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IMPACT OF SEASONAL VARIATION FLUX ON GROWTH, LEAF PHENOLOGY AND FRUIT DEVELOPMENT IN NAGPUR MANDARIN OF JHALAWAR DISTRICT

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ABSTRACT : It may be inferred that during early bearing phase of Nagpur mandarin, the major contribution of vegetative growth was from spring and rainy season flushes. In the early bearing phase of Nagpur mandarin, the extent of seasonal vegetative growth was maximum in spring flush (45.03%) followed by rainy season flush (42.02%), however, the winter fall flush comprised only scanty flush of the annual vegetative growth to the tune of 10.75% only. Likewise, spring flush leaves exhibited the minimal values of leaf sclerophylly i.e. leaf fresh weight and dry weight, density of foliar tissue and leaf succulence with respect to rainy and winter season flushes inferring that growth during spring season is utilized as a sink for developing fruits. About 72 per cent of the fruit radius was found contributed by peel thickness in I phase of fruit growth. During phase II, fruit growth was found dependent upon increase in pulp tissue thickness contributing about 81 per cent of the total fruit weight. Finally, during III phase of maturity and ripening there was comparatively decreased rate of increase in fruit weight and size and little bit increased rate of dry weight, rind thickness and reduction in moisture percentage.

Keywords: *Nagpur mandarin, seasonal growth, leaf sclerophylly, fruit growth,*

Citrus fruits occupy second position amongst cultivated fruits of India. Being rich source of vitamin C, they are economically important fruit crops of the world which are grown in developed and developing countries for fruits. Amongst citrus fruits; Nagpur mandarin occupies significant position within mandarin group. In Rajasthan state, this variety holds dominion position in Jhalawar district. It is the main cash crop of farmers of the district. In India, citrus fruits are being grown over 9.87 lakh ha area with a total production of 96.38 lakh tonnes having the productivity level of 9.67 tonnes ha^{-1}. Mature citrus trees throughout Central India tend to produce growth flushes at about the same time annually. Three distinct growth flushes appear on the plant coinciding spring (February- March), rainy season (July-August) and winter fall (October-November). Stages of vegetative growth flushes and ontogeny of fruit development are important in view point of adoption of measures of plant protection, irrigation and fertilizer scheduling. There is very scanty literature available on the estimation of foliage growth with respect to season or quantity. Simanton (11) estimated that amount of new tender growth on spring flush comprised 59 per cent of annual growth; however, fall growth was found minor and erratic. The magnitude of differences in different growth flushes are mostly attributed to temperature and soil moisture effect immediately preceding or during the flush period and crop load. In bearing plants with full crop load, the rainy season flush is either minor or less due to sink pressure by vegetative and fruit development. Goldschmidt (5) reported that the annual changes in carbohydrate levels represent a combination of developmental and seasonal trends with the demand exerted by developing vegetative and reproductive sink organs.In fully expanded leaves starch and soluble sugar levels decline and stay low during summer and autumn, because of the heavy demand of developing fruits on the tree. Hence, the gratis utility of adequate foliage to yield and quality of crop is well recognized. Iglesias (7) stated that regulation of fruit growth and development in citrus is an intricate phenomenon which depends upon many internal and external factors that may operate both sequentially and simultaneously. Davies and Albrigo (3) reported that cell enlargement phase in citrus phase persists for 3 to 4 months depending upon cultivar and environmental conditions. Such variations hold importance in view of their implication in commercial trait of the plant. Accordingly, the elements and mechanisms whereby endogenous and environmental stimuli affect fruit growth are being interpreted and this knowledge may help to provide tools that allow optimizing production and fruit with enhanced nutritional value under changing climate scenario. Physical and frictional propterties of fruits as well as

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oranges are also important for designing the post harvest handling and processing machineries (Sayyad *et al.* 10). Keeping in view the above facts, the present study was undertaken. The study intends to explore the data quantitatively on the new foliar growth arising during varying seasonal flushes and fruit development pattern of Nagpur mandarin, which will cater to obtaining required resource input for harnessing maximum output at critical growth stages.

MATERIALS AND METHODS

Plant material and growth conditions

The experiment was conducted during the years 2011 and 2012 at the experimental orchard of Fruit Instructional Farm of the Department of Fruit Science, College of Horticulture and Forestry, Jhalawar, India, located at $23^0 4'$ to $24^0 52'$ N-Latitude and $75^0 29'$ to $76^0 56'$ E-Longitude in South Eastern Rajasthan. Agro-climatically, the district falls in Zone V, known as Humid South Eastern Plain. About 84.22 per cent population of the district is rural whose main occupation is agriculture. Average rainfall in the region is 954.7 mm. Maximum temperature range in the summer is 43^0 - 48^0 C and minimum 1^0 - 2.6^0 C during winter. Rainfall mostly takes place through South-Western *monsoon*. Agriculture and forest lands occupy 73.5 per cent area, respectively in the district. The district has attained premier position in cultivation of Nagpur mandarin orange.

