behind this was tried to explain with heat units as cv. Jaffa required (13 days) 35.45 heat units but in 2015 it takes 15 days to acquire required amount of heat units i.e. 35.85. The change in weather pattern resulted here in form of changed duration for bud break. Cumulatively the period of transition from bud initiation to bud beak was less numerically in year 2015 than in 2014 in almost all species and their cultivars except Jaffa might be because the year 2015 was warmer than year 2014. Thus heat units accumulated faster and shorten the duration of transition phase. In Jaffa cultivar of sweet orange, bud break was found more under the influence of cool temperature than higher temperature. These results were in harmony with several workers (Lord and Eckard, 1985; Poerwanto and Inoue, 1990 and Guardiola, 1997) suggested that bud differentiation processes of citrus is under the influence of day length and low temperature.

Duration of flower formation and heat unit utilization

Time elapsed in between bud initiation (dormancy break) to flower primordia formation was regarded as duration of flower formation, was counted as days. This period was found in relation with heat units accumulation (Table 2). Lovatt *et al.* (1984) reported the rate flower development was positively correlated with degree days. Poerwanto and Inoue (1990) observed flower sprouting within seven days at 30/30ºC, 11 days at 30/15ºC, 21 days at 15/30ºC, and 33 days at 15/15ºC,

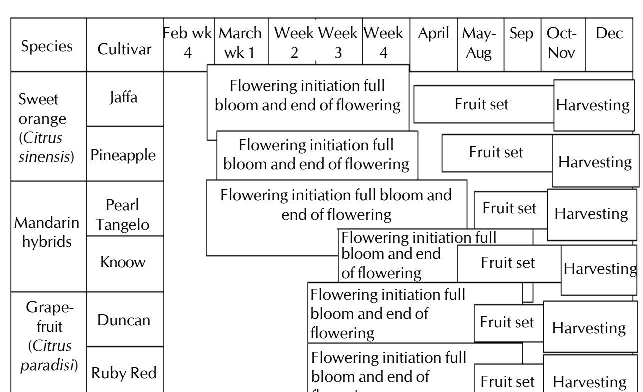


Figure 1: Phenological stages observed in citrus species and their cultivars/hybrids in spring flush during period of two years of investigation

Bud Initiation

Sweet Orange
Jaffa

Mandarins
Pearl Tangelo

Grapefruits
Duncan

Pineapple

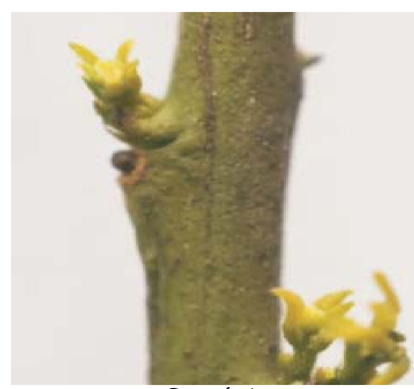
Kinnow

Ruby Red

Bud Break

Sweet Orange
Jaffa

Mandarins
Pearl Tangelo



Grapefruits
Duncan

Pineapple

Kinnow

Ruby Red

Plate1: Glimpses of Bud initiation and bud break in different citrus species

Table 4: The flowering density and fruit set percentages in different citrus species and cultivars during 2014 and 2015

Citrus species	Cultivars	2014 Flowering density (%)	Fruit set(%)	2015 Flowering density (%)	Fruit set(%)
Sweet orange(*Citrus sinensis*)	Jaffa	1.63	46.9	2.44	57.5
	Pineapple	1.81	30.5	3.18	37.5
Mandarin hybrids	Pearl Tangelo	1.42	35.1	2.57	40.5
	Kinnow	1.07	56.2	1.72	72.6
Grapefruit(*Citrus paradisi*)	Duncan	2.63	13.4	2.55	18.2
	Ruby Red	3.86	15.3	6.23	29.9
Mean		2.07	32.9	3.11	42.7
SE(m) ±		0.25	5.02	0.37	4.36
CD at 5%		0.71	14.1	1.06	12.4

