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Studies on fruit growth and development in Daisy tangerine

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ABSTRACT

The changes in physical and biochemical characteristics during fruit growth and development of 'Daisy' tangerine was studied under sub-montane region of northern India. Fruit size and weight substantially increased throughout the fruit maturation period and single sigmoid curve was observed when fruits were harvested at 15 day intervals starting from 150 to 240 days after fruit set (DAFS). Final fruit length 63.0 mm, diameter 68.9 mm, weight 178.3 g, juice 46.8%, TSS 11.8°Brix and TSS/acid ratio 16.8 was attained after 210 DAFS or 10th November and thereafter decline in majority of fruit characteristics was observed with the delay in fruit harvesting. Increase in chroma (C^*) coordinates and decrease in hue angle (θ) denoted chlorophyll degradation, which was substantially continued up to 240 DAFS and finally fruits developed orange peel colour. It is concluded that 'Daisy' tangerine must be harvested at physiological maturity between 195 to 210 DAFS at the best fruit size, weight, juice per cent and maximum values for total soluble solids, TSS/ acid blend, and ascorbic acid juice content and minimum titratable citric acid.

Key words: Daisy tangerine, fruit development, growth.

INTRODUCTION

Citrus fruits, belongs to the genus *Citrus* of the family Rutaceae comprising of sweet oranges, grapefruits, mandarins, lemons, limes *etc*. are the most important fruits of tropical and sub-tropical regions of the world. It is well documented that South-East Asia is the primary centre of origin and many *Citrus* species are recognized for their distinct fruit size, colour, flavour, phyto-chemicals, therapeutic and nutraceutical properties. The diversity found in various nutritive and medicinal properties significantly influences the socio-economic status of local population as this provides livelihood, and also nutritional security. They are grown commercially in more than 50 countries around the world due to conducive agro-environmental conditions. India ranks fourth worldwide after Brazil, USA and China in terms of total area and production under citrus crop and have a share of about 4.6% globally in the total fruit production from cultivated area of 1.07 m ha with 11.1 mt annual fruit production (Anon, 2). The major citrus growing states in the country are Andhra Pradesh, Maharashtra, Madhya Pradesh, Punjab, Gujarat, Rajasthan, Karnataka, Assam, Odisha and Haryana and these states contribute about 71.1 per cent of the total citrus production.

Kinnow, a hybrid between King (*C. nobilis* Lour.) × Willow Leaf (*C. delicosa* Tenore) is an important fruit crop in Punjab. Its share is about 95.0% in the total citrus fruit production in the state from an estimated area of 47,101 ha with annual production of 1.01 m MT and productivity of 21.6 MT/ha (Anon, 2). The area under Kinnow cultivation is escalating due to precocious bearer, high yielding, aromatic flavour and good lucrative returns for the last two decades in the northern India particularly in Punjab, Haryana, foothills of Himachal Pradesh and J&K; and parts of Rajasthan. The cultivation of Kinnow to the large extent in the region has created the problem of glut in the market as fruit matures between Ist fortnight of January to mid-February. Punjab Agricultural University has released 'Daisy' tangerine an early season cultivar for the general cultivation in the Punjab after their evaluation to come across the demand for early maturing citrus cultivars. 'Daisy' tangerine, a cross between Fortune mandarin × Fremont mandarin named by Mr Dowling Young of Young's Nursery, California (USA) has extremely attractive fruit with deep orange colour, sweet taste, higher nutritional properties, low number of seeds per fruit and ripens in the month of November.

The fruit development period from flowering to fruit maturity is a complex process and various physiological changes occur during cell division, cell differentiation and cell growth significantly convert a small citrus ovary into a fruit of considerable economic value within a time period. The harvesting of citrus fruits at optimum maturity is highly desirable to maintain the fruit quality and consumer acceptability due to non-climacteric nature. Fruit colour is an important maturity indices and L^*, a^* and hue angle coordinates are the best parameters to categorize

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different maturity stages and for standardization of fruit harvesting time. The information pertaining to the physico-chemical changes in 'Daisy' tangerine at different stages of maturity and ripening is not available. It is therefore, a comprehensive study was carried out to understand fruit maturation in 'Daisy' tangerine under sub-tropics of North India.

