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Bearing behaviour and correlation of fruit development stages with weather parameters in Kinnow mandarin under semi-arid irrigated conditions

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ABSTRACT

The present investigations were carried out with the objective to find the basic understanding of bearing behavior of Kinnow and correlation of fruit development stages with weather parameters. During four years of study, two years were observed as on years (high yield) and two years off years (low yield). There was 20-25 per cent yield reduction in off year. It was observed that during off years, flowering was delayed (19th March) with reduced flowering duration (12 days) and days to form flower (15 days) as compared to early flowering (11th and 14th March) with more flowering duration (15 and 14 days) and days to form flower (18) during on years. No much variation in flowering density was observed in on and off years. Among yield parameters June drop was higher (66.97% and 69.77%) which results in less fruit retention (16.96% and 14.78%) during off years in comparison to less June drop (53.60% and 59.50%) and more fruit retention (21.37% and 19.54%) during on years. Average fruit weight was also less in off years (153.44 and 162.18g) as compared to on years (174.12 and 178.14g). During off years' leaf potassium content was found in deficient range. So, it may be concluded that delay in flowering, more June drop, less fruit weight and deficient leaf potassium content are responsible for low yield in Kinnow during off year. However, no significant involvement of peel content, juice content and residue content was observed. Temperature and pan evaporation were positively correlated with fruit growth parameters (diameter, fresh weight and dry weight) during early fruit growth stage (April-May) and a negetive correlation with mid (June-Sept.) and late fruit growth stages (Oct-Dec). Whereas, Temperature and pan evaporation showed significantly positive correlation with peel thickness during early and mid fruit growth stages and negative during later growth stages.

Key words: *Citrus nobilis* × *Citrus delciosa,* fruit growth, flowering phenology, irregular bearing.

INTRODUCTION

Citrus is the leading tree fruit crop of the world, it is cultured in tropical and subtropical areas as a commercial crop in about 49 worldwide countries Reykande *et al.*(15). Kinnow mandarin *(Citrus nobilis* Lour. × *Citrus delciosa* Tenore*)*,is a predominant citrus fruit of Punjab and Haryana, very efficiently cultivated in the Haryana under arid to semi arid agroclimatric region of the state and ranks first with respect to area and production Mahajan *et al.*(11). The most serious problem in citrus production is reported as alternative bearing which considerably reduces citrus yield. Alternate bearing in citrus trees is a habit of fruiting heavily in one year called the "on-year" and poor yield the second year called the "off-year". Monselise and Goldschmidt (12) defined alteration as a rule and whose degree extremely marked with many of the so-called easy peeling types (*Citrus reticulata, C.unshiu* and hybrids within *C.reticulata* or between the latter and *C.sinensis or C.paradisi*). In some cases, heavy crop load during on years may result in decline and collapse of tree [Jones *et al.*(10); Smith (16)]. Alteration not only reduces yields but the fruits produced are of low value; few very large and coarse fruits are produced in the off-year and numerous small fruits are produced in on-year. Decline of tree as a consequence of overload is extremely undesirable additional result. Various degrees of alteration can be found in citrus species. As a standard rule, seedless cultivars of orange, grapefruit and lemon are regular bearers. Some of these however may alternate to a considerable degree in areas or soils and on rootstock providing less than optimum fruiting conditions.

Outstanding examples of such behavior are 'Valencia' oranges in cool areas of coastal California given by Jones *et al.* (9) and in cool interior areas of Australia by Gallash *et al.* (3); 'Shamouti' oranges under semi-arid conditions, in heavy soils and budded to sour orange stock, in Israel by Monselise and Goren (13); 'Washington' navel oranges in various areas by Goren and Monselise (7).In hotter agroclimatric regions and under more arid locations fruit develop more rapidly in weight, circumference and volume. In arid regions citrus trees are highly prone to heat injury or sun burn, drying of fruit, burning and death of bark and slightly dis-colouration of fruit skin. For instance,