a. Leafy inflorescence **b. Non-leafy inflorescence**

Plate 2: Types of inflorescence observed in citrus species and cultivars during 2014 and 2015

respectively on Satsuma mandarin *(Citrus unshiu* Marc. cv. Okitsu Wase). Thakur *et al.* (2008) concluded that early maturing varieties required less heat units than the late maturing varieties. Heat unit requirement differs from place to place for the same variety (Joshi *et al.,* 2015). The variation in the heat unit's requirement with the variation in date of maturity was also reported in Ber (Singh *et al.,* 1998); Mango (Shinde *et al.,* 2001) and Litchi (Rai *et al.,* 2002).

Type of inflorescence

Flowers are borne on short new growth in cymose clusters, with two types of inflorescence *viz*. leafy inflorescence (87.85% and 74.45 % in year 2014-15) in sweet orange cv. Jaffa (Table 3) and leafless inflorescence (59.83 % and 55.93 %) in grapefruit cv. Duncan in 2014 and 2015. Lowest leafy inflorescence per cent was found in grapefruit cv. Ruby Red (55.40% and 60.08% in 2014-15). Least mean per cent leafless inflorescence were counted on Kinnow (9.16% and 13.61%) in both years. Results were in harmony with Iglesias *et al.* (2007) who confirms the dependency of fruit set on type of inflorescence. Leafless inflorescences emerge first and contain a bouquet of flowers with low probability to set fruit. But, flowers in leafy inflorescences associated with higher fruit set (Jahn, 1973). Flowering shoots with a high leaf-to-flower ratio have the highest fruit set (Lovatt *et al.,* 1984) due to increased net CO_2 assimilation and supply of photo-assimilates from developing leaves (Syvertsen and Lloyd, 1994). These might also influence ovary growth and fruit set through the provision of gibberellins since leafy inflorescences contain higher hormonal levels than leafless ones.

Flowering density and fruit set

Higher flower density was recorded in cultivar Ruby Red (3.86%) at par with cultivar Duncan (2.63%) than others in both years i.e. 6.23 % and 2.55 % (2015) (Table 4). This might be associated with ratio of each kind of inflorescence with flowering intensity and cultivars. Leafy inflorescence contains a distinct central xylem cylinder. The vascular area of leafless inflorescence was about one quarter of leafy ones. Thus due to thin stem and more leafless inflorescence, flowering density was found maximum in grapefruits. Whereas mandarin cultivars Pearl Tangelo and Kinnow had significantly lower flowering density (1.42% and 2.57 %) (1.07% and 1.72%) may be because of well-developed vascular bundles and less number of flowers i.e. leafy inflorescence. As a result mandarin per cent fruit set was higher than grapefruits. These results were in conformity with the finds of Erner and Shomer (1996). Sweet orange cultivars were also at par with mandarin in terms of flowering density. The data pertaining to fruit setting in citrus species and their cultivars was given in Table 4.

The per cent of fruit set was significantly higher in cv. Jaffa (56.22 and 72.62%) Sweet orange than other cultivars but it was at par with Mandarin hybrid Kinnow (46.92 and 57.49%). The cultivar Pineapple of sweet orange (13.45 and 18.18%) and Ruby Red of the Grapefruit (15.33 and 29.94%) having lowest per cent of fruit set were at par with each other during both the years of investigation. Fruit set is highly dependent upon the type of inflorescence. Leafless inflorescences had low probability to set fruit. On the other hand, leafy inflorescences had leaves along the shoot thus associated with higher fruit set (Jahn, 1973; Iqbal and Karacali, 2004). It may be due to unavailability of carbohydrates required for fruit growth so false fruit set takes place but as in April-May temperature hiked to peak it get abscised soon (Dalal *et al.,* 2013). Flowering shoots with a high leaf-to-flower ratio have the highest fruit set (Lovatt *et al.,* 1984). The positive influence of leaves on fruit set appears to be associated with increased net CO_2 assimilation and supply of photo-assimilates from developing leaves (Syvestern and Lloyd, 1994).

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