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STUDIES ON THE SEASONAL VARIATION OF MAJOR ELEMENTS DURING FRUIT DEVELOPMENT STAGES AND EVALUATION OF POST-HARVEST CHANGES IN MANGO GERMPLASM

Sana Rashid[1], Laiba Ali[2*], Akasha Saleem[3], Khadija Ummer[2], Iram Nisar[2], Farooq Ahmed[2], Muhammad Ahmad Ali[4] and Ishrat Fatima[5]

[1]Institute of Horticultural Sciences; [2]Institute of Soil and Environmental Sciences; [3]Department of Chemistry; [4]Department of Agricultural Extensions, Education and Rural Development, University of Agriculture, Faisalabad-38040, Pakistan
[5]Department of Chemistry, Government College University, Faisalabad-38000, Pakistan

**Corresponding author*: laiba.ali204@gmail.com

ABSTRACT

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae and is one of the important fruits grown and consumed all over the world. Presently it is grown on an area of 173.8 thousand ha with 1.85 million tones production in the country. The production area and the fruit production season influence the composition of nutrients, especially carotenoids, ascorbic acid, flavonoid, and thiamine. Seasonal variations, also known as seasonality, refer to alterations in behavior, biological rhythms, physiology, and more, prompted by cyclic shifts in the environment caused by the changing seasons. The fruit quality, vegetative growth, reproductive growth, and yield depend on the proper nutrition of trees. Analyzing leaves plays a pivotal role in determining the nutrient requirements of mango trees, as the roots may face challenges in absorbing adequate nutrients from the soil. The research was planned to study the seasonal variation of major elements during fruit development stages and then evaluate the post-harvest changes in mango. Sixteen mango varieties were selected for the evaluation, and the collection of leaves was done every month from the marble stage to the harvesting for one year. Fruits were harvested at four distinct developmental stages, and an examination of biochemical properties such as superoxide dismutase (SOD), peroxidase (POD), Catalase (CAT), and others was conducted. Leaf essential macro elements (N, P, and K) were also assessed. Data were analyzed by Statistics 8.1 statistical software and means were compared by Tukey's significant test. The texture of all varieties was found to be smooth at first morphological stage. Malda, Keittn (SSI), Collector, Temora, and Zaafran exhibited a rough texture during observation. Among the varieties studied, Chaunsa SB, Tommy Atkin, and Rohi Raat displayed a more pronounced fruit aroma compared to others. Swarnerka, Keitt, and Pohi Raat exhibited notable color characteristics at the time of harvesting. Catalase in selected mango varieties showed the highest value in Malda. Hydrogen peroxide was highest in Zaafran. Malondialdehyde showed maximum value in Chaunsa SB. Peroxidase dismutase showed the maximum value in Chaunsa Lahori (8.50mg/g protein). Superoxide dismutase showed maximum value in Swarnerka. Titratable acidity was notably higher in Pop (13.53%) and Langra (11.25%) but lower in Chaunsa Lahori and Tommy Atkin (3.83%). In summary, the findings underscore the significant influence of each morphological stage on the various parameters studied.

***Keywords*: Mango germplasm, Seasonality, Biochemical Macro-Elements, Nutrient Composition, Post-Harvest Variations, Developmental and Morphological Stages

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1. INTRODUCTION

Mango (*Mangifera indica* L.) belongs to the family *Anacardiaceae* and is one of the important fruits grown and consumed all over the world. It is considered the king of fruits and among the tropical fruits of the world, it occupies the second position due to its excellent aroma, delicious flavor, and high nutritional profile. Moreover, contains essential vitamins, minerals, antioxidants, and phenology (Singh et al. 2016). Its origin was dated back to India (Mukherjee 1972). The origin of cultivated mango is in the Assam Burma region. (Singh et al. 2016). The largest producer of mango is India, whereas Pakistan stands 4th in line for the production of mango, globally (Murtaza et al. 2020). In 94 countries it is commercially cultivated. The area under cultivation of mango in the world is 5681310 ha, whereas the production was 50649147 tonnes (FAO 2017).

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In export fresh mangoes have got remarkable potential and every year contributes to international trade. Mango production is grown on 63% of the land in Punjab, which accounts for 75% of total mango production, and 37% of the land in Sindh, which accounts for 25% of total mango production in Pakistan. The primary areas of intervention include the enhancement of the value chain, the improvement of quality and yield through improved varieties, a decrease of losses through improved comprehensive pest and disease management (FAO 2023).

Different kinds of phytochemicals *e.g.,* quercetin, beta-carotenoids, and astragalin. Yellow and orange fruits contain beta-carotene-a pigment. This pigment is converted to Vitamin A, which is useful for keeping healthy vision along with skin and neurological functions. Quercetin is also found in mango that helps kill cancer cells, prevent heart issues, reduce inflammation, and control blood sugar. One of the compounds "astragalin" used for curing cancer, inflammation, ulcer and diabetes has been reported to be found in the mango for medicinal purposes. A minimum quantity of citric, malic, and tartaric acid is also present in them. All the parts of trees have some pharmacological activities. Different diseases can also be cured with mango including anti-diarrheal, syphilis, dysentery, and urinary and analgesic disorders (Khan et al. 2017).

Seasonal variations or seasonality are the changes in behavior, biological rhythms, physiology, etc. that occur due to periodic variations in the environment due to the passage of the reasons (Zafar et al. 2023; Rehman et al. 2023). The four developmental stages of mangoes are the marble stage, pre-stone stage, stone hardening stage, and pre-harvesting stage in which there are major elements that have different concentrations. (Ambuko et al. 2006). Fruit developmental stages evaluation from flowering helps in the determination of maturity and harvest indices (Matarazzo et al. 2013). The number of indices evaluated during development is based on shape, diameter, color, soluble solids, and Titratable acidity (TA), (Biale 1964). The morphological indices of mango are mostly based on shape and appearance which can be seen visually without using other parameters i.e. color (Filgueiras et al. 2000). Changes in structure, physiology, and biochemical traits are regarded as the developmental stages of fruit. The ripening of mango is marked by pulp softening, change in the color of pulp and skin, reduction in bitterness and flavor, and aroma development in fruit (Chitarra and Chitarra 2005).

The problems regarding mango cultivation include the environmental factors which ultimately affect the major nutrients of the fruit at the post-harvest level. These environmental factors include temperature, light, humidity and rain pattern, etc. among these environmental factors quality of traits is also influenced due to the biotic factors that include Mango Anthracnose as well as Mango fruit fly (Prakash and Srivastava 1987; Pena et al. 1998). The production area and the fruit production season influence the composition of nutrients, especially carotenoids, ascorbic acid, flavonoid, and thiamine (Silva et al. 2008). The change in temperature through the production of fruit period has a significant influence on the proportion of growth and development of fruits by affecting the concentration of mineral absorption through the soil (Austin et al. 1999). Quality as well as the post-harvest traits can be affected significantly due to these factors (Ambuko et al. 2006).

Qualities and properties are influenced because of the maturity of the fruit after harvesting it (Crisosto 1996). The target market is the major factor influencing the stage of maturity at which the fruit will be harvested. The early stage of maturity is preferred for distant markets e.g. international and regional markets (HCDA 2010). Fruit developmental stages are influenced by environmental conditions and these conditions ultimately affect the components of tree, leaves, and fruits (Ambuko et al. 2006).

2. MATERIALS AND METHODS

The study was conducted on 14 to 16 years old tree's fruits and leaves of different mango cultivars at Square # 32, Institute of Horticultural Sciences, University of Agriculture, Faisalabad will be selected for physical and biochemical assessment during the 2019-2020 growing seasons.

2.1. Plant Material

The following 16 mango cultivars were selected: Langra Anwar Ratool, Neelam, Swarnerka, Maya, Malda, Sobhi-di-Ting, Keitt (SSI), Chaunsa Lahori, Chaunsa SB, Tommy Atkin, Pohi Raat, Pop, Collector, Temoria, Zaafran. Fruit after collection, decapped with 1% lime solution, dried under shade, packed in corrugated board boxes, and transported to the Post harvest Research and Training Centre, Institute of Horticultural Sciences, University of Agriculture Faisalabad using. Thus, one of the essential solutions for meeting human dietary demands is to preserve fruit quality and prevent losses during post-harvest (Bambalele et al. 2021).

2.2. Ripening Storage Conditions

Treated and untreated mangoes were stored and/or allowed to ripen either at ambient temperature at 14±1°C; or 80-85%. The fruit was considered ripe when they reached the eating soft stage and /or the skin color was more than 75% yellow.

2.3. Data Collection

Data regarding Major elements in fruits during four developmental stages (Marble, Pre-stone formation, Stone hardening, and Pre-harvest) and leaves after every thirty days and Fruit (size, weight, texture, aroma, color), Seed

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(shape, size, weight, flavor, and quality of fiber on seed), Peel (thickness, weight, color, and surface), Stone (size, weight, length, and width), Pulp (weight, color, and taste), Total soluble solids (˚Brix), Titratable acidity (%), TSS: TA, Vit–C (ml of juice), Superoxide dismutase (mg/mol protein), Peroxidase dismutase (mg/mol protein), Catalase (mg/mol protein), Malondialdehyde (g/mol DW), Total soluble protein (mg/mol DW), Hydrogen peroxide (g/mol DW) were determined at fully ripe stage (eating soft).

2.4. Major Element Detection

2.4.1. Leaf Sample Collection: Healthy, disease-free, and mature leaves with 4-7 months of age were selected for nutrient analysis. About 40 leaves from each variety were collected and packed in labeled porous paper bags and transferred to Pomology Lab IHS, UAF.

2.5. Preparation of Leaf Samples

Leaves were washed after washing, leaves were kept under shade for 48 hours until free moisture was evaporated. Leaves were placed in an oven at 60 ℃ for 48 hours for complete removal of moisture contents. Then leaves were brought out from the oven and ground. The ground fine powder was kept for storage for further analysis in airtight labeled plastic bottles at room temperature.