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environmental conditions may influence some or advance stages related to flowering (blooming) and flower development and prevent natural process of these stages El-Otmani (2). Besides, at higher mean temperatures, citrus flower blooms sooner (within short period of time), fruit mature earlier, fruit size gets bigger and acidity level of fruit juice remains low. Deris *et al.* (1) found that the day (maximum temperature) and night (minimum) temperature fluctuations results in better fruit colouration and sugar accumulation. The phenological stages of citrus fruit tree, in fact refers to the relation between weather conditions and previous crop load. Factors related to phenological stages directly or indirectly are influenced by three factors (physiological, chemical and biological) as well as physiological processes of the preceding crop load that may differ from season to season due to difference in climatic conditions or agroclimatric regions and crop load. An adverse weather condition and crop load during the different stages like flowering, fruiting, yield and mineral nutrition throws the economy of the grower/farmer. The knowledge of the prevailing weather conditions and fruiting behaviour over a period of time at a particular site is important to raise Kinnow crops. Different previous studies have been previewed for the correction of alteration by Galliani *et al.* (4); Goldschmidt and Golomb (5) and Golamb and Goldschmidt (6) which deals with carbohydrate and mineral balance and with abscisic acid content. Therefore, keeping in view the inseparable relationship of climate and crop load on phenological stages of Kinnow in this particular semi arid region of country, the present investigation was carried out to investigate the horticultural factors responsible for irregular bearing in Kinnow mandarin and the relation of climatic factors with fruit growth attributes.

MATERIALS AND METHODS

Field experiment was conducted from 2011 to 2014 at experimental orchard, Department of Horticulture, CCS HAU, Hisar, Haryana situated at 29^0 10' N lat.; 75^0 46' E long.; alt. 215.2m. Soil of the experimental site is sandy loam and categorized as semi-arid irrigated with annual rainfall of 450 mm. The maximum rainfall occurs in July-August from South-West monsoon. The meteorological data used for study was collected from Agromet observatory situated at 0.5 km away from the kinnow orchard.

Five representative plants of uniform vigor were selected from a block of one acre Kinnow orchard raised on rough lemon rootstock of 10-year age. Four fruit bearing shoots before flowering were tagged on each tree in all the directions to collect the flowering data. Date of flower bud initiation (FBI) was taken when 5% of flower buds across the block were visible. Days to form flower were counted between dates of FBI to opening of flower. Duration of flowering was noticed between openings of first flower to last flower on each shoot and consequently duration of flowering was calculated. Flower density (FD) was observed by dividing the number of flowers on shoot by the branch cross sectional area (cm^2 BCSA) of the respective shoot and expressed as number of flowers/cm^2 BCSA. Initial fruit set was observed by counting the number of actual fruit formed from total number of flowers per shoot and expressed in percentage. From one-acre orchard 12 uniform plants were selected for collecting the data on yield, quality and nutritional status of the leaf taking one plant as a single replication. June drop and pre harvest fruit drop was observed by counting the dropped fruits from fruit set to end of June and September till harvesting, respectively. Fruit yield was calculated by weighing the harvested fruits/ tree in last week of December each year. Average fruit weight was measured by dividing the total fruit weight by the number of fruits of that tree. Three fruit per plant were collected for analyzing the peel and juice content. The juice and peel was weighed with electronic balance and percentage was worked out on the basis of total weight of fruit and the weight of juice and peel, respectively. Residue (%) was estimated by subtracting peel content and juice content from total fruit weight. For estimation of leaf N, P& K contents the leaves collected just behind the fruit in the month of September and digested in diacid H_2S0_4: $HCIO_4$ in the ratio of 4:1. Nitrogen was estimated with Nesseler's Reagent method and P through Vandomolybdo yellow colour method as described by Jackson (8) and K by Flame photometer as described by Piper (14). On the basis of yield, two years with less yield was considered as off year and two years with high yield as on year and analyzed statistically with independent t-test by taking twelve replications.