MATERIALS AND METHODS

The present investigation was carried out at the orchard of private fruit grower in village Chaunni Kalan, district Hoshiarpur situated at 296 m above mean sea level. Ten uniform five-year-old 'Daisy' tangerine plants budded on Carrizo rootstock; spaced at 6 m × 6 m and maintained under uniform cultural practices were selected at different locations in the orchard. Fruits were tagged at post-anthesis phase on all four sides of the selected plants immediately after fruit set. Twenty fruits were collected at different maturity stages starting from 10th September (150 DAFS) to 10th December (240 DAFS) at 15-day intervals for the estimation of various physico-chemical attributes, *viz*., fruit weight, fruit size (length and diameter), peel weight, total soluble solids (TSS), juice acid content, TSS/ acid ratio and vitamin C. These parameters were estimated as per the standard procedures suggested by AOAC (1). Fruit size (length and diameter) was recorded with the help of digital Vernier calipers (Mitutoyo, Japan) and average fruit weight with electronic precision calibrated scale. Fruit juice on the basis of fresh weight was extracted from the pulp after squeezing and straining through muslin cloth under aseptic conditions. The juice obtained was measured and juice per cent was determined from the volume of the juice divided by fruit weight and multiplied by 100. Fruit peel colour was randomly measured on two opposite sites at fruit equator using Colour Flex spectrophotometer (Hunter Lab Color Flex, Hunter Associates Inc., Reston, VA, USA) expressing L^*, a^* and b^* colour values. Where 'L^* is lightness coefficient, *i.e.* '0' is black or total absorption at the bottom and '100' is white at the top; 'a^*' represents green and redness chroma perception as the value increase from negative to positive and '$+b^*$' represents 'yellowness'. These values are used to calculate hue angle (θ) [$\tan^{-1}$ (b^*/a^*)]; where 0° = red purple, 90° = yellow, 180° = bluish-green and 270° = blue and chroma ([$C^* = a^{*2} + b^{*2}]^{1/2}$), depicts the intensity or colour saturation (McGuire, 8). Total soluble solids (TSS) were recorded by digital hand refractometer (Atago, Japan) after making subsequent corrections at 20°C. Fruit juice acid content in term of citric acid was estimated by titrating 5 ml juice against N/10 NaOH solution using 0.1 per cent phenolphthalein solution as an indicator. Ascorbic acid (vitamin C) content was determined by using 2,6-dichlorophenol indophenol dye method AOAC (1). The data were analyzed with SAS software version 9.3 (SAS Institute Inc., Cary, NC, USA) using one-way analysis of variance. The differences between the means were tested using the least significant of differences at 5% level.

RESULTS AND DISCUSSION

The results pertaining to changes in physical growth parameters of Daisy tangerine during the different fruit development and growth stages are presented in Fig. 1 (a,b). Fruit growth (length, diameter and weight) had shown appreciably increasing trend throughout the fruit development period from 10th September (150 DAFS) to 10th November (210 DAFS). The fruits approaching physiological maturity showed comparatively slow growth rate, which ultimately confirmed that fruit development had taken place up to 210 DAFS under sub-tropical conditions of Punjab. Maximum fruit length (63.0 mm), diameter (68.9 mm) and weight (178.3 g) were recorded on 210 DAFS. Growth pattern of Daisy fruit followed a linear trend upto 210 DAFS and slightly declined in fruit size and weight thereafter is might be due to loss of water from fruits through transpiration (Patel *et al*., 9). The increase in fruit length, diameter and weight due to occurrence of cell division in the early stages and cell enlargement in the later stages of fruit growth as reported by Singh *et al*. (10), while studying fruit development in Kinnow mandarin under north Indian climatic conditions. Fruit size (L × D) and weight had attained maximum marketable acceptability when these were harvested between 195-210 DAFS; furthermore fruit physical characteristics were noticeably decreased if harvesting period was extended up to 10th December (240 DAFS) but the results obtained during last two harvesting periods were statistically non-significant with each other. It is also cleared that distinctly linear exponential fruit growth was observed between 150 and 195 days after fruit set and later on to some extent at a slow pace but increased in fruit growth was noted until 10th November. Fruit length (R^2 = 0.83) and fruit weight (R^2 = 0.75) were correlated with fruit maturation and values indicate that variation of 83 and 75% in data can be interpreted by the change in fruit length and fruit weight, respectively. Similar results were also reported by Josan *et al*. (5) who studied fruit growth and development in 'Wilking' mandarin under arid irrigated zone of north India and observed that fruit length, diameter and weight had shown three distinct phases and formed a sigmoid curve. The initial and second period of fruit development represents the period of cell division and cell enlargement due to accumulation of carbohydrates in later stage of growth (Coombe, 3);