Experimental conditions

The soil of the experimental orchard was low in organic carbon (0.30%), medium in available nitrogen (258.66 kg/ha) and phosphorous (20.83 kg/ha) and high in potash content (286 kg/ha). The experiment was conducted on six years old Nagpur mandarin plants budded on *Citrus jambhirii* rootstock and planted at 6m spacing with uniform cultural practices.

Growth assessment

The active vegetative growth cycle appeared trifurcated into three flushes i.e. spring flush (February-March), rainy season flush (July-August) and winter fall (October-November). The quantitative magnitude of flush growth and trunk diameter was estimated for these three different flushes during 2011. The flush growth from the respective seasons was quantified after growth cessation from the trees and their fresh weight was measured by electronic weighing balance. The trunk diameter was measured 5 cm above the bud union during mid of January, April and September in the next year and trunk growth rate/season was estimated by working out the differences for the spring, rainy and winter fall seasons, respectively.

Physiological parameters of leaf

Twenty physiological mature leaves, three months old per replication were collected from each tree from each season flush and leaf parameters like: leaf area (LA) by Laser Leaf Area Meter (Spectra), leaf fresh weight (FW) and dry weight (DW) per leaf using electronic balance were estimated during the year 2012. The leaves were brought to the laboratory in polythene bags. The leaves were then weighed immediately after harvest to estimate their fresh weight. Then these leaves were oven dried at 72^oC for 48 hours and their dry weight was measured. Leaf physiological parameters {Specific leaf area (SLA = LA/DW: in $cm^2 g^{-1}$, specific leaf weight (SLW= DW/FW x 1000: in gkg^{-1} and succulency {S= (FW-DW)/LA: in mg $H_2O\ cm^{-2}$}. were measured according to the formulae as suggested by Ennajeh *et al*. (4). The experiment was carried out in randomized block design using four replications taking single plant as unit replication.

Fruit development and other parameters

Fruit growth was estimated in terms of incremental fruit diameter, peel and pulp thickness, fresh weight of fruit, dry weight of fruit and moisture content. These attributes were measured from end of April onwards at monthly intervals up to the month of December during the years 2011 and 2012 and the average of these two years data was used for statistical analysis. Fruit diameter was estimated by tagging fruits on four plants i.e four fruits on each plant comprising all four directions of the tree and the same fruits were used every month for measuring diameter by Vernier Calipers. Twelve fruits were harvested on each date of observation and weighed with electronic balance. These fruits were subsequently cut into two halves and peel thickness and fruit peel were measured in horizontal region with Vernier Calipers. Afterwards, fruits were cut into little pieces and oven dried at 52^0C till their constant weight was achieved. Moisture content percentage of fruits was worked out by subtracting the dried weight from fresh weight on fresh weight basis. Two years data of fruit growth was collected and averaged.

Data analysis

Healthy and uniform plants of Nagpur mandarin were selected on the basis of trunk diameter and canopy volume from the experimental block. For growth assessment and leaf physiological parameters, the treatments were replicated four times by taking single plant as unit replication**.** Data were analyzed statistically in a Completely Randomized Design and differences between treatments were considered statistically at $P < 0.05$. All statistical analyses were performed using the Windostat software package (India).

RESULTS AND DISCUSSION

The magnitude of vegetative flush variation amongst different flushes varied significantly in the early bearing phase (Table 1). The magnitude of variation of spring flush was found to be statistically significant and higher (4.55 kg plant^{-1}) over rainy season (4.20 kg plant^{-1}) and winter fall flush (1.02 kg plant^{-1}). The comparative contribution of growth on fresh weight basis was estimated again higher in spring flush (46.57%) followed by rainy season flush (42.98%) and winter fall flush (10.44%) of the total annual growth. Variation in trunk growth rate was found significantly influenced during the different seasons. The maximum growth rate in trunk was found during the spring season (0.57cm) closely followed by rainy season (0.53 cm) and statistically lowered trunk growth rate was observed in winter fall season (0.38 cm).