Fruit growth and development period was divided into 3-stages as per phenological events appeared in kinnow. Stage-1(April -May): Early fruit growth stage; Stage-II (June-Sept.): Mid fruit growth stage and stage-III (Late fruit growth stage): maturity & ripening period. During these three fruit growth stages (stages I, II & III) data was collected on fruit fresh and dry weight, fruit diameter and peel thickness. For the collection of data on fresh and FDW, and PT two fruits per plant were harvested on each date of observation i.e. 15^{th}& 30^{th} of each month and their fresh weight was observed and then these fruits were cut at the equator into 2-equal halves and peel thickness (PT) was measured at the equatorial line

to right angle at four places with the help of Vernier's caliper and averaged. Then these fruits were cut into small pieces and dried in hot air oven by gradually increasing the temperature to 68°C till the constant weight was achieved. Diameter of the developing fruits were measured by tagging 15 fruit per plant in all directionsduring month of April and diameters of these fruits were measured regularly on each date of observation in two directions opposite to each other with Vernier's caliper and averaged. Fruit growth and weather parameters were statistically analyzed by estimating the correlation coefficient.

RESULTS AND DISCUSSION

Flower bud initiation (FBI) delayed about 10 days during off years as compared to on years (Table 1). Flower bud initiation was observed on 4th and 5th March during 2012-13 and 2014-15(off years) as compared with 22nd and 24th February during 2011-12 and 2013-14(on years), respectively. Days taken to form flower from bud was also reduced by three days in off years than on years (15 days during off years as compared with 18 days during on years). Time of start and end of flowering was also delayed in off years and simultaneously reduced flowering duration. Flowering started on 19th March (during both off years) whereas during on years flowering commenced 7 and 5 days earlier (during 2011-12 and 2013-14, respectively). Similar delay was observed in end of flowering. Flowering ended on 31st and 30th March during 2012-13 and 2014-15 (off years), whereas an early response was observed during on years i.e. 26th and 27th March during both on years (5 and 3 days early in respect to both off years, respectively). The reduced flowering duration might be one of vital reasons for reduced yield parameters as the flowers did not get enough time to complete their cycle in most natural way accumulating healthy reserve for upcoming fruits in early stage of fruit growth due to previous crop load resulting in increased fruit drop and similarly affecting other yield parameters. Flowering density during 2011-12 (on year) was found (31.82/ cm^2 BCSA) significant over succeeding year (28.31/ cm^2 BCSA). However, no effect was observed during 2013-15**.** Therefore, a delay in flower bud initiation, reduced days taken to form flower, delay in start of flowering followed by reduced flowering duration might be considered factors responsible for irregular bearing in Kinnow and may act as an early indicator to identify off years despite relying solely on yield parameters.

Initial fruit set varied significantly during 2011-13 and higher fruit set (55.47%) was observed during 2012-13 over 2011-12 (52.93%), however no significant effect was recorded during 2013-15. June drop was significantly affected and found more i.e. 66.87% and 69.77% during 2012-13 and 2014-15 (off years) in comparison to 53.60% and 59.50% during 2011-12 and 2013-14 (on years) depicting June drop as another vital factor causing irregular bearing in Kinnow. However, pre harvest drop was significantly less in off years as compared to on years i.e. 13.50% and 12.38% during on years (2011-12 and 2013-14, respectively) whereas in case of off years pre harvest fruit drop was recorded at 8.56% and 9.56% (2012-13 and 2014-15, respectively). This might be due to the fact that more fruitlets dropped during June drop in off years leaving behind less fruit drop potential for pre harvest fruit drop. So, it might be concluded that considering June drop as a vital irregular bearing factor instead of pre harvest fruit drop is more scientific and justifiable approach as the later is dependent on the former. Fruit retention was significantly more in on years; 21.37% and 19.54%during 2011-12 and 2013-14, respectively as compared to off years (16.96 and 14.78% during 2012-13 and 2014-15, respectively). This enhanced fruit retention during on years as compared to off years is a culmination and result of all the processes and phenological stages starting from time of flower bud initiation, days taken to form flower, flowering duration, initiation, initial fruit set,

Table 1. Flowering behaviour in Kinnow during on and off years.