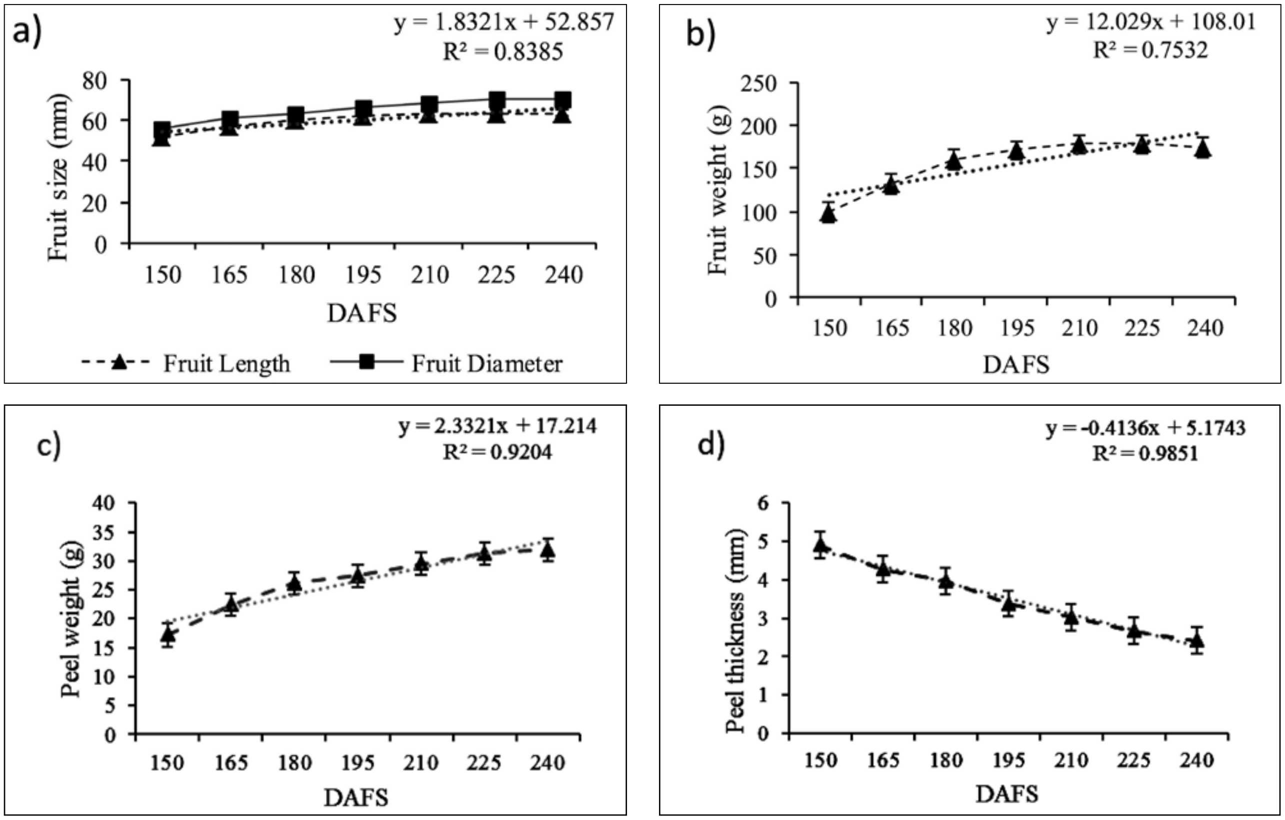

Fig. 1 (a-d). Seasonal changes in exogenous parameters during fruit developmental stages of Daisy tangerine. Vertical bar represents ± SE. R^2 indicates the least significant difference test at P<0.05.

and slow growth near to physiological maturity was attributed to the fact that fruit already had acquired the metabolites to its full capacity.

