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Pre-harvest Factors Influencing the Postharvest Quality of Fruits: A Review

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Authors' contributions

This work was carried out in collaboration between all authors. Author ST designed the study. Authors ST, SS and MI wrote the protocol. Author ST also wrote the first draft of the manuscript. Authors KR and SSM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Fruits play a good role in nutritional security as well as generate high income to the growers. Pre-harvest factors have a great effect on postharvest quality of fruits. The combination of these factors includes genetic, environmental, cultural practices and physiological components. In this paper, we provide a review of studies on how pre-harvest factors influence the post quality of fruits. The influence of pre-harvest factors can be controlled by various cultural practices and high tech recent management practices. It was concluded by this study that understanding and managing pre-harvest factors properly will maintain the postharvest quality of fruits.

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1. INTRODUCTION

Fruits have been demonstrated to exhibit a broad spectrum of benefits including protection against different diseases and disorders, as well as having antioxidant, antimicrobial, anti-inflammatory, anti-diabetic and anti-aging properties. These protective effects are reported to be due to their high content of bioactive compounds, such as vitamin C, vitamin E, phenolic acids, ellagitannins, flavonoids and carotenoids. India is the second largest producer of Fruits after China, with a production of 44.04 million tonnes of fruits from an area of 3.72 million hectares. There is several pre-harvest factors affect the quality of many fruits. Quality means a combination of characteristics, attributes and properties that gives the values to human and enjoyments. Several pre-harvest factors like genetic , cultural practices as well as all the environmental factors are primarily influences the fruit growth, development, maturation and their physical impact on fruit quality. Poor orchard management and field sanitation leading to latent infections pathological and physiological disorders and insect damage. Efforts toward understanding the role of pre-harvest factors on postharvest quality brings growers into actively controlling the quality of their product and helps to make them willing participants in the quest for optimizing product quality. In the present article we review how pre-harvest factors can potentially impact the postharvest quality of fruit crops.

2. PRE-HARVEST FACTORS

Many aspects such as genetics, environmental factors, cultural practices and physiological factors affect the post-harvest quality of fruit crops.

2.1 Genetic Factors

The cultivar and species is the first factor determining the prevalence of different quality parameters of fruit such as colour, shape, size, and weight with biochemical composition. Several parameters of quality are controlled genetically. The quality parameters of fruits varieties differed from one another, which are supposed to be due to different genetic makeup of the variety and also because of the difference in their total fruit development and ripening period. Quality factors are reported to be more or less genetically controlled, as the level and chemical composition of the bioactive compounds vary according to cultivar [1]. In case of papaya fruits from bisexual plants are usually cylindrical or pyriform with small seed cavity and thick wall of firm flesh which stands handling and shipping well, while fruits from female flowers are nearly round or oval and thin-walled [2]. Cordenunsi et al. [3] reported significant differences in chemical composition among strawberry cultivars (Table 1). Cultivar and specie selection is therefore critical to the postharvest qualities of fruits.

2.2 Environmental Factors

2.2.1 Radiation

In many cases, modifications in the level of nutritional composition and antioxidant capacity of fruit have been associated with changes in the radiation interception in the field. Sun-exposed sides of fruits have higher levels of phenolic and vitamin C than shaded regions [4]. Studies performed with avocado produced with exposed to the sun on the tree (sun fruit) vs. shade have shown that fruit produced with exposed to the sun contained higher dry matter, higher levels of calcium, magnesium and higher oil content than shady fruit [Woolf et al. 5] (Table 2). However, the optimal irradiance levels required to maximize accumulation of the different nutritional and antioxidants composition in fruits.

2.2.2 Temperature

The fruit crops are particularly sensitive to temperature, most having specific temperature requirements for the optimum development of yield and quality parameters. Temperature influences the uptake and metabolism of mineral and nutrition by plant. Increasing temperature increase the transpiration, while lower temperature influences the flower sex and fruit setting. During the development stage of fruit, variation in temperatures can affect photosynthesis, respiration, aqueous relations and membrane stability as well as levels of plant hormones. High temperatures can increase the rate of biochemical reactions catalyzed by different enzymes and affect the mineral accumulation. Fruits like grapes and apple contain higher sugar and lower acid content when grown under high temperature. Wurr et al. [6] reported that kiwi grown under higher temperatures matured earlier that the same crops grown under lower temperatures. High temperature also increase sunburn and cracking in apples, apricot and cherries and increase in temperature at maturity will lead to fruit cracking and burning in litchi [7]. High temperature during fruit development stage of olive influence the accumulation and subsequent turnover of tannins and incomplete tannin inferior flavour development. Higher temperatures can increase the capacity of air to absorb water vapour and, consequently, generate a higher demand for water. Higher evapotranspiration indices could lower or deplete the water reservoir in soils, creating water stress in plants during dry seasons. For example, Exposure to elevated temperatures can cause morphological, anatomical, physiological, and, ultimately, biochemical changes in plant tissues and, as a consequence, can affect growth and development of different plant organs. These events can cause drastic reductions in commercial yield. Wang and Zheng [8] observed that 'Kent' strawberries grown in warmer nights (18–22°C) and warmer days (25°C) had a higher antioxidant activity than berries grown under cooler (12°C) days (Table 3).