Parameters	2011-12	2012-13	(t value)	2013-14	2014-15	(t value)
	On year	Off years		On years	Off years	
Time of flower bud initiation (visible)	22nd Feb.	4th March	-	24th Feb	5th March	-
Days to form flower	18	15	-	18	15	-
Time of start of flowering	11th March	19th March	-	14th March	19th March	-
Time of end of flowering	26th March	31th March	-	27th March	30th March	-
Duration of flowering	15	12	-	14	12	-
Flowering density(nos./cm^2 BCSA)	31.82	28.31	9.80*	31.16	31.26	0.22

*Significant at P <0.01

fruit drop etc. which further effected average fruit weight and yield of Kinnow. Average fruit weight was also found significantly more in on years as compared to off years and values varied from 174.12-178.14 g (2011-12 and 2013-14) and l53.44-l62.18 g (2012-13 and 2014-15), respectively (Table 2). During off years there was about 20-25% reduction in the yield as compared to on years. During on years significantly higher yield i.e. 114.63 kg/tree and 122.53 kg/tree (during 2011-12 and 2013-14, respectively) was observed as compared to fruit yield of 86.52 kg/tree and 98.65 kg/tree during off years (2012-13 and 2014-15, respectively). As far as yield parameter is concerned initial fruit set (%), June drop (%) and fruit retention (%) and fruit weight could be considered factor of immense importance and vital indicator for depicting irregular bearing behaviour in Kinnow.

Leaf nitrogen and phosphorus content was observed in optimum range in all the years under study (Table 3). However, Nitrogen content was found significantly less in off years (2.54% and 2.41% during 2011-12 and 2013-14, respectively) as compared to on years (2.30% and 2.22% in 2012-13 and 2014-15, respectively). Leaf potash content was significantly affected and estimated in deficient range during off years (0.73% and 0.75% during 2012-13 and 2014-15, respectively), whereas, it was in optimum range (1.21% and 1.17% during 2011-12 and 2013-14, respectively) during on years. Reduced leaf nitrogen and potassium content could be suggested as causal factors of irregular bearing in Kinnow. Fruit physical quality in terms of peel content (%), Juice (%) and Residue (%) was not found to be much affected during all the years of investigation (Table 4).

During early fruit growth (Stage I) T_{max}, T_{min} and pan Ep showed significant positive correlation, whereas, RHm & RHe showed significantly negative correlation with the fruit diameter, fruit fresh weight and dry weight and peel thickness (Table 5). T_{min} and Ep was found significantly positively correlated with the FFW (0.85 and 0.82, respectively), FD (0.85 and

Table 2. Yield parameters and yield of Kinnow during on and off years.

Yield Parameters	2011-12	2012-13	(t value)	2013-14	2014-15	(t value)
	On year	Off years		On years	Off years	
Initial fruit set (%)	52.93	55.47	,3.64*	54.40	54.05	0.46
June drop (%)	53.60	66.97	20.23*	59.50	69.77	13.62*
Pre-harvest fruit drop (%)	13.50	8.56	20.26*	12.38	9.56	10.58*
Fruit retention (%)	21.37	16.96	12.42*	19.54	14.78	14.09*
Average fruit weight (g)	174.12	153.44	13.68*	178.14	162.18	10.26*
Yield (kg/plant)	114.63	86.52	28.59*	122.53	98.65	22.33*

*Significant at P <0.01

Table 3. Leaf macronutrients contents in Kinnow during on and off years.

Nutrient content (%)	2011-12	2012-13	(t value)	2013-14	2014-15	(t value)
	On year	Off years		On years	Off years	
Nitrogen (%)	2.54	2.30	6.32*	2.41	2.22	4.41*
Phosphorus (%)	0.13	0.13	0.85	0.14	0.13	2.91
Potassium (%)	1.21	0.73	29.69*	1.17	0.75	39.76*

*Significant at P <0.01

Table 4. Physical quality of Kinnow during on and off years.

Quality parameters	2011-12	2012-13	(t value)	2013-14	2014-15	(t value)
	On year	Off years		On years	Off years	
Peel content (%)	20.67	19.98	1.38	25.44	23.34	2.67
Juice (%)	50.15	49.87	1.94	45.29	47.64	3.57
Residue (%)	29.18	30.15	2.82	30.27	29.02	2.53

*Significant at P <0.01

Table 5. Correlation coefficient of stage wise pooled data of Kinnow fruit growth and weather parameters.