A linear and significant increase in peel weight with fruit development was observed up to 210 DAFS and subsequently, non-significant augmentation in peel weight was noted till the last date of fruit harvesting, *i.e.*, 240 DAFS. This increment in peel weight is due to increase in fruit size and weight during maturation is related to peel growth. It is clear from Fig. 1 that peel thickness decreased significantly from 150 DAFS (4.90 mm) to 240 DAFS (2.42 mm). These results are corroborated with the findings of Ladaniya and Mahalle (7) that peel thickness decreased from 180 to 250 DAFS in Mosambi sweet orange fruits growing under central Indian conditions. The gradual and significant increase in fruit juice content from 38.0 to 46.8% was observed with the fruit maturation. The increase was rapid up to 195 DAFS and later slow growth rate in fruit juice proportion was observed at 210 DAFS. Subsequently, a drastic reduction in juice content to the tune of 36.7 per cent was observed at 240 DAFS. Loss of water from juice and breaking down of polysaccharides to monosaccharides during later stages could be the reason for the reduction in juice content. A strong correlation between fruit juice per cent with different fruit developmental periods was observed (Fig. 2a) and these results are in confirmatory with the findings noted by Singh *et al.* (11).

The TSS contents during the initial period of fruit development, *i.e.* 150 DAFS were minimum (7.77°Brix) and increased gradually up to 210 DAFS; ultimately attained maximum value of 11.8°Brix; thereafter it was decreased with the delay in fruit harvesting. The increase in TSS content during the development processes is the effect of starch degradation and metabolic transformation in soluble sugars in the fruits as polysaccharides during later stages of harvesting. Similar results were also reported by Singh *et al.* (10) in Kinnow where they reported that TSS increased with the advancement of fruit maturity. Young fruits contain more juice titratable acid (TA) and pH content might be attributed to the improvement in biosynthesis of organic acid; however, TA declined throughout maturation due to their conversion to sugars. Juice citric acid content of 0.60 per cent was observed when fruits were