2.6. Estimation of Total Nitrogen

To estimate total nitrogen contents in leaves, a method devised by Chapman and Parker (1961) was used that includes assimilation of plant material (leave powder) with digestion mixture and concentrated sulfuric acid. The digestion mixture contained copper ferrous and potassium sulfate in the proportion of 10:0.5:1.1g of oven-dried leaf sample along with 10g digestion mixture and 30mL concentrated sulfuric acid was shifted to digestion flask. This sample was restrained for about half an hour and then warmed gradually followed by a full heating unit light color greenish liquid material was obtained. Thus, this light-colored liquid greenish material was cooled and shifted in a 250mL flask and distilled water was added. 10mL was obtained from the aliquot and distilled by using micro-Kjeldahl apparatus with 10ml 40% Na-OH, NH_3 vapors were collected in a beaker with 10mL 4%H_3BO_3 and thoroughly combined with methyl red and bromocresol green indicator. The distilled solution was titrated against N/10 concentrated H_2SO_4 when the color of that distillate was changed from light pink to light green. This process continued until the actual color of methyl red was re-established.

2.7. Wet Digestion of the Elements Excluding Nitrogen

A wet digestion strategy is used to estimate the components of other than nitrogen. Wet digestion was performed by the method proposed by (Yashoda et al. 2007). For this method, 1g oven-dried ground leaves were taken in a 250mL flask along with 10mL concentrated nitric acid. Watch glass was used to cover the flask and kept the sample for about 30min. After that, heating of the samples was done on a hot plate until the material in the flask completely vanished. Then samples were cooled and 5mL of perchloric acid was mixed into all samples and samples heated again till the point when colorless material was obtained. The sample volume was decreased to 1mL and cooled down and shifted in a flask of 100mL and was made up to the mark with distilled water. The filtrate was stored in airtight plastic bottles to perform further analysis.

2.8. Phosphate Estimation

Chapman and Parker (1961) devised a strategy to estimate phosphate contents using a spectrophotometer. Three solutions, 5% ammonium molybdate, 5mL of 0.25% of ammonium vanadate, and 5ml sulfuric acid were added to attain a sample color. Various concentration. Potassium dihydrogen phosphate developed a standard curve. Obtained samples containing different solutions were subjected to a spectrophotometer which was set at 420nm wavelength and reading was noted. That was compared later with a standard curve to calculate the number of elements in ppm in the colored sample.

2.9. Potassium Estimation

Chapman and Parker (1961) devised a strategy to calculate potassium contents in leaves by utilizing a flame photometer. Emission of flame photometer was collated with a standard curve to assess the elemental aggregate in ppm which was transformed later in %.

2.10. Fruit Physical Parameters

The following parameters of the fruit were determined: Fruit (fruit size, weight, texture, aroma, color), Seed (shape, size, weight, flavor, and quality of fiber on seed)**,** Peel (thickness, weight, color, and surface)**,** Stone (size, weight, length and width)**,** Pulp (weight, color and taste).

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2.11. Fruit Chemical Parameters

Following parameters were estimated: Total soluble solids (Brix), Titratable acidity (%), Vit –C, TSS: TA, Super-oxide dismutase (mg/mol protein), Peroxidase (mg/mol protein), Catalase (mg/mol protein), Malondialdehyde (g/mol DW), Total soluble protein (mg DW), Hydrogen peroxide (g/mol DW).

2.12. Statistical Analysis

The experiment will be laid out under Randomized Complete Block Design (RCBD) with the two-factor factorial arrangement and three replications. Data will be analyzed by using Statistics 8.1 and means will be compared by Tukey's significant test.

3. RESULTS AND DISCUSSION

3.1. Major Elements in Leaves

3.1.1. Nitrogen Contents in Leaves: The interaction of varieties and month intervals for nitrogen content in leaves was significant. The mean comparison for varieties and month intervals showed the highest value in April. In the varieties mean the highest value was shown by Malda (1.36%) followed by Langra (1.25%) and the lowest was in Neelam (0.87%) statistically at par with Anwar Ratol (0.86%). In March, the highest value was recorded in Neelam (1.47%) followed by Collector (1.39%) and the lowest was in Swarneka (0.77%). In April the highest value was seen in Anwar Ratol (1.47%) and the lowest was seen in Maya (0.84%) statistically at par with Sobhi-di-Ting (0.85%).

For May the highest value was estimated in Malda (1.37%) and the lowest in Sobhi-di-Ting (0.85%). In June the highest value was recorded in Chaunsa SB (1.43%) and the lowest was in Neelam (0.4%). The highest value was noted in Malda (1.87%) and the lowest was in Neelam (0.12%). For July month. For august month the maximum value was recorded in Malda (1.87%) and the lowest was in Anwar Ratol (0.66%).

In September and October, the highest value was seen in Malda (1.83 and 1.80%) followed by Langra (1.30, and 1.27%), and the lowest was in Anwar Ratol (0.66 and 0.66%), respectively. In November, the maximum value was observed in Langra (1.30%) and the lowest in Anwar Ratol (0.72%). In December, the highest value was estimated in Langra (1.30%) followed by Malda (0.9%), and the lowest in Neelam (0.80%) statistically at par with Anwar Ratol (0.81%). In January month the highest value was in Neelam (1.33%) and the lowest in Anwar Ratol (0.87%). For February, the maximum value was noted in Langra (1.50%) and the lowest in Tommy Atkin (0.87%) The results indicated that the nitrogen content was higher in Malda and it was minimum in Neelam and Anwar Ratol as shown in Table 1. Our results are in satisfaction with Avilan (1971) who reported that nitrogen in mango leaves was higher during flowering and fruit formation.

Table 1: Mean comparison for nitrogen content in leaves of selected mango varieties in various months of the year

Varieties	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Var Mean
Langra	0.97^{fu}	1.44^{af}	1.07^{du}	1.17^{dr}	1.20^{dq}	1.20^{dq}	1.30^{dn}	1.27^{do}	1.30^{dn}	1.30^{dn}	1.33^{cl}	1.50^{ad}	1.25^{B}
Anwar Ratool	0.97^{fu}	1.47^{ae}	1.33^{cl}	0.64^{u}	0.66^{tu}	0.66^{stu}	0.66^{stu}	0.66^{stu}	0.72^{ru}	0.81^{ou}	0.87^{ju}	1.13^{dt}	0.88^{G}
Neelam	1.47^{ae}	1.27^{do}	1.27^{do}	0.12^{v}	0.12^{v}	0.74^{qu}	0.81^{ou}	0.80^{ou}	0.80^{ou}	0.80^{ou}	1.10^{du}	1.10^{du}	0.87^{G}
Swarnerka	0.77^{pu}	1.20^{dq}	0.93^{hu}	0.90^{iu}	1.03^{du}	1.13^{dt}	1.17^{dr}	1.17^{dr}	1.07^{du}	1.07^{du}	1.10^{du}	1.10^{du}	1.05^{DE}
Maya	1.27^{do}	0.84^{mu}	1.17^{dr}	0.97^{fu}	1.17^{dr}	1.08^{du}	1.08^{du}	1.08^{du}	1.08^{du}	1.01^{eu}	1.01^{eu}	1.17^{dr}	1.08^{DE}
Malda	0.83^{nu}	1.34^{ck}	1.37^{bi}	1.03^{du}	1.87^{a}	1.87^{a}	1.83^{ab}	1.80^{abc}	1.23^{dp}	0.93^{hu}	1.10^{du}	1.10^{du}	1.36^{A}
Sobhi-di-Ting	1.13^{dt}	0.85^{mu}	0.85^{lu}	1.30^{dn}	0.87^{ku}	1.00^{eu}	1.03^{du}	1.03^{du}	1.03^{du}	1.03^{du}	1.03^{du}	1.03^{du}	1.02^{EF}
Keitt (SSI)	0.97^{fu}	1.07^{du}	1.34^{ck}	1.20^{dq}	1.35^{ck}	1.35^{cj}	1.32^{dm}	1.22^{dq}	1.07^{du}	1.13^{dt}	1.10^{du}	1.10^{du}	1.18^{BC}
Chaunsa Lahori	0.86^{lu}	1.10^{du}	1.17^{dr}	0.80^{ou}	1.13^{dt}	1.20^{dq}	1.07^{du}	1.07^{du}	1.07^{du}	1.07^{du}	1.10^{du}	1.10^{du}	1.06^{DE}
Chaunsa SB	1.10^{du}	1.20^{dq}	1.03^{du}	1.43^{ag}	1.17^{dr}	1.17^{dr}	1.13^{dt}	1.10^{du}	1.10^{du}	1.01^{eu}	1.01^{eu}	1.01^{eu}	1.12^{CD}
Tommy Atkin	1.00^{eu}	1.44^{af}	1.23^{dp}	0.96^{gu}	1.27^{do}	1.17^{dr}	1.07^{du}	1.03^{du}	1.03^{du}	1.03^{du}	0.87^{ku}	0.87^{ku}	1.08^{CDE}
Pohi Raat	0.96^{gu}	1.13^{dt}	1.27^{do}	0.87^{ku}	0.83^{nu}	0.87^{ku}	0.93^{hu}	0.90^{iu}	0.90^{iu}	0.90^{iu}	0.90^{iu}	0.90^{iu}	0.95^{FG}
Pop	1.14^{ds}	1.27^{do}	1.07^{du}	0.89^{iu}	1.07^{du}	1.00^{eu}	1.03^{du}	1.07^{du}	1.08^{du}	1.08^{du}	1.08^{du}	1.08^{du}	1.07^{DE}
Collector	1.39^{ah}	0.99^{eu}	0.93^{hu}	1.03^{du}	0.96^{gu}	0.96^{fu}	0.97^{gu}	0.96^{gu}	0.96^{gu}	0.96^{gu}	0.96^{gu}	0.96^{gu}	1.00^{EF}
Temoria	0.93^{hu}	1.07^{du}	1.17^{dr}	1.20^{dq}	1.20^{dq}	1.10^{du}	1.10^{du}	1.07^{du}	1.03^{du}	1.03^{du}	1.03^{du}	1.03^{du}	1.08^{CE}
Zaafran	1.00^{eu}	1.30^{dn}	1.05^{du}	1.17^{dr}	1.02^{eu}	1.02^{eu}	1.01^{eu}	1.01^{eu}	1.02^{du}	1.00^{eu}	1.00^{eu}	1.02^{eu}	1.05^{DEF}
Var X Time	1.05^{CD}	1.19^{A}	1.14^{AB}	0.98^{D}	1.06B^{CD}	1.09B^{C}	1.09^{BC}	1.08^{BC}	1.03^{CD}	1.01^{CD}	1.04^{CD}	1.07^{CD}	

Values with different letters are significantly different at $P \leq 0.05$.