Fruit growth stages	Fruit growth parameters	Temperature		Relative humidity		Pan evaporation
		T_{max}(°C)	T_{min}(°C)	RHm (%)	RHe (%)	Ep (mm)
Stage-I (Early fruit growth) (April- May)	Diameter	0.79	0.85*	-0.54	-0.37	0.82*
	Fresh weight	0.79	0.85*	-0.55	-0.42	0.82*
	Dry weight	0.78	0.86*	-0.52	-0.36	0.82*
	Peel thickness	0.90*	0.88*	-0.78	-0.68	0.91*
Stage-II (Mid fruit growth) (June- Sep.)	Diameter	-0.90*	-0.60	0.87*	0.74	-0.85*
	Fresh weight	-0.85*	-0.65	0.80*	0.67	-0.80*
	Dry weight	-0.84*	-0.56	0.82*	0.67	-0.82*
	Peel thickness	0.89*	0.45	-0.86*	-0.74	0.85*
Stage-III (Late fruit growth) (Oct.- Dec.)	Diameter	-0.64	-0.68	0.73	0.21	-0.76
	Fresh weight	-0.62	-0.71	0.68	0.13	-0.76
	Dry weight	-0.71	-0.75	0.64	0.20	-0.82*
	Peel thickness	-0.75	-0.73	0.49	0.29	-0.76

*Significant at P< 0.05

0.82, respectively), FDW (0.86 and 0.82, respectively) and peel thickness was found significantly positively correlated with maximum temperature (0.90) that might be due to favourable temperature for the photosynthesis activity and fast accumulation of carbohydrate to optimized physiological processes that resulted in more growth by cell division of peel tissues of Kinnow fruit during stage-I.

During mid growth stage (Stage II) T_{max} and Ep were significantly negatively correlated with FD (-0.90 and -0.85, respectively), FFW (-0.85 and -0.80, respectively) and FDW (-0.84 and -0.82, respectively), and significantly positively correlated with the PT (0.89 and 0.85, respectively) whereas, RHm had significant positive correlation with FD (0.87), FFW (0.80) and FDW (0.82) and negative with PT (-0.86). Maximum temperature and pan evaporation showed significantly negative correlation with fruit fresh weight, dry weight and diameter, whereas, significantly positive correlation with peel thickness. During this stage fruit growth takes place due to cell enlargement of juice tissues, require more sink of photosynthates and water. During these month temperature remains higher than optimum which resulted in more energy utilized in respiration and secondly high temperature causes more transpiration rate which adversely affect the sink source and ultimately fruit growth. Similarly, lower rate of sink accumulation in juice tissue exert less pressure on peel tissues resulted in less stretching of peel results in thicker peel.

Similarly, during late growth stage (Stage III) T_{max} and Ep showed negative correlation with fruit diameter, FFW and FDW and PT. RHm positively correlated with FD, FFW and FDW and PT whereas, RHe had non-significantly positive correlation with these parameters. Whereas, pan evaporation showed significantly negative correlation with fruit dry weight (-0.82). During 3rd stage i.e. maturation and ripening processes takes place which require low temperature for colour and quality development. But when temperature is somewhat higher there is more vegetative flush (autumn season growth) at the cost of transferring of reserve photosynthate to the vegetative flush, hence slower growth. Negative correlation of peel thickness to temperature during this stage may be due to slower rate of disintegration of albedo tissue and softening of peel at higher temperature than normal temperature, resulted in thinner peel.

Among the horticultural factors, delayed flowering, more June drop, fruit weight and deficiency of potash in leaf are the factors responsible for irregular bearing in Kinnow mandarin. Temperature and pan evaporation were positively correlated with fruit growth parameters (diameter, fresh weight, dry weight and peel thickness) during early fruit growth stage (April-May) and a negetively correlated during mid (June-Sept.) and later stage (Oct-Dec). Except peel thickness, which showed positive correlation with temperature during middle growth stage.

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