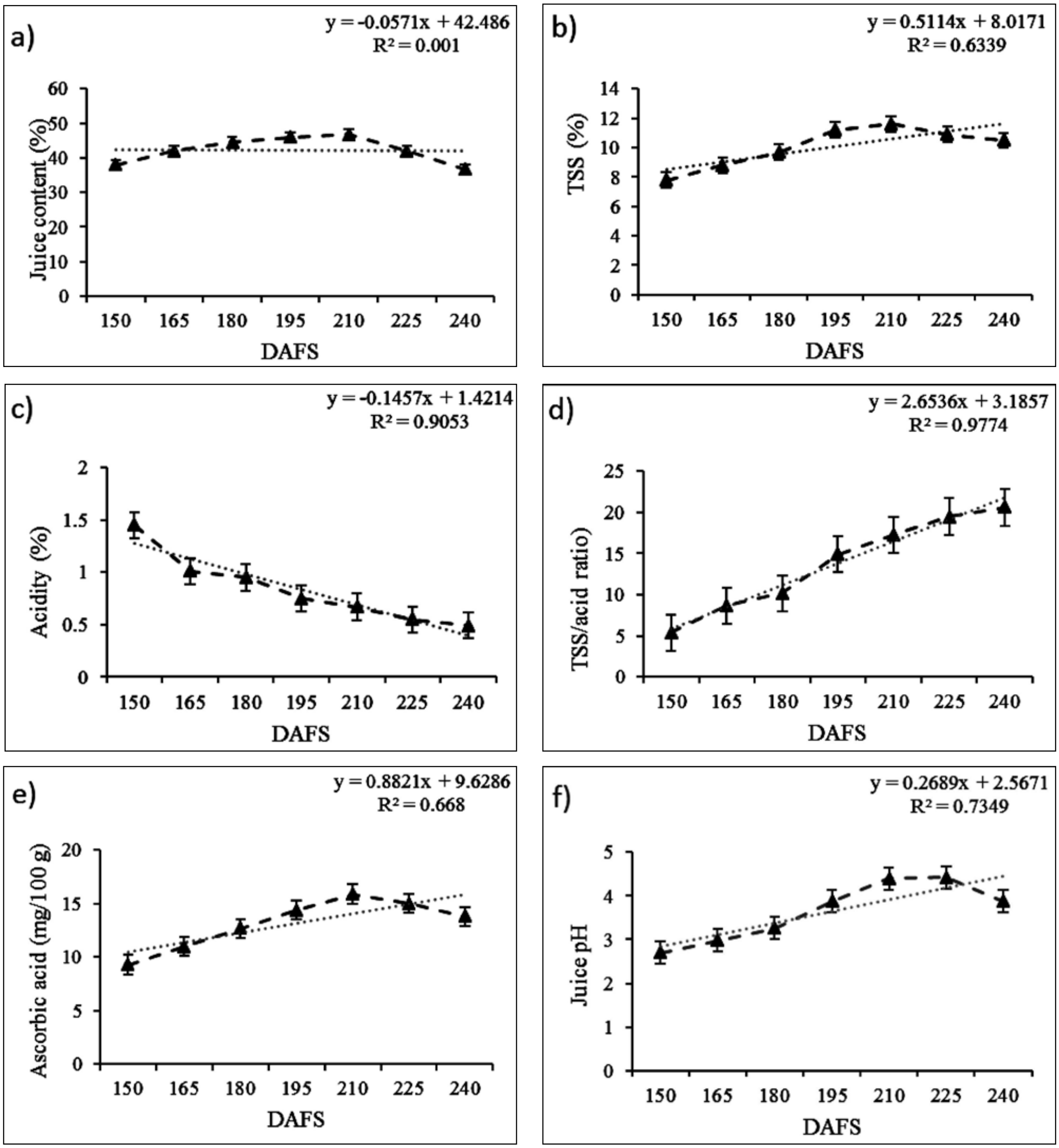

Fig. 2 (a-f). Seasonal changes in biochemical parameters during fruit developmental stages of Daisy tangerine. Vertical bar represents ± SE. R^2 indicates the least significant difference test at $P<0.05$.

harvested on 225 DAFS as compared to 1.45 per cent at 150 DAFS. The increase in total soluble solids to acid ratio was due to soluble solids accumulation and decrease in organic acids. Similar increase in TSS/acid ratio with delayed harvesting was observed by Ladaniya (6) in Nagpur mandarin, though the increase was non-significant. The decrease in titratable acidity was considered to be due to dilution as fruit increased in size and enhancement in juice per cent content. A decrease in the concentration of acid with the gradual increase in the ratio of TSS/acid determines the optimum fruit maturity and their palatability. Ascorbic acid content increased and decreased with the delay harvest might be attributed to an oxidation of ascorbic acid. The increase in ascorbic acid content is related to adequate supply of sugars due to photosynthetic activity and synthesis of ascorbic acid from hexose sugars. Similar results were also reported by Dubey *et al*. (4) in Khasi mandarin under Meghalaya conditions.

Fruit colour is a non-destructive method used to determine reliable maturity indices in citrus fruits. The fruit peel colour was gradually improved over the period from green to orange and significantly increased in values for L^*, a^*, b^*, C^* coordinates and decreased in hue angle (θ) between yellow to red region in a colour wheel of 360° was observed when fruits were harvested at different stages. Regression equations for the prediction of fruit maturity based on chroma and hue coordinates (Fig. 3 a-e) confirmed that there exist highly significant ($p < 0.05$) correlations