Table 1 : Seasonal changes in the vegetative growth of Nagpur Mandarin

Seasons	Fresh weight of growths/ plant	Growth on fresh weight basis (%)	Trunk growth rate (% increase in trunk diameter cm/season)
Spring season	4.55	46.57	0.57
Rainy season	4.20	42.98	0.53
Winter fall	1.02	10.44	0.38
CD (P = 0.05)	0.37	4.31	0.07

The cyclic growth is a characteristic feature of woody plants and also that spring flush comprise 59 per cent of annual growth and fall growth was usually minor and erratic. The results of present findings are in conformity to those as reported by Simanton (11). Spring flushes comes up more intensely after dormant period exposure to low temperatures under Northern hemispheres due to resumption of active root growth in the rhizosphere.

There were significant variations in leaf physiological parameters amongst different flushes (Table2.). Rainy season leaves exhibited the maximum leaf area (19.64 cm^2 leaf^{-1}), leaf fresh weight (0.46g) and leaf dry weight (0.18g) which was significantly higher over spring and winter fall flushes. The minimum leaf fresh weight (0.35g), leaf dry weight (0.13g), specific leaf weight (0.007 g/cm^2), density of foliar tissue (371.42 g kg^{-1}) and succulency (0.013 mg H_2O cm^{-2}) was observed from spring flush leaves. Winter fall flush had significantly higher leaf dry weight (0.19g), specific leaf weight (0.013 g cm^{-2}) and density of foliar tissue (463.41 g kg^{-1}), however, succulency was at par with rainy season flush. The higher values of leaf area, leaf fresh weight and leaf dry weight obtained under rainy season might be due to better availability of soil moisture, high relative humidity, low transpiration losses and better mobilization of nutrients. However, minimum values of leaf fresh weight, dry weight, specific leaf weight, density of foliar tissue and succulency obtained under spring flush might be attributed to prevailing higher temperatures at the time of leaf sampling thus favouring rapid transpirational losses owing to the lower values of leaf attributes during spring season. The lower fresh weight, dry weight of leaf during spring season may be explained in the light of the fact that in fully expanded leaves starch and soluble sugar levels decline and stay low during summer and spring, because of the heavy demand of developing fruit and reserve carbohydrates are being utilized to sustain the developing fruits (Goldschmidt, 6). He also reported that citrus trees are “source-limited” and that the availability of photosynthate restricts their growth and development. The spring flush, soon followed by floral development, anthesis, and fruit set, demands large amounts of photosynthate for organ growth as well as for high rates of respiration. The persistence of the previous year’s foliage in citrus undoubtedly plays a critical role in provision of photosynthate during the emergence of the spring flush, at least prior to full expansion of the

Table 2 : Seasonal changes in the leaf sclerophylly of Nagpur Mandarin.

Seasons	Leaf area (cm^2/leaf)	Leaf fresh weight (g)	Leaf dry weight (g)	Specific leaf area (cm^{2}g^{-1})	Specific leaf weight (gcm^{-2})	Density of foliar tissue (gkg^{-1})	Succulency (mg H_2Ocm^{-2})
Spring season	16.79	0.35	0.13	129.15	0.007	371.42	0.013
Rainy season	19.64	0.46	0.18	109.11	0.009	391.30	0.014
Winter fall	14.36	0.41	0.19	75.57	0.013	463.41	0.015
CD (P=0.05)	1.181	0.043	0.047	4.75	0.002	14.37	0.003

new leaves (Shimizu *et al*., 9). High specific leaf area under spring season might be due to decreased density of foliar tissue of spring season flush. Similar findings are reported by (Dalal *et al*., 2) in Kinnow mandarin.

Fruit growth was measured periodically as fresh fruit weight, dry weight, moisture content, fruit diameter, peel and pulp thickness. Growth and development of citrus fruit follows a typical sigmoid growth curve, divided into three clear-cut stages (Bain, 1). A fruit diameter growth was rapid up to August and then progressively slows down till the harvest. The initial phase, or phase I, is an approximately two-month interval of cell division and slow growth including the period between an approximately two-month interval of cell division and slow growth including the period between anthesis and June drop. During initial stage in April month, peel thickness was highest in the month of April contributing approximately about two-thirds of the fruit radius (70.2%) while it got declined rapidly in July (38.9%). However in the month of September it was found drastically reduced to 2.61mm followed by increase in peel thickness reaching 3.52mm at maturity. The contribution of pulp tissue during April month was only 29.4% followed by a fast increase in pulp tissue thickness during months of May and June contributing approximately 69.18% and 81.48%, respectively of the fruit radius. Thereafter, the pulp tissue increased with a linear decreasing rate continuously up to fruit maturity. From September onwards, there is a very slow increase in pulp tissue growth up to December month. In Nagpur mandarin just after fruit set in the month of March end, initially for one month up to April, the increase in fruit diameter might be primarily due to increase in peel thickness and subsequently increased in fruit size may be due to increased pulp tissue. This may be chiefly due to increase in cell division during early stages leading to increase in peel tissue thickness. Thereafter, in the rapid growth period (phase II) fruit experiences a huge increase in size by cell enlargement and water accumulation during four to six months. Therefore, developing fruitlets become sinks during the cell division period and act rather as storage sinks during