3.2. Phosphorus Contents in Leaves

The interaction of varieties and month intervals for nitrogen content in leaves was significant. For mean comparisons of variety x month interval, the highest value was seen in July (0.19%) statistically at par with August (0.19%) and September (0.19%). The variety means showed the highest value in Chaunsa SB (0.64%) and all the other varieties were statistically at par with each other. In March, April, May, and June all the varieties were statistically at par with each other. In all the remaining months (July, August, September, October, November,

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December, January, and February) the highest value was noted in Chaunsa SB (1.11% and 0.78%) and other varieties were statistically at par with each other (Table 2).

The results showed that for phosphorus contents the varieties were statistically at par with each other with Chaunsa SB being statistically different from them. Phosphorus is important for good fruit set and prolific root development and timely ripening. In our study, the P and Ca contents varied little among the fruits of different stages of maturity, which confirms the finding of variation from that of the green mature and half-ripe fruits. The phosphorus content in the peel and leaf is similar, but at 65 DAFS, the stone showed a larger concentration than the leaf, which then gradually decreased. At the conclusion of the sampling period, the leaf had the lowest phosphorus levels when compared to the peel and stone (Kour et al. 2020).

Table 2: Mean comparison for phosphorus contents in leaves of selected mango varieties in various months of the year

Varieties	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Var.Mean
Langra	0.12^{b}	0.11^{b}	0.13^{b}	0.15^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{B}
AnwarRatool	0.12^{b}	0.12^{b}	0.13^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.11^{B}
Neelam	0.13^{b}	0.11^{b}	0.15^{b}	0.12^{b}	0.13^{b}	0.12^{b}	0.12^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.12^{B}
Swarnerka	0.14^{b}	0.11^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.11^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.12^{B}
Maya	0.14^{b}	0.13^{b}	0.12^{b}	0.12^{b}	0.13^{b}	0.17^{b}	0.16^{b}	0.16^{b}	0.13^{b}	0.13^{b}	0.11^{b}	0.11^{b}	0.13^{B}
Malda	0.12^{b}	0.10^{b}	0.12^{b}	0.12^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{B}
Sobhi-di-Ting	0.11^{b}	0.14^{b}	0.14^{b}	0.14^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{B}
Keitt(SSI)	0.13^{b}	0.12^{b}	0.11^{b}	0.13^{b}	0.11^{b}	0.12^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.12^{b}	0.12^{b}	0.12^{B}
ChaunsaLahori	0.11^{b}	0.13^{b}	0.13^{b}	0.12^{b}	0.21^{b}	0.22^{b}	0.22^{b}	0.15^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.15^{B}
Chaunsa SB	0.11^{b}	0.12^{b}	0.11^{b}	0.11^{b}	1.11^{a}	1.11^{a}	1.11^{a}	0.78^{a}	0.78^{a}	0.78^{a}	0.78^{a}	0.78^{a}	0.64^{A}
TommyAtkin	0.12^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.12^{B}
Pohi Raat	0.12^{b}	0.13^{b}	0.13^{b}	0.14^{b}	0.17^{b}	0.17^{b}	0.16^{b}	0.16^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.14^{B}
Pop	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{B}
Collector	0.11^{b}	0.12^{b}	0.13^{b}	0.13^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{B}
Temoria	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{B}
Zaafran	0.12^{b}	0.12^{b}	0.11^{b}	0.12^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.11^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{b}	0.12^{B}
VarX Time	0.12^{B}	0.12^{B}	0.13^{B}	0.12^{B}	0.19^{A}	0.19^{A}	0.19^{A}	0.17^{AB}	0.16^{AB}	0.16^{AB}	0.16^{AB}	0.16^{AB}	

Values with different letters are significantly different at $P \leq 0.05$.

3.3. Potassium Contents in Leaves

The interaction of varieties and month intervals for potassium content in leaves was significant. For mean comparisons of variety x month interval, the highest value was seen in March month (31.20%) and the lowest was at month June (28.22%). For variety means the highest value was recorded in Chaunsa SB (31.41%) followed by Chaunsa Lahori (33.26%) and the lowest value was in Malda (24.59%) statistically at par with Temoria (25.28%).

In March the highest value was seen in Temoria (35.63%) and the lowest was in Sobhi-di-Ting (22.67%). In April the highest value was seen in Pohi Raat (33.30%) and the lowest was seen in Swarnerka (25.57%). For May the highest value was estimated in Collector (38.07%) and the lowest in Anwar Ratool (26.53%) and Pop (26.73%). In June, the highest value was recorded in Chaunsa SB (35.10%) and the lowest was in Malda (25.30%). The highest value was noted in Chaunsa SB (36.00%) and the lowest was in Malda (22.10%) for July month.

For August month the maximum value was recorded in Chaunsa SB (35.80%) and the lowest was in Malda (22.10%). In September, October, and November the highest value was seen in Chaunsa SB (35.70, 35.73 and 35.37%) and the lowest was in Malda (22.03, 22.03 and 22.00%) respectively. In December and January, the highest value was estimated in Chaunsa SB (35.33%) and the lowest in Malda (23.00, 23.17%) statistically at par. For February, the maximum value was noted in Chaunsa SB (35.33%) and the lowest in Pohi Raat (25.43%) (Table 3). The results indicated that the nitrogen content was higher in Chaunsa SB and it was minimum in Malda and Temoria. Moreover, the requirement of K at the initial stage means that the marble stage is the highest. It can be explained based on its higher mobility as it travels to phloem along with photo-assimilates and as a result reaches the fruit over the growing season.

3.4. Major Elements in Fruits

3.4.1. Nitrogen Contents in Fruits: The interaction of varieties and stage for nitrogen content in fruits was significant. The mean comparison for varieties and stages showed the highest value at the pre-stone formation stage. In the varieties mean the highest value was shown by Sobhi-di-Ting (0.99%) and the lowest was in Langra (0.480%), Swarnerka (0.48%), and Pohi Raat (0.53%) which were statistically same. At the time point marble and pre-stone formation stage the highest value was recorded in Sobhi-di-Ting (1.23%) and the lowest was in Swarneka (0.37%). The highest value was seen in Pop (1.07%) and the lowest was seen in Langra (0.30%). For the pre-harvest stage the highest value was estimated in Pop (1.17%) and the lowest in Malda (0.45%) as presented in Table 4. Results indicated that nitrogen was more significant in Sobhi-di-Ting and it was lower in langra, Swarnerka, and

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Pohi Raat. Our results are in satisfaction with Avilan (1971) who reported that nitrogen in mango leaves was higher during flowering and fruit formation.

Table 3: Mean comparison for potassium content in leaves of selected mango varieties in various months of the year

Varieties	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Var Mean
Langra	27.63^{ys}	27.17^{ys}	33.20^{bq}	27.50^{ys}	27.73^{ys}	28.07^{xr}	28.13^{wr}	28.27^{vq}	28.23^{vr}	28.07^{xr}	28.23^{vr}	28.23^{vr}	28.37^{F}
Anwar Ratool	35.60^{ah}	28.63^{tq}	26.53^{bv}	29.07^{sp}	29.10^{so}	29.10^{sn}	29.20^{sn}	29.17^{sn}	29.13^{so}	29.17^{sn}	29.17^{sn}	29.17^{sn}	29.42^{E}
Neelam	28.97^{sp}	26.20^{fv}	27.70^{ys}	30.33^{jc}	30.33^{jc}	30.20^{k}	30.17^{le}	29.83^{nj}	30.00^{mh}	30.03^{mg}	30.07^{mf}	30.07^{mf}	29.49^{E}
Swarnerka	27.77^{ys}	25.57^{lx}	25.97^{jw}	27.67^{ys}	25.90^{kx}	26.03^{iv}	26.30^{dv}	26.07^{iv}	26.13^{gv}	26.10^{hv}	26.10^{hv}	26.10^{hv}	26.31^{g}
Maya	33.13^{br}	30.13^{le}	28.13^{wr}	30.03^{mg}	28.13^{wr}	28.47^{uq}	28.33^{vq}	26.33^{dv}	26.33^{dv}	26.27^{ev}	26.43^{cv}	29.30^{qm}	28.42^{F}
Malda	31.73^{gx}	28.13^{wr}	29.17^{sn}	25.30^{nx}	22.10^{wz}	22.10^{wz}	22.03^{xyz}	22.03^{xyz}	22.00^{xyz}	23.00^{uz}	23.17^{tz}	24.33^{ry}	24.59^{H}
Sobhi-di-Ting	22.67^{vz}	28.80^{tq}	28.30^{vq}	29.83^{nj}	31.70^{hx}	32.00^{ew}	32.03^{ew}	31.70^{hx}	31.83^{fx}	32.00^{ew}	31.87^{fx}	31.87^{fx}	30.38^{D}
Keit (SSI)	29.63^{nk}	27.03^{zt}	29.47^{pl}	29.30^{qm}	29.57^{ok}	29.67^{nk}	29.37^{ql}	29.37^{ql}	29.17^{sn}	29.17^{sn}	29.17^{sn}	29.17^{sn}	29.17^{EF}
Chaunsa Lahori	34.10^{bk}	31.73^{gx}	30.93^{iz}	32.27^{cu}	33.13^{br}	33.53^{bn}	33.43^{bo}	33.77^{bm}	33.77^{bm}	34.03^{bl}	34.20^{aj}	34.20^{aj}	33.26^{B}
Chaunsa SB	29.63^{nk}	27.30^{ys}	36.27^{ab}	35.10^{ah}	36.00^{ad}	35.80^{ae}	35.70^{af}	35.73^{af}	35.37^{ah}	35.33^{ah}	35.33^{ah}	35.33^{ah}	34.41^{A}
Tommy Atkin	34.73^{ai}	28.03^{xr}	35.50^{ah}	27.70^{ys}	31.00^{iy}	30.93^{iz}	29.93^{mi}	30.00^{mh}	30.00^{mh}	29.70^{nk}	29.70^{nk}	29.70^{nk}	30.58^{D}
Pohi Raat	32.73^{bs}	33.30^{bp}	29.53^{ok}	23.97^{sy}	25.17^{px}	25.60^{lx}	25.43^{mx}	25.43^{mx}	25.43^{mx}	25.43^{mx}	25.43^{mx}	25.43^{mx}	26.91^{g}
Pop	28.57^{tq}	26.87^{au}	26.73^{bu}	26.13^{gv}	26.30^{dv}	26.27^{ev}	26.43^{cv}	26.43^{cv}	26.10^{hv}	26.00^{jw}	26.00^{jw}	26.00^{jw}	26.49^{g}
Collector	36.07^{abc}	26.67^{bu}	38.07^{a}	27.57^{ys}	29.27^{rm}	29.17^{sn}	29.03^{sp}	27.57^{ys}	27.2^{ys}	27.20^{ys}	27.20^{ys}	27.20^{ys}	29.35^{E}
Temoria	35.63^{ag}	30.13^{le}	21.07^{yz}	19.33^{z}	21.07^{yz}	25.00^{qx}	25.00^{qx}	25.23^{ox}	25.23^{ox}	25.23^{ox}	25.23^{ox}	25.23^{ox}	25.28^{H}
Zaafran	30.67^{ja}	29.03^{sp}	32.10^{dv}	30.40^{jb}	32.07^{ev}	32.10^{dv}	32.00^{ew}	32.07^{ev}	32.10^{dv}	32.10^{dv}	32.10^{dv}	32.40^{bt}	31.59^{C}
Var X Time	31.20^{A}	28.42^{CD}	29.91^{B}	28.22^{D}	28.66^{CD}	29.00^{C}	28.9^{CD}	28.69^{CD}	28.63^{CD}	28.68^{CD}	28.7^{CD}	28.98^{C}	