2.2.3 Carbon dioxide (CO2) and ozone (O3) concentrations

Carbon dioxide and ozone (O3) concentrations in the atmosphere are changing during the last decade and are affecting many aspects of fruit crops production around the globe [9,10]. Ozone concentration in the atmosphere is also increasing which can potentially cause postharvest quality alterations in fruit crops. Stomata conductance and ambient concentrations are the most important factors associated with ozone uptake by plants. Ozone enters plant tissues through the stomates, causing direct cellular damage, especially in the palisade cells [11]. The damage is probably due to changes in membrane permeability and may or may not result in visible injury, reduced growth and, ultimately, reduced yield [12].

Table 1. Chemical composition (Mean ± SD of triplicate assays) of six strawberry cultivars harvested at the ripe stage

	Cultivar					
Constituen	**Mazi**	**Oso Grande**	**Dover**	**Pajaro**	**Toyonoka**	**Campineiro**
Water (%)	91.2 ± 0.2	90.5 ± 0.3	93.1 ± 0.1	90.8 ± 1.3	89.7 ± 0.2	92.8 ± 0.2
Soluble solids (%)	7.5	8.0	5.4	9.0	9.4	6.0
Glucose (mg/100 g)	713 ± 108	1713 ± 23	1520 ± 82	951 ± 52	1495± 271	1371 ± 389
Fructose (mg/100 g)	1327 ± 353	1928 ± 37	1852 ± 99	1232 ± 66	1591 ± 18	1547 ± 372
Sucrose (mg/100 g)	661 ± 120	1803 ± 67	908 ± 30	807 ± 48	1316± 212	847 ± 298
Citric acid (mg/100 g)	600	590	680	ND	590	710
Total ascorbic acid (mg/100 g)	50.9 ± 0.4	63.3 ± 2.3	40.1 ± 5.5	69.3 ± 2.1	55.6 ± 3.8	85.3 ± 0.8
Anthocyanin (mg/100 g)	54.9 ± 5.6	42.2 ± 8.3	52.2 ± 6.6	21.2 ± 2.0	19.1 ± 1.5	13.4 ± 2.3
Total phenolics (mg/100 g)	174.3 ± 2.3	249.8 ± 0.7	219.7 ± 0.6	233.1 ± 2.1	158.6± 3.0	289.2 ± 8.7

Source: Cordenunsi et al. [3]

Table 2. Fruit attributes of sun fruit (exposed to the sun on the tree) and shade fruit (inside the canopy) in avocado

Attribute measured	Sun exposed fruit	Shade fruit
Dry weight (%)	49.2	40.8
Total oils (%)	29.2	24.0
Ca (mg/100 g/ Fwt.)	30.9	14.9
Mg (mg/100 g/ Fwt.)	94.0	61.0

Source: Woolf et al. [5]

Table 3. Effect of Plant growth temperature on antioxidant activity against Peroxyl Radicals (ROO•), Superoxide Radicals (O2 •-), Hydrogen Peroxide (H2O2), Hydroxyl Radicals (OH•), and Singlet Oxygen (1O2) in fruit juice of two strawberry cultivars