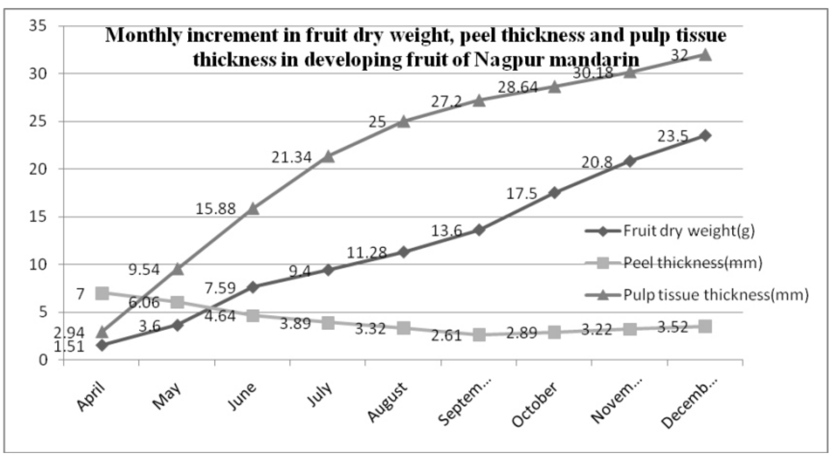

Fig.1. Average data of two years 2011-2012.

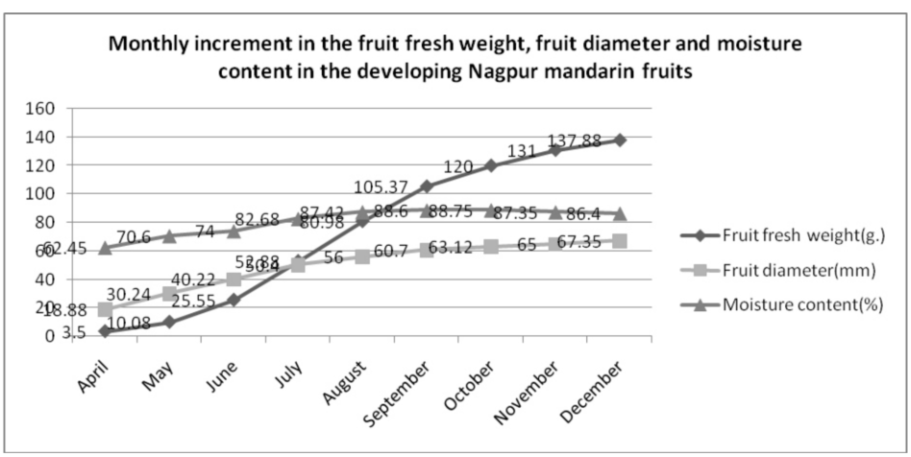

Fig. 2. Average data of two years 2011-12.

phase II (Mehouachi *et al*., 8).The decrease in peel thickness from May onwards may be due to the accelerated growth of the pulp tissue and development of juice sacs which stretches the peel tissue. Finally, in phase III or ripening period growth is mostly arrested and fruits undergo a non-climacteric process.

Fresh fruit weight and dry weight increased steadily up to maturity and harvest. Fresh fruit weight increased rapidly from May onwards to October and then the rate of increase was slow increased up to December. The graphical trend as depicted in Fig. 1 clearly reveals that dry weight gained rapidly up to June month followed by a comparatively slow increase in July, August and September months. Subsequently, rate of increase in dry weight was faster in October, November and December months. Moisture content of developing fruits increased progressively up to August, followed by little upsurge in September-October months and thereafter declining trend was noted up to harvest. Increased fruit weight might be attributed to increase in cell division and cell enlargement favouring continued formation of juice sacs during stage I. Growth of juice sacs during this phase might be primarily due to cell division. However, most of the volume of growth that occurs in Stage I might be due to peel growth. During the early parts of Stage II, the peel grew in thickness. The demarcation between stages is not abrupt, but Stage II had characteristic of very rapid growth and gain in fresh fruit weight from June to September months as depicted in Fig.2.

A similar finding has been reported by Bain (1) in Valencia orange. During maturation period i.e. Stage III, volume of fruit growth continues as long as the fruit remain attached on the tree but rate of growth was considerably lower than Stage II.

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