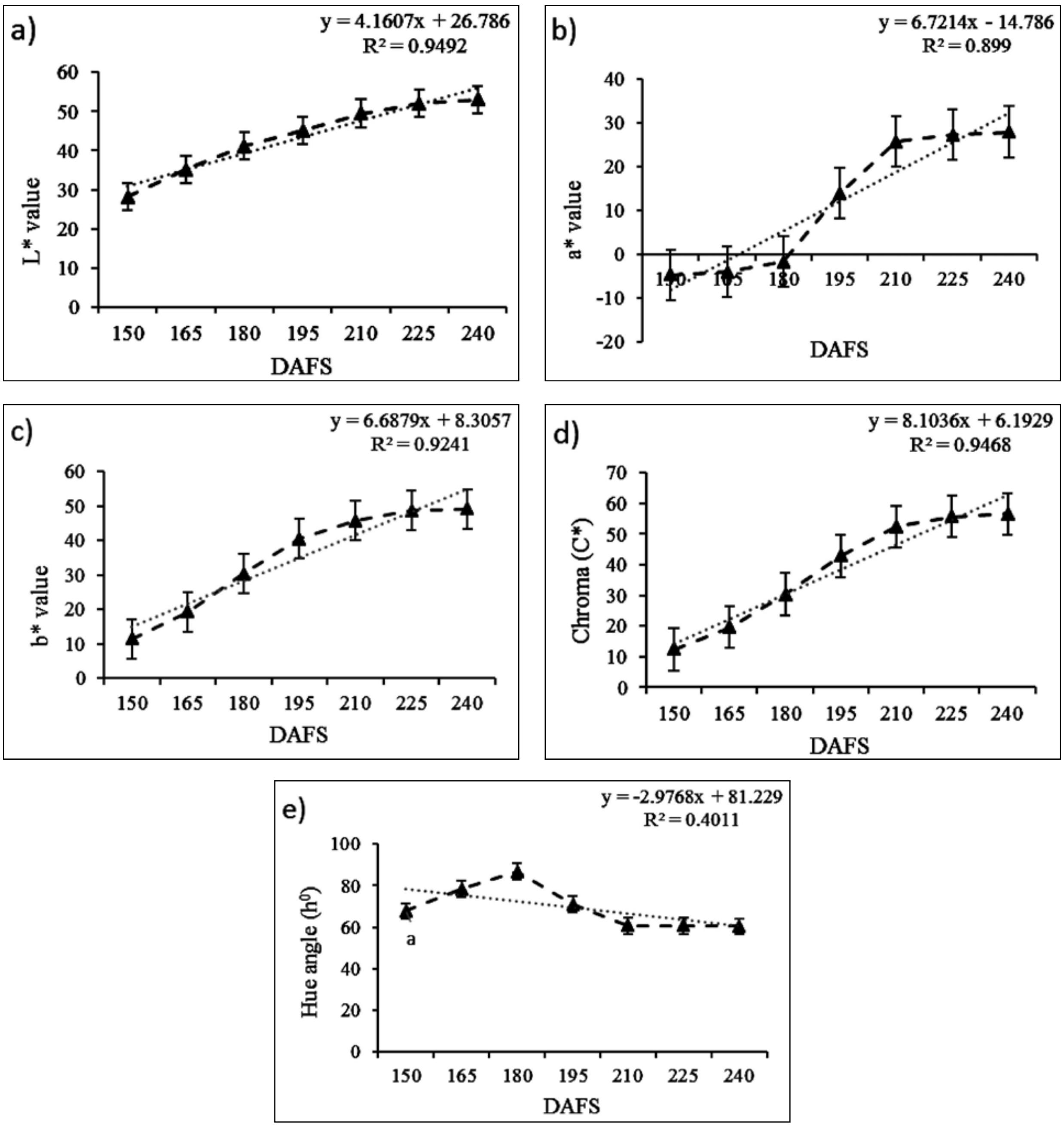

Fig. 3 (a-e). Seasonal changes in peel colour parameters during fruit developmental stages of Daisy tangerine. Vertical bar represents ± SE. R^2 indicates the least significant difference test at P<0.05.

between peel coordinates with fruit development. Similar results were also observed by Xie *et al*. (12) who reported that red peel colour of sweet orange 'Tarocco' is due to chlorophyll degradation and accumulation of anthocyanin pigments in peel. It is concluded that changes in the physical and biochemical composition of Daisy tangerine fruits take place during fruit growth and development process and suggested that time of harvesting is between end October to Ist fortnight of November under sub-montane zone of north India.

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