Temperature (day/night °C)	Cultivar	ROO• ORAC (µmol TE/g)	O2 •- (µmol R-tocopherol/g)	H2O2 (µmol ascorbate/g)	OH• (µmol chlorogenic acid/g)	1O2 (µmol â-carotene/g)
18/12	Earliglow	12.6±0.3	4.24±0.13	2.16±0.04	4.19±0.23	0.55±0.02
	Kent	14.2±0.2	4.38±0.09	2.21±0.03	4.76±0.16	0.58±0.03
25/12	Earliglow	15.4±0.3	4.39±0.11	2.51±0.08	4.38±0.25	0.63±0.04
	Kent	16.40±.2	4.51±0.08	2.62±0.07	5.13±0.29	0.68±0.02
25/22	Earliglow	16.8±0.1	4.42±0.26	2.80±0.11	4.61±0.32	0.69±0.01
	Kent	17.6±0.3	4.73±0.15	2.98±0.15	5.34±0.18	0.70±0.02
30/22	Earliglow	18.9±0.2	4.67±0.18	3.36±0.09	5.73±0.42	0.70±0.03
	Kent	19.8±0.3	4.95±0.21	3.48±0.12	6.32±0.27	0.77±0.04
LSD0.05		0.75	0.13	0.11	0.18	0.04

Source: Wang and Zheng [8]

2.2.4 Rainfall

Rainfall affect the water supply to the plant resulting influences the composition of harvested fruits. Fruits are more susceptible to mechanical damage during shipment. Rain increased the susceptibility of fruit to handling damage. During prolonged periods of rain fruit quality may revert to that prevailing prior to the start of the rain event. High rainfall and the consequences on fruit growth also increase incidence of skin cracking disorders, such as found in cherries [13] and in apples [14].

2.2.5 Harvesting season and time

Quality of produce are greatly influenced by harvesting season e.g. Winter season harvest having more shelf life as compared to other season. When fruits are harvested in off season give more remunerative price to the grower. Harvesting during or immediately after rains should not be carried out since it creates most favourable conditions for multiplication of micro-organisms. Harvesting at improper maturity leading to lower eating quality, failure to ripen or excessive softening. Fruits should be harvested when temperature is mild because, higher temperature leads to faster respiration. In case of guava fruits of rainy season crop are rough, insipid, poor in quality and attacked by several insect pest and pathogen, where as winter season crop is superior in quality, free from disease pest and has high market value. Immature fruit lightly susceptible to shrivelling and mechanical damage and fruit pre mature or late are more susceptible to physiological disorders. Non climacteric fruits like cherry, strawberry, grapes pine apple, pomegranate are produce very small quantities of ethylene and responds to ethylene treatments. It should be picked at full ripe stage. Climacteric fruits like apple, mango, papaya, pear, peach sapota etc. produce larger quantities of ethylene and it should be picked at full maturity stage. Nagy [15] reported that immature citrus fruits contained the highest concentration of vitamin C, whereas ripe fruits contained the least.

2.3 Cultural Practices

2.3.1 Root stock scion relationship

The rootstocks in tree fruit crops are used to influence precocity, tree size, fruit quality, yield efficiency, mineral uptake, and to withstand adverse environmental conditions. Rootstock effect is clearly identifiable in the development of fruit firmness, fruit weight, and biochemical composition. Scion-rootstock-fruit quality interactions determine certain citrus fruit quality traits but there appear to be more direct rootstock effects on juice quality related to plant water relations. Gon Calves et al. [16] investigated scion-rootstock interaction by measuring, among others, fruit mass, firmness, total soluble solids, and titratable acids. They demonstrated that any rootstock species found to be the best choice for a particular scion cultivar can also be the worst choice for another cultivar. Spinardi et al. [17] reported that rootstock influences the accumulation of sugars, acids, polyphenols, anthocyanins, and vitamins in cherry fruit. It should also be noted that the quality properties of 'Kordia' variants change very rapidly in the later stages of ripening. Thus, growers should consider very carefully timing the harvest of 'Kordia' cherries because the quality of the fruit will change significantly in just a few days. Kremer-Köhne and Köhne, [18] illustrated the influence of 'Fuerte' vs. 'Hass' avocado on susceptibility to chilling injury. They also observed that internal fruit quality was much better in "Hass'' as influenced by different root stock (Table 4).

2.3.2 TCSA (trunk cross sectional area) of root stock

Trunk cross-sectional area influenced the fruit quality in terms of TSS, acidity and leaf nutrients contents [19]. Trunk cross-sectional area of tree fruit crops may be a useful index for estimation of growth, yield and quality of fruits [20]. Kumar et al. [21] reported positive relationship between TCSA and yield in apricot. A positive and significant correlation was also observed between TCSA and fruit yield (+0.953) and TSS (+0.872) in Kinnow [19] (Table 5). The improvement in fruit weight and size due to lower TCSA might be attributed to the reduction in number of fruit per trees. Divert more number of nutrients for development of limited number of fruit available on trees. The fruit size decreased with increased TCSA which might due to availability of less nutrient for development for more number of fruit/trees. More uptake of nutrient from the soil and translocation through TCSA which increased the photosynthetic activity of leaves. The trees having higher TCSA might be responsible for higher uptake and translocation of nutrient from the soil to aerial part of the tree. TCSA is measured by $TCSA=Grith^2/4P$ [22].

2.3.3 Pruning and thinning

Pruning reduce the vegetative buds and increase the development of new shoot and attributes to altered hormonal conditions better nutritional translocation in more number of new shoots and canopy frame work. In competition between vegetative and reproductive growth observations fruit are dominance sink and reproductive sink have a higher priority for water and nutrient than other plant parts. Asrey et al. [23] reported that anthracnose and stem-end rot disease percentage were reduced in ripe fruits from pruned trees of mango (Table 6).Pruning treatment appears to be an alternative strategy to obtain better yield and quality in densely populated old mango orchards [23]. Fruits of severe and medium pruning had more TSS content in ber [24]. Shoot pruning is also helpful in reducing the tree size and improving the fruit quality of guava [25].

Table 4. Internal quality and mineral content of Fuerte and Hass fruit as influenced by different rootstocks

Cultivar	Rootstock	Clean fruit (%)	PPM in dry mass		
			K	Mg	Ca
Fuerte	Duke 7	48	14980	1180	440
	G6	59	14140	1260	460
Hass	Duke 7	96	18250	1025	200
	G6	91	17100	975	225
	G755C	97	17250	950	275

Source: Kremer-Köhne and Köhne, [18]

Table 5. Effect of trunk cross-sectional area (TCSA) on growth, yield, productive efficiency, quality and leaf nitrogen and phosphorus contents in Kinnow mandarin

TCSA (cm^2)	Canopy volume (m^3)	Leaf area (cm^2)	Yield (kg/tree)	Productive efficiency (fruits/cm2)	TSS (%)	Acidity (%)	Leaf nitrogen (%)	Leaf phosphorus (%)
60.16	6.99	14.76	17.56	1.84	10.17	0.934	2.21	0.112
66.90	7.62	14.95	20.24	1.97	10.32	0.899	2.28	0.114
76.45	9.32	15.06	24.16	2.16	10.67	0.853	2.30	0.119
86.63	9.88	15.12	27.39	2.19	11.12	0.837	2.39	0.125
97.45	10.34	15.17	32.01	2.32	11.17	0.795	2.45	0.133
CV	11.37	0.77	7.50	7.83	2.29	5.94	3.42	4.33
CD at 5%	1.21	0.14	2.19	0.2	0.29	0.062	0.1	0.006
r with TCSA	0.779	0.736	0.953	0.731	0.872	-0.718	0.758	0.84

*r = Co-efficient of correlation;*p = 0.05; Source: Dalal and Brar [19]*

Table 6. Effects of pruning on postharvest disease incidence of 'Amrapali' mango fruits

Treatments	Anthracnose incidence (%)		Stem-end rot incidence (%)	
	2010	2011	2010	2011
Pruned	56.45 ± 0.99	57.82 ± 0.92	22.04 ± 0.75	24.48 ± 0.87
Unpruned	88.62 ± 1.11	86.26 ± 0.67	45.06 ± 0.98	48.59 ± 0.85

Source: Asrey et al. [23]

Thinning reduces the competition between fruits or plants and thus promotes a good balance between the vegetative and fruit parts and improves quality. In case of grapes over cropping can reduced fruit quality in current season and can also result in poor bud break, delayed growth and reduced fruit yield in the following season. With the increase in cluster in per vine, carbohydrates content in berries was also reduced to the maximum extent. The increase in carbohydrates content might be due to profuse canopy with increase in leaf area in lowest cluster load treatment that have been resulted in highest active biosynthesis rate ,which help to store more carbohydrates in the sink ,the bunch. This increase in food material is then transported from source to sink, the berries. Somkuwar et al. [26] observed that the reduction in cluster per grape vine resulted in to increase in TSS, acidity, and reducing sugar in berries (Table 7). Fruitlet thinning is one of the most efficient and widely used methods ofobtaining high quality apples [27]. BA treatments for fruit thinning led to fruit elongation, decreased fruit firmness and starch index, increased soluble solids content in apple [28]. Flower bud thinning was more effective in enhancing the fruit size, weight and quality as compared to flower and fruitlet thinning in Kiwifruit [29].

2.3.4 Planting density

High density planting (HDP) increases competition between plants, reduces light availability, and thus may decrease fruit quality. The average light intensity and temperature during the fruit season has been reported to affect the