Values with different letters are significantly different at $P \leq 0.05$.

Table 4: Mean comparison for nitrogen content in fruit of selected mango varieties at various stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest	Var. Mean
Langra	0.38 ± 0.00^{qu}	0.43 ± 0.00^{pt}	0.300 ± 0.01^{sv}	0.80 ± 0.07^{fk}	0.480^{F}
Anwar Ratool	0.49 ± 0.00^{nr}	0.57 ± 0.07^{mq}	0.75 ± 0.03^{hm}	$0.75\pm^{hm}$	0.64^{E}
Neelam	$0.83^{ek}\pm$	0.85 ± 0.00^{dj}	0.47 ± 0.03^{os}	0.84 ± 0.00^{dj}	0.75^{D}
Swarnerka	0.37 ± 0.13^{ru}	0.37 ± 0.04^{ru}	0.400 ± 0.05^{qu}	0.79 ± 0.00^{fl}	0.48^{F}
Maya	0.84 ± 0.03^{dj}	0.84 ± 0.03^{dj}	0.23 ± 0.02^{uv}	0.70 ± 0.07^{im}	0.65^{E}
Malda	0.77 ± 0.00^{gl}	0.77 ± 0.07^{gl}	0.66 ± 0.03^{jn}	0.45 ± 0.00^{pt}	0.66^{E}
Sobhi-di-Ting	1.23 ± 0.00^{a}	1.23 ± 0.00^{a}	0.70 ± 0.03^{im}	0.78 ± 0.03^{gl}	0.99^{A}
Keit(SSI)	0.95 ± 0.10^{cg}	0.95 ± 0.04^{cg}	0.97 ± 0.03^{cf}	0.91 ± 0.00^{ch}	0.94^{ABC}
Chaunsa Lahori	0.85 ± 0.00^{di}	0.85 ± 0.00^{di}	0.14 ± 0.03^{v}	0.75 ± 0.06^{hm}	0.65^{E}
Chaunsa SB	0.94 ± 0.03^{cg}	1.00 ± 0.0^{be}	1.07 ± 0.00^{abc}	0.71 ± 0.01^{im}	0.93^{ABC}
Tommy Atkin	0.73 ± 0.01^{hm}	0.73 ± 0.03^{hm}	0.43 ± 0.03^{pt}	0.61 ± 0.01^{lp}	0.63^{E}
Pohi Raat	0.80 ± 0.03^{fl}	0.83 ± 0.03^{ej}	0.22 ± 0.03^{uv}	0.27 ± 0.00^{tuv}	0.53^{F}
Pop	0.77 ± 0.00^{gl}	0.80 ± 0.01^{fl}	1.07 ± 0.00^{abc}	1.17 ± 0.00^{ab}	0.95^{AB}
Collector	0.96 ± 0.00^{cg}	0.96 ± 0.00^{cg}	1.03 ± 0.01^{bcd}	0.64 ± 0.00^{ko}	0.90^{BC}
Temoria	0.79 ± 0.00^{fl}	0.77 ± 0.00^{gl}	0.87 ± 0.01^{di}	1.03 ± 0.00^{bcd}	0.86^{C}
Zaafran	0.86 ± 0.03^{di}	0.86 ± 0.03^{di}	0.88 ± 0.01^{ci}	0.90 ± 0.00^{ch}	0.87^{BC}
Var X Time	0.79^{AB}	0.80^{A}	0.64^{C}	0.76^{B}	

Values with different letters are significantly different at $P \leq 0.05$.

3.5. Phosphorus Contents in Fruits

The interaction of varieties and stages for phosphorous content in fruits was significant. The mean comparison for varieties and stages showed the highest value at the pre-stone formation stage. In the variety mean the highest value was shown by Sobhi-di-Ting (0.99%) and the lowest was in Langra (0.480%) statistically at par with Swarnerka (0.48%), and Pohi Raat (0.53%). At the time of pre-stone formation, the highest value was recorded in Sobhi-di-Ting (1.23%) and the lowest was in Swarneka (0.37%). For the stone hardening stage, the highest value was estimated in Chaunsa SB and Pop (1.07%) and the lowest in Langra (0.30%). At the pre-harvest stage, the highest value was recorded in Pop (1.17%) and the lowest was in Pohi Raat (0.27%) as demonstrated in Table 5.

As a result, it surged during the reproductive phase. Nitrogen intake is correlated with fruit yield. This fits with our understanding that fruit development and flowering consume a large portion of carbon and nutrients. Consequently, if the tree receives too much or too little N, it will hinder its ability to grow and produce fruit, which will lower its need for N and P (Silber et al. 2022).

3.6. Potassium Contents in Fruits

The interaction of varieties and stages for potassium content in fruits was significant. The mean comparison for varieties and stage showed the highest value at pre-stone formation. In the variety mean the highest value was

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shown by Sobhi-di-Ting (0.99%) and the lowest was in Langra (0.480%) statistically at par with Swarnerka (0.48%). At the time point marble and pre-stone formation stage the highest value was recorded in Sobhi-di-Ting (1.23%) and the lowest was in Swarneka (0.37%). For the stone hardening stage, the highest value was estimated in Chaunsa SB and Pop (1.07%) and the lowest in Langra (0.30%). At the pre-harvest stage, the highest value was recorded in Pop (1.17%) and the lowest was in Pohi Raat (0.27%) (Table 6).

Results indicated that potassium was more significant in Sobhi-di-Ting and it was lower in Swarnerka, and Pohi Raat. The results for potassium can be explained by the fact that these elements are exported in large proportions to the mango fruit (Da Costa et al. 2011). Thus, as the reproductive organs are preferred drains, the trend is that these elements are mobilized from leaf to fruit (Dias et al. 2013).

Table 5: Mean comparison for phosphorus content in fruit of selected mango varieties at various stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest	Var. Mean
Langra	0.38 ± 0.00^{qu}	0.43 ± 0.00^{pt}	0.300 ± 0.01^{sv}	0.80 ± 0.07^{fk}	0.480^{F}
Anwar Ratool	0.49 ± 0.00^{nr}	0.57 ± 0.07^{mq}	0.75 ± 0.03^{hm}	0.75 ± 0^{hm}	0.64^{E}
Neelam	0.83 ± 0^{ek}	0.85 ± 0.00^{dj}	0.47 ± 0.03^{os}	0.84 ± 0.00^{dj}	0.75^{D}
Swarnerka	0.37 ± 0.13^{ru}	0.37 ± 0.04^{ru}	0.400 ± 0.05^{qu}	0.79 ± 0.00^{fl}	0.48^{F}
Maya	0.84 ± 0.03^{dj}	0.84 ± 0.03^{dj}	0.23 ± 0.02^{uv}	0.70 ± 0.07^{im}	0.65^{E}
Malda	0.77 ± 0.00^{gl}	0.77 ± 0.07^{gl}	0.66 ± 0.03^{jn}	0.45 ± 0.00^{pt}	0.66^{E}
Sobhi-di-Ting	1.23 ± 0.00^{a}	1.23 ± 0.00^{a}	0.70 ± 0.03^{im}	0.78 ± 0.03^{gl}	0.99^{A}
Keitt(SSI)	0.95 ± 0.10^{cg}	0.95 ± 0.04^{cg}	0.97 ± 0.03^{cf}	0.91 ± 0.00^{ch}	0.94^{ABC}
ChaunsaLahori	0.85 ± 0.00^{di}	0.85 ± 0.00^{di}	0.14 ± 0.03^{v}	0.75 ± 0.06^{hm}	0.65^{E}
Chaunsa SB	0.94 ± 0.03^{cg}	1.00 ± 0.01^{be}	1.07 ± 0.00^{abc}	0.71 ± 0.01^{im}	0.93^{ABC}
Tommy Atkin	0.73 ± 0.01^{hm}	0.73 ± 0.03^{hm}	0.43 ± 0.03^{pt}	0.61 ± 0.01^{lp}	0.63^{E}
Pohi Raat	0.80 ± 0.03^{fl}	0.83 ± 0.03^{ej}	0.22 ± 0.03^{uv}	0.27 ± 0.00^{tuv}	0.53^{F}
Pop	0.77 ± 0.00^{gl}	0.80 ± 0.01^{fl}	1.07 ± 0.00^{abc}	1.17 ± 0.00^{ab}	0.95^{AB}
Collector	0.96 ± 0.00^{cg}	0.96 ± 0.00^{cg}	1.03 ± 0.01^{bcd}	0.64 ± 0.00^{ko}	0.90^{BC}
Temoria	0.79 ± 0.00^{fl}	0.77 ± 0.00^{gl}	0.87 ± 0.01^{di}	1.03 ± 0.00^{bcd}	0.86^{C}
Zaafran	0.86 ± 0.03^{di}	0.86 ± 0.03^{di}	0.88 ± 0.01^{ci}	0.90 ± 0.00^{ch}	0.87^{BC}
Var X Time	0.79^{AB}	0.80^{A}	0.64^{C}	0.76^{B}	

Values with different letters are significantly different at $P\leq0.05$.

Table 6: Difference of potassium content in fruit of selected mango varieties at various stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest	Var. Mean
Langra	0.38 ± 0.00^{qu}	0.43 ± 0.00^{pt}	0.300 ± 0.01^{sv}	0.80 ± 0.07^{fk}	0.480^{F}
Anwar Ratool	0.49 ± 0.00^{nr}	0.57 ± 0.07^{mq}	0.75 ± 0.03^{hm}	0.75 ± 0^{hm}	0.64^{E}
Neelam	0.83 ± 0^{ek}	0.85 ± 0.00^{dj}	0.47 ± 0.03^{os}	0.84 ± 0.00^{dj}	0.75^{D}
Swarnerka	0.37 ± 0.13^{ru}	0.37 ± 0.04^{ru}	0.400 ± 0.05^{qu}	0.79 ± 0.00^{fl}	0.48^{F}
Maya	0.84 ± 0.03^{dj}	0.84 ± 0.03^{dj}	0.23 ± 0.02^{uv}	0.70 ± 0.07^{im}	0.65^{E}
Malda	0.77 ± 0.00^{gl}	0.77 ± 0.07^{gl}	0.66 ± 0.03^{jn}	0.45 ± 0.00^{pt}	0.66^{E}
Sobhi-di-Ting	1.23 ± 0.00^{a}	1.23 ± 0.00^{a}	0.70 ± 0.03^{im}	0.78 ± 0.03^{gl}	0.99^{A}
Keitt(SSI)	0.95 ± 0.10^{cg}	0.95 ± 0.04^{cg}	0.97 ± 0.03^{cf}	0.91 ± 0.00^{ch}	0.94^{ABC}
Chaunsa Lahori	0.85 ± 0.00^{di}	0.85 ± 0.00^{di}	0.14 ± 0.03^{v}	0.75 ± 0.06^{hm}	0.65^{E}
Chaunsa SB	0.94 ± 0.03^{cg}	1.00 ± 0.01^{be}	1.07 ± 0.00^{abc}	0.71 ± 0.01^{im}	0.93^{ABC}
Tommy Atkin	0.73 ± 0.01^{hm}	0.73 ± 0.03^{hm}	0.43 ± 0.03^{pt}	0.61 ± 0.01^{lp}	0.63^{E}
Pohi Raat	0.80 ± 0.03^{fl}	0.83 ± 0.03^{ej}	0.22 ± 0.03^{uv}	0.27 ± 0.00^{tuv}	0.53^{F}
Pop	0.77 ± 0.00^{gl}	0.80 ± 0.01^{fl}	1.07 ± 0.00^{abc}	1.17 ± 0.00^{ab}	0.95^{AB}
Collector	0.96 ± 0.00^{cg}	0.96 ± 0.00^{cg}	1.03 ± 0.01^{bcd}	0.64 ± 0.00^{ko}	0.90^{BC}
Temoria	0.79 ± 0.00^{fl}	0.77 ± 0.00^{gl}	0.87 ± 0.01^{di}	1.03 ± 0.00^{bcd}	0.86^{C}
Zaafran	0.86 ± 0.03^{di}	0.86 ± 0.03^{di}	0.88 ± 0.01^{ci}	0.90 ± 0.00^{ch}	0.87^{BC}
Var X Time	0.79^{AB}	0.80^{A}	0.64^{C}	0.76^{B}	

Values with different letters are significantly different at $P\leq0.05$.

3.7. Physiological Parameters of Fruits

3.7.1. Fruit Size: The interaction of varieties x stage in the analysis of variance for the size of fruit was significant. For varieties, the x stage means the highest value was observed at the pre-harvest stage. In the variety mean the maximum size was obtained by Chaunsa Lahori, Keitt(SSI), Pohi raat, Tommy atkin, Collector, Temoria and Zaafran (1.75 cm) statistically at par to each other.

At stage marble and pre-stone formation the size of fruit all the varieties were statistically at par to each other (1.00cm). Similarly, at stone hardening stage all the varieties were statistically at par to each other for the size of fruit (2.00cm). All the values were statistically at par to each other at pre-harvest stage (3.00cm) according to Table 7. The results showed that all the varieties for the size of fruit at different stages were not statistically different from one another. This change occurred because of physiological and genetic factors. Chaudhari et al. (1997) also reported the change in the length of fruits in different varieties of mangoes.

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Table 7: Difference of fruit size in selected mango varieties at various stages

Varieties	Stage				Var. Mean
	Marble	Pre-stone formation	Stone hardening	Pre-harvest	
Langra	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.7^{A}
Anwar Ratool	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Neelam	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{ab}	1.67^{AB}
Swarnerka	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{ab}	1.67^{AB}
Maya	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{ab}	1.67^{AB}
Malda	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{ab}	1.67^{AB}
Sobhi-di-Ting	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{c}	1.50^{B}
Keitt(SSI)	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
ChaunsaLahori	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Chaunsa SB	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Tommy Atkin	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Pohi Raat	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Pop	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{bc}	1.58^{AB}
Collector	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Temoria	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Zaafran	1.00^{d}	1.00^{d}	2.00^{c}	3.00^{a}	1.75^{A}
Var.XTimeMean	1.00^{C}	1.00^{C}	2.00^{B}	2.8^{A}	

Values with different letters are significantly different at $P \leq 0.05$.

3.8. Fruit Weight

The interaction of varieties x stage in the analysis of variance for the weight of fruit was significant. For varieties, x stage mean the highest value was seen at the pre-harvest stage (71.06g). for variety means maximum weight was attained by Zaafran (46.33g) followed by Maya (43.17g) and the lowest was seen in Neelam (31.75g) followed by Anwar Ratol (33.17g).

For the marble stage the highest value was seen in Zaafran (27.67g) and the lowest was seen in Neelam (11.67g). At the pre-stone formation stage, the maximum weight was seen in Zaafran (32.00g) followed by Pop (28.33g) statistically at par with Sawarnerka (28.00g). At the stone hardening stage the maximum value was seen in Zaafran (42.33g) and the lowest was seen in Neelam (28.67g). For the pre-harvest stage the highest value was seen in Zaafran (83.33g) statistically at par with Maya (80.00g) and the lowest was in Anwar Ratol (64.33g) as displayed in Table 8. The results showed that the highest value was seen in Zaafran and the lowest was seen in Neelam. Our results confirm the study Doreyappagowda and Huddar (2001) who reported the maximum reduction in the weight of fruit. In the present study variation in fruit weight of the different mango, germplasm had been noticed. There are several concerns about how increasing elevation would affect mango productivity and fruit quality, given that mango cultivation has recently shifted to higher altitudes in an effort to mitigate the possible effects of climate change on mango production. The effects of rising temperatures and CO_2 on the morpho-physiological traits of mangos, such as fruit quality, flowering, photosynthesis, and vegetative growth. Mango cultivars grown at higher altitudes must therefore be evaluated for quality and productivity (Zhang et al. 2022). Potassium carbonate was used to record the heaviest fruits (412.0) (T3). However, feldspar (T2 and T1) recorded the heaviest values in the second season (438.33 and 418.67, respectively (Taha et al. 2014).

Table 8: Difference of fruit weight in selected mango varieties at various stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest	Var. Mean
Langra	25.33^{ot}	29.67^{kp}	39.67^{fg}	71.00^{cd}	41.42^{BCD}
Anwar Ratool	15.67^{wz}	21.33^{rw}	31.33^{jo}	64.33^{e}	33.17^{IJ}
Neelam	11.67^{z}	18.67^{uy}	28.67^{lq}	68.00^{cde}	31.75^{J}
Swarnerka	24.33^{pu}	28.00^{lq}	38.00^{fi}	78.33^{ab}	42.17^{BC}
Maya	22.67^{qv}	30.00^{kp}	40.00^{fg}	80.00^{a}	43.17^{B}
Malda	19.33^{ty}	24.00^{pu}	34.00^{gm}	78.33^{ab}	38.92^{DEF}
Sobhi-di-Ting	24.33^{pu}	26.67^{ns}	36.67^{fj}	68.33^{cde}	39.00^{DE}
Keitt (SSI)	19.00^{ty}	24.00^{pu}	34.00^{gm}	70.33^{cde}	36.83^{EFG}
Chaunsa Lahori	14.67^{xyz}	21.33^{rw}	31.33^{jo}	68.67^{cde}	34.00^{HIJ}
Chaunsa SB	25.33^{ot}	27.00^{ns}	37.00^{fj}	72.33^{bc}	40.42^{BCD}
Tommy Atkin	21.00^{sx}	26.00^{ns}	37.67^{fj}	64.67^{de}	37.33^{EFG}
Pohi Raat	17.33^{vz}	23.67^{pv}	34.33^{gl}	65.33^{de}	35.17^{gHI}
Pop	26.00^{ns}	28.33^{lq}	38.33^{fgh}	68.00^{cde}	40.17^{CD}
Collector	17.33^{vz}	25.33^{ot}	35.67^{gk}	66.33^{cde}	36.17^{FGH}
Temoria	13.67^{yz}	21.00^{sx}	31.67^{io}	69.67^{cde}	34.00^{HIJ}
Zaafran	27.67^{mr}	32.00^{hn}	42.33^{f}	83.33^{a}	46.33^{A}
Var.x Time Mean	20.33^{D}	25.44^{C}	35.67^{B}	71.06^{A}	

Values with different letters are significantly different at $P \leq 0.05$.

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3.9. Fruit Texture

The texture was observed to be smooth and rough on the surface of the fruits. The texture of the varieties was found to be smooth on the marble stage. Malda, Keitt (SSI), Collector, Temoria, and Zaafran started showing rough texture in the pre-stone formation stage. Among other varieties, Malda, Keitt (SSI), Collector, Temoria, and Zaafran were showing rough texture at stone hardening and pre-harvest stage, and they were the rough texture varieties (Table 9). The decaying of cellulose and hemicellulose is mainly caused due the decomposition of substances called pectin. As a consequence, the texture of the fruit becomes soft (Liu et al. 2009; Prasanna et al. 2007). Reduced respiration rates and elevated CO_2 levels are the primary elements in MAP that preserve mango quality. These results lower respiration levels. This indicates that fruit ripening is indicated by changes in skin color and respiration rate firmness. Fruit held in an atmosphere with low oxygen concentration also demonstrated a decrease in ethylene production, flesh firmness, and color losses (Rathore et al. 2007).

3.10. Fruit Aroma

Varieties and stage interaction significantly affected the aroma of fruits in mangoes. All the varieties were similar in mild aroma at the marble and pre-stone formation stages. Chaunsa SB, Tommy Atkin, and Rohi Raat were giving intermediate aroma at the stone hardening stage. The pre-harvest stage was with strong aroma within Chaunsa SB, Tommy Atkin, and Rohi Raat. The rest of the varieties showed mild aroma at the harvesting stage of maturity. It can be concluded from the results that Chaunsa SB, Tommy Atkin, and Rohi Raat were the varieties with a stronger aroma than the rest as displayed in Table 10.

Table 9: Difference in fruit texture of mango varieties at different stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest
Langra	1	1	1	1
Anwar Ratool	1	1	1	1
Neelam	1	1	1	1
Swarnerka	1	1	1	1
Maya	1	1	1	1
Malda	1	2	2	2
Sobhi-di-Ting	1	1	1	1
SSI	1	2	2	2
Chaunsa Lahori	1	1	1	1
Chaunsa SB	1	1	1	1
Tommy Atkin	1	1	1	1
Pohi Raat	1	1	1	1
Pop	1	1	1	1
Collector	1	2	2	2
Temoria	1	2	2	2
Zaafran	1	2	2	2

Fruit Texture: (1= Smooth, 2=Rough)

Table 10: Difference in fruit aroma of mango varieties at different stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest
Langra	1	1	1	2
Anwar Ratool	1	1	1	2
Neelam	1	1	1	2
Swarnerka	1	1	1	2
Maya	1	1	1	2
Malda	1	1	1	2
Sobhi-di-Ting	1	1	1	2
SSI	1	1	1	2
Chaunsa Lahori	1	1	1	2
Chaunsa SB	1	1	2	3
Tommy Atkin	1	1	2	3
Pohi Raat	1	1	2	3
Pop	1	1	1	2
Collector	1	1	1	2
Temoria	1	1	1	2
Zaafran	1	1	1	2

Fruit Aroma: (1=Mild, 2 = Intermediate, 3 = Strong)

3.11. Fruit Color

The color of the mango fruits depends on the morphological stage in which it is being harvested. For the marble and pre-stone formation, morphological stage lush green color was observed within all the varieties and there was no difference among them. Swarnerka, SSI, and Pohi Raat were the varieties showing 25% yellow color from the shoulder sides of fruits at the stone hardening morphological stage. The pre-harvest stage was the stage with 50% yellow color observed among all the varieties except Swarnerka, SSI, and Pohi Raat which were showing 75% of yellow color at the shoulder of the mango fruits (Table 11). Swarnerka, SSI, and Pohi Raat were showing prominent color at harvesting. Hence these results were recorded. In mango, for the idea of fruit ripening, fruit color is considered to be the main factor (Ninio et al. 2003; Ornelas-Paz et al. 2007). The variability found in the present study is satisfactory to Mukherjee (1997), who reported that the color of the fruit is dependent on genotype at maturity. The results conform with the findings of Haque et al. (1993). He said maximum fruits turned to yellow or greenish-yellow during ripening.

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Table 11: Difference in fruit color of mango varieties at different stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest
Langra	1	1	1	2
Anwar Ratool	1	1	1	2
Neelam	1	1	1	2
Swarnerka	1	1	2	3
Maya	1	1	1	2
Malda	1	1	1	2
Sobhi-di-Ting	1	1	1	2
Keitt(SSI)	1	1	2	3
Chaunsa Lahori	1	1	1	2
Chaunsa SB	1	1	1	2
Tommy Atkin	1	1	1	2
Pohi Raat	1	1	2	3
Pop	1	1	1	2
Collector	1	1	1	2
Temoria	1	1	1	2
Zaafran	1	1	1	2

Fruit Color: (1=100%green, 2 = 1-25% yellow, 3 = 26-50%, yellow, 4 = 51-75% yellow, 5 = 76-100% yellow)

3.12. Physiological Parameters of Seed

3.12.1. Size of Seed

The interaction of varieties x stage in the analysis of variance for the seed size was significant. For varieties, the x stage mean the highest value was seen in the pre-harvest stage (1.31 cm). For the varieties mean maximum size was seen in Chaunsa SB (1.42 cm) and the minimum was seen in Maya (0.00 cm). At the marble stage, all the values were statistically at par with each other (0.00 cm). At the pre-stone formation stage to maximum attained in size of varieties was (0.67 cm) and the minimum was (0.33 cm). At the stone hardening stage, the highest value was observed in Anwar Ratol, SSI, Chaunsa SB, and Pohi Raat (2.00 cm) statistically at par with each other. And the lowest was seen in Neelam, Maya, Malda, Pop, and Temoria (0.33 cm) statistically at par with each other. At the pre-harvest stage, the maximum size was noted in Anwar Ratol, Keitt(SSI), and Chaunsa SB (3.00 cm) statistically at par with each other and the minimum was seen in Neelam, Swarnerka, Pop, and Temoria (0.33 cm). The results showed that the highest value was seen in Chaunsa SB and the lowest was in Maya as shown in Table 12.

Table 12: Difference in seed size of mango varieties at different stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest	Var. Mean
Langra	0.00^{c}	0.67^{bc}	0.67^{bc}	2.00^{ab}	0.83^{BCD}
Anwar Ratool	0.00^{c}	0.33^{c}	2.00^{ab}	3.00^{a}	1.33^{AB}
Neelam	0.00^{c}	0.33^{c}	0.33^{c}	0.33^{c}	0.25^{EF}
Swarnerka	0.00^{c}	0.33^{c}	0.33^{c}	0.33^{c}	0.25^{EF}
Maya	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{F}
Malda	0.00^{c}	0.33^{c}	0.33^{c}	2.00^{ab}	0.67^{CDE}
Sobhi-di-Ting	0.00^{c}	0.33^{c}	0.33^{c}	2.00^{ab}	0.67^{CDE}
Keitt(SSI)	0.00^{c}	0.00^{c}	2.00^{ab}	3.00^{a}	1.25^{AB}
Chaunsa Lahori	0.00^{c}	0.67^{bc}	0.67^{bc}	0.67^{bc}	0.50^{DEF}
Chaunsa SB	0.00^{c}	0.67^{bc}	2.00^{ab}	3.00^{a}	1.42^{A}
Tommy Atkin	0.00^{c}	0.67^{bc}	0.67^{bc}	0.67^{bc}	0.50^{DEF}
Pohi Raat	0.00^{c}	0.33^{c}	2.00^{ab}	2.00^{ab}	1.08^{ABC}
Pop	0.00^{c}	0.33^{c}	0.33^{c}	0.33^{c}	0.25^{EF}
Collector	0.00^{c}	0.67^{bc}	0.67^{bc}	0.67^{bc}	0.50^{DEF}
Temoria	0.00^{c}	0.33^{c}	0.33^{c}	0.33^{c}	0.25^{EF}
Zaafran	0.00^{c}	0.67^{bc}	0.67^{bc}	0.67^{bc}	0.50^{DEF}
Var.XTim.Mean	0.00^{D}	0.42^{C}	0.83^{B}	1.31^{A}	

Values with different letters are significantly different at $P \leq 0.05$.

3.13. Weight of Seed

The interaction of varieties x stage in the analysis of variance for the seed weight was significant. For varieties, x stage mean the highest value was seen at time point four (24.53g). In Variety mean the maximum attained in weight was seen in Malda (20.05g) and the minimum was in Langra (11.70g). At the marble stage, all the varieties were statistically at par with each other. In the pre-stone formation stage, all the varieties were statistically at par with each other with Collector (2.46g) being statistically different from them. At the stone hardening stage, the highest value was seen in Anwar Ratol (35.70g) and the lowest was in Pohi Raat (22.17g). For the pre-harvest stage the highest value was recorded in Pop (44.72g) statistically at par with Malda (44.54g) and SSI (43.63g) and the lowest was in Langra (24.53g) (Table 13). The results showed that the highest value was seen in Malda and the lowest was in Langra.

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Table 13: Difference in seed weight of mango varieties at different stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest	Var. Mean
Langra	0.00^{r}	1.46^{r}	22.27^{p}	24.53^{no}	11.70^{K}
Anwar Ratool	0.00^{r}	1.56^{r}	35.70^{de}	38.19^{c}	18.47^{B}
Neelam	0.00^{r}	1.30^{r}	23.16^{op}	26.19^{lm}	12.34^{J}
Swarnerka	0.00^{r}	3.60^{r}	31.79^{hi}	34.81^{def}	16.65^{DE}
Maya	0.00^{r}	1.87^{r}	32.57^{gh}	38.20^{c}	17.69^{C}
Malda	0.00^{r}	0.06^{r}	35.60^{de}	44.54^{a}	20.05^{A}
Sobhi-di-Ting	0.00^{r}	2.27^{r}	22.00^{p}	40.55^{b}	15.64^{gH}
Keitt (SSI)	0.00^{r}	0.04^{r}	31.50^{hi}	43.63^{a}	18.79^{B}
ChaunsaLahori	0.00^{r}	7.53^{r}	31.69^{hi}	32.02^{hi}	15.93^{FG}
Chaunsa SB	0.00^{r}	3.77^{r}	32.57^{gh}	36.02^{d}	17.15^{CD}
Tommy Atkin	0.00^{r}	5.60^{r}	30.84^{i}	34.82^{def}	16.42^{EF}
Pohi Raat	0.00^{r}	1.40^{r}	22.17^{p}	25.01^{mn}	11.80^{JK}
Pop	0.00^{r}	0.47^{r}	34.51^{ef}	44.72^{a}	19.93^{A}
Collector	0.00^{r}	2.46^{q}	33.61^{fg}	40.01^{b}	19.02^{B}
Temoria	0.00^{r}	1.60^{r}	27.07^{kl}	28.17^{jk}	13.81^{I}
Zaafran	0.00^{r}	8.53^{r}	28.74^{j}	31.37^{hi}	15.03^{H}
Var.XTim.Mean	0.00^{R}	1.46^{R}	22.27^{P}	24.53^{NO}	11.70^{K}

Values with different letters are significantly different at $P \leq 0.05$.

3.14. The Shape of the Seed

The shape of the seed was visually observed based on the shape scale. There was no seed formation at the marble stage of morphology on which fruits were collected. Ellipsoid type of seed shape was observed among all the varieties of mango at the pre-stone formation stage. Anwar Ratool was the only variety with an oblong shape of seed at the stone hardening stage of collecting fruits. Variation in the shape of seed was found among all the varieties at the pre-harvest stage of morphology. Among other physiological traits, seed shape also showed variation at the pre-harvest stage of morphology. Langra, Neelam, Maya, Malda, Sobhi-di-Ting, Tommy Atkin, Pop, Collector, Temoria, and Zaafran were the varieties with Oblong type of seed shapes. Anwar Ratool, Swaarnerka, Keitt (SSI), Chaunsa Lahori, Chaunsa SB, and Pohi Raat showed a reniform shape of a seed (Table 14). It can be concluded from the results that variation among the varieties based on the shape of the seed is significant. Variation in development along with adopting a certain shape goes on continued until the pre-harvest stage.

Table 14: Difference in seed shape of mango varieties at different stages

Varieties	Marble	Pre-stone formation	Stone hardening	Pre-harvest
Langra	0	1	1	2
Anwar Ratool	0	1	2	3
Neelam	0	1	1	2
Swarnerka	0	1	1	3
Maya	0	1	1	2
Malda	0	1	1	2
Sobhi-di-Ting	0	1	1	2
Keitt (SSI)	0	1	1	3
Chaunsa Lahori	0	1	1	3
Chaunsa SB	0	1	1	3
Tommy Atkin	0	1	1	2
Pohi Raat	0	1	1	3
Pop	0	1	1	2
Collector	0	1	1	2
Temoria	0	1	1	2
Zaafran	0	1	1	2

Seed Shape: (1 Ellipsoid 2 Oblong 3 Reniform)

3.15. The Flavor of the Seed

Sensory evaluation of flavor highly depends on the morphological stage in which fruits are being harvested. No seed was developed at the marble morphological stage and there was no recording of flavor done. Pre-stone formation morphological stage was with the development of seed but there was no taste assessed in any variety. With the development and growth of seed bitter taste were found among all the varieties of mangoes at the stone hardening morphological stage of collection. Minute assessment for the flavor of seed was observed among varieties at the pre-harvest stage. Anwar Ratool, Swarnerka, Chaunsa Lahori, and Chaunsa SB were the varieties with a bit touch of sourness in the flavor of the seed (Table 15). Hence it can be concluded that flavor within seeds develops with the morphological stages of maturity. Anwar Ratool, Swarnerka, Chaunsa Lahori, and Chaunsa SB were the varieties that gave sour flavor in the pre-harvest stage of development.

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3.16. Quality of Fiber on Seed

Morphological stage data for quality of fiber was highly varying among the mango varieties. No fiber was observed visually among any of the mango varieties on marble and pre-stone formation morphological stage of development. Anwar Ratool, Sobhi-di-Ting, Chaunsa Lahori, Chaunsa SB, and Zaafran showed little or low presence of fiber on seed and it was neglectable among the rest of the varieties. It was observed that at the pre-harvest stage all the varieties were with the fiber present over the seed. Anwar Ratool was the variety with a thick presence of fiber on the seed. Sobhi-di-Ting, Chaunsa Lahori, Chaunsa Sb, and Zaafran were recorded with the intermediate presence of fiber among them. Langra, Neelam Swarnerka, Maya, Mala, Keitt (SSI), Tommy Atkin, Pohi Raat, Pop, Collector, and Temoria showed a lower amount of fiber over the seed in Table 15. It can be concluded from the results that the highest fiber was found in Anwar Ratool. The richness of fiber causes lower pulp but varieties with a thick density of fiber showed better germination and adaptability among other varieties.

Table 15: Difference in seed flavor and quality of fiber of mango varieties at different stages

Varieties	Seed Flavor					Quality of Fiber			
	Marble	Pre-stone formation	Stone hardening	Pre-harvest		Marble	Pre-stone formation	Stone hardening	Pre-harvest
Langra	0	4	1	1		0	0	0	3
Anwar Ratool	0	4	1	2		0	0	3	7
Neelam	0	4	1	1		0	0	0	3
Swarnerka	0	4	1	2		0	0	0	3
Maya	0	4	1	1		0	0	0	3
Malda	0	4	1	1		0	0	0	3
Sobhi-di-Ting	0	4	1	1		0	0	3	5
Keitt (SSI)	0	4	1	1		0	0	0	3
Chaunsa Lahori	0	4	1	2		0	0	3	5
Chaunsa SB	0	4	1	2		0	0	3	5
Tommy Atkin	0	4	1	1		0	0	0	3
Pohi Raat	0	4	1	1		0	0	0	3
Pop	0	4	1	1		0	0	0	3
Collector	0	4	1	1		0	0	0	3
Temoria	0	4	1	1		0	0	0	3
Zaafran	0	4	1	1		0	0	3	5

Seed Flavor: (0= no flavor 1= Bitter 2= Sour 3= Sweet 4= Tasteless). Seed Quality of Fiber: (0= Absent, 3= Low, 5= Intermediate, 7= High)

3.17. Fruit Chemical Parameters

3.17.1. Titratable Soluble Solids: Analysis of variance for total soluble solids in selected mango varieties was significant. The mean comparisons of varieties showed the maximum value Maya (22.23 ˚Brix) followed by Tommy Atkin (17.50 ˚Brix) and the minimum value was observed in Chaunsa SB (6.83 ˚Brix) statistically at par with Sobhi-di-Ting (7.97 ˚Brix). The results showed that the maximum value for titrable soluble solids was recorded in Maya and the lowest was in Chaunsa SB and Sobhi-di-Ting (Fig. 1). The progression of the ripening process leads to increased sugar levels. Bhuyan and Guha (1995), experimented and found 16.22 to 24.14% TSS in 14 mango germplasm under the climatic conditions of Rajshahi. Sarder (1995), and Sharma and Josan (1995) also reported that TSS varied depending upon germplasm.

Analysis of variance for titratable acidity in selected mango varieties was significant. The mean comparisons of varieties showed the maximum value in Pop (13.53%) followed by Langra (11.25%) and the minimum was in Chaunsa Lahori and Tommy Atkin (3.83%) statistically at par with each other. The results indicated that the highest value for titrable acidity was recorded in Pop and the lowest was in Chaunsa Lahori and Tommy Atkin. Citric and malic acid is believed to be the cause of a decrease in the acidic contents of mango during the ripening process as shown in Fig. 1.

Analysis of variance for TSS: TA in selected mango varieties was significant. The mean comparisons of varieties showed the maximum value was seen in Tommy Atkin (4.57) and the minimum value estimated in Langra (0.89). The results showed that the highest value for TSS: TA was recorded in Tommy Atkin and the lowest was in Langra. Due to the presence of citric and malic acid in mango the acidity content decreases during the ripening process. Likewise, a greater titratable acidity (TA) (0.42%) was maintained by the bilayer coating of gA/CMC in Dashehari varieties (Gupta et al. 2023).

Analysis of variance for Vitamin C in selected mango varieties was significant. The mean comparisons of varieties showed the maximum value Tommy Atkin (0.83mg) followed by Chaunsa Lahori (0.75mg) statistically at par with Anwar Ratol (0.75mg) and the minimum value was seen in Langra (0.30mg). The results showed that the highest value for vitamin C contents in selected mango varieties was highest recorded in Tommy Atkin and the lowest was in Langra as represented in Fig. 1. During ripening the decline in the contents of ascorbic acid is due to oxidative destruction at high temperatures (De Oliveira et al. 2020).

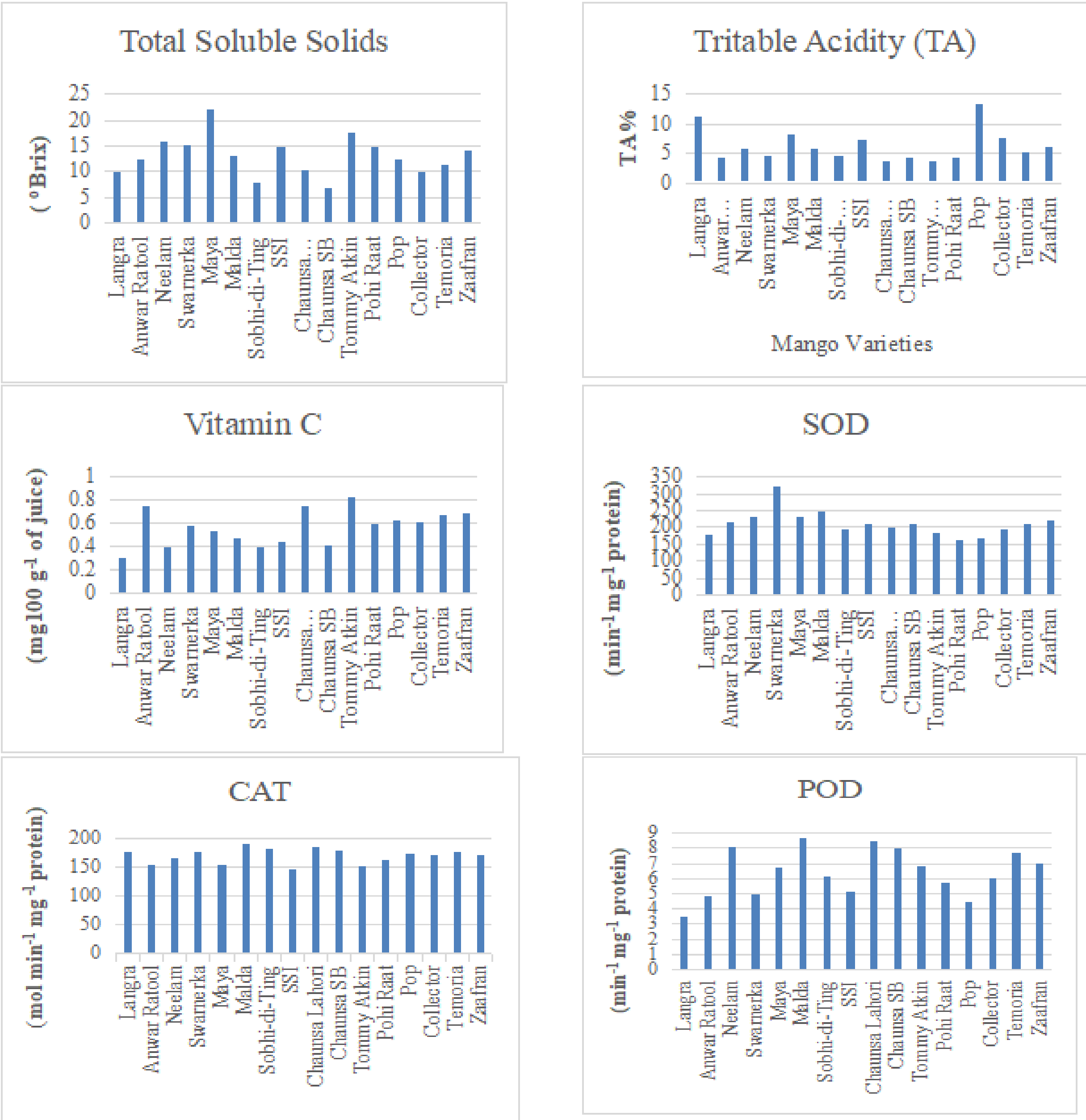

Fig. 1: Quantification of Total Soluble Solids (TSS), Tritable Activity (TA), Vitamin C, Superoxide Dismutase (SOD), Catalase (CAT) and Peroxidase (POD) in selected mango varieties.

Analysis of variance for superoxide dismutase in selected mango varieties was significant. The mean comparisons of varieties showed the maximum value in Swarnerka (322.16mg protein) followed by Malda (246.32mg/mol protein) and the minimum value was in Pohi Raat (163.99 mg protein). The results showed that the highest value for superoxide dismutase was seen in Swarnerka and the lowest was in Pohi Raat (Fig 1). According to Rogiers et al. (1998), in green fruits, a higher concentration of SOD and CAT was observed but there was a reduction in matured fruits. The activity of antioxidant enzymes, at the color stage, reached the maximum value with a reduction in the following stages, in guava (Mondal et al. 2004). A trend of substantial increase during ripening (Rogiers et al. 1998; Huang et al. 2007), with a prominent decline in the stages of ripening.

Analysis of variance for Peroxidase dismutase (POD) in selected mango varieties was significant. The mean comparisons of varieties showed the maximum value in Chaunsa Lahori (8.50 mg protein) statistically at par with Malda (8.66 mg protein) and Neelam (8.07 mg protein) and the minimum value was seen in Langra (3.48mg protein). The results showed that the highest value was recorded in Chaunsa Lahori and Malda and the lowest was in Langra (Fig 1). There was no change in SOD activity with an increase in POD activity in the ripening of apricots (De Martino et al. 2006). Activities of POD have also been reported to be increased in the pulp tissue during the ripening of mango (Marin and Cano, 1992).

Analysis of variance for Catalase in selected mango varieties was significant. The mean comparisons for Catalase in selected mango varieties showed the highest value in Malda (190.25mg/mol protein) followed by Sobhi-di- Ting (184.03mg/mol protein) statistically at par with Chaunsa Lahori (186.40mg/mol protein) and the lowest was observed in Keitt (SSI) (145.89 mg/mol protein) as presented in Fig. 1. The results showed that the highest value was recorded in Malda and the lowest was in SSI. Antioxidative enzymes such as SOD, CAT, and POX play a protective role for fruits against oxidative damage (Sala, 1998) and maintain the production of ROS below the damaging levels (Rao et al. 1996). During ripening an increase in the production of CAT was found in tomatoes (Mondal et al. 2004; Andrews et al. 2004). Singh and Dwivedi (2008) reported a decrease in the functioning of SOD and CAT. Moreover, the same trend was noted in oranges (Huang et al. 2007).

Analysis of variance for malondialdehyde in selected mango varieties was significant. The results showed the maximum value of malondialdehyde in Chaunsa SB (6.93g/mol DW) followed by Chaunsa Lahori (45.70g/mol DW) and the minimum value was seen in Temoria (4.03g/mol DW) statistically at par with Maya (4.04g/mol DW). The results indicated that the highest value was seen in Chaunsa SB and the lowest was in Temoria and Maya.

Analysis of variance for total soluble proteins in selected mango varieties was significant. The mean comparisons of varieties showed the maximum value for total soluble proteins in Anwar Ratol (1.93 mg/mol DW) followed by Chaunsa SB (1.45mg/mol DW) and a minimum value was noted in Sobhi- di- Ting (0.90 mg/mol DW) statistically at par with Temoria (0.95mg/mol DW). The results indicated that the highest value for total soluble proteins was seen in Anwar Ratol and the lowest was in Sobhi- di- Ting, and Temoria. The enzyme amylases cause the hydrolysis of sugar which leads to an increase in SSC Hence, The enzyme amylase breaks down starch into simple sugars (Mukhtar et al. 2021).

Analysis of variance for hydrogen peroxide in selected mango varieties was significant. For mean comparisons of hydrogen peroxide for selected mango varieties, the graph showed the highest value was noted in Zaafran (2.50g/mol DW) statistically at par with Temoria (2.43 g/mol DW) and Sobhi-di- Ting (2.37g/mol DW). Pop and Neelam showed the lowest value (1.48g/mol DW) statistically at par with each other.

The results declared the highest value of hydrogen peroxide was recorded in Zaafran, Temoria, Sobhi-di- Ting and the lowest was in Pop and Neelam. In about every living being that is revealed to oxygen, CAT which is a hydrogen peroxide oxide reductase enzyme is present, where it helps to catalyze the breakdown of hydrogen peroxide into water and oxygen by saving extra H_2O_2 develop and helping to appropriate crucial cellular processes (Chelikani et al. 2004). Improved the activity of CAT during ripening had also been registered in fruits like apples, grapes, mango, papaya, and pear (Ezell and Gerhardt 1942; Brenan and Frenkel 1977; Pal and Selvaraj 1987).

4. CONCLUSION

In conclusion, this study delved into the seasonal variation of major elements during the various stages of mango fruit development and conducted a comprehensive evaluation of post-harvest changes in mango germplasm. Mango, belonging to the Anacardiaceae family, stands as a significant fruit globally, with a substantial cultivation area and production volume in the country. The research meticulously examined 16 mango varieties, collecting leaves monthly from the marble stage to harvesting over a year. It investigated biochemical properties such as SOD, POD, CAT, and essential macro elements (N, P, K) in leaves. Additionally, the study focused on the morphological and biochemical aspects of fruits at different developmental stages, shedding light on parameters like texture, aroma, color, and various enzyme activities. Results highlighted intriguing findings, such as the evolution of fruit texture and aroma across different varieties and stages. Notably, Catalase exhibited the highest activity in Malda, while Hydrogen Peroxide reached its peak in Zaafran. Malondialdehyde levels were highest in Chaunsa SB, and Peroxidase showed its maximum value in Chaunsa Lahori. Superoxide dismutase activity reached its peak in Sawarnerka. Titrable acidity, a crucial indicator of fruit quality, displayed significant variation among varieties, with Pop and Langra exhibiting higher values. This research provides valuable insights into the intricate dynamics of mango fruit development and post-harvest changes. The observed variations in morphological and biochemical parameters underscore the importance of considering distinct developmental stages for a comprehensive understanding of mango quality and nutritional attributes. The findings contribute to the knowledge base for optimizing nutrient management practices and enhancing the overall quality of mango cultivation.

LIST OF ABBREVIATIONS

SOD	Superoxide Dismutase
POD	Peroxide
CAT	Catalase
SSI	Solution Services Innovation (Agric. Farm)
TA	Titratable Acidity
TSS	Total Soluble Solids
DW	Dry Weight
TSP	Total Soluble Protein
Ppm	Parts Per Million
Mg	Milligram
Mol	Mole
RCBD	Randomized Complete Block Design
SSC	Saline-Sodium Citrate
HIS	Institute of Horticulture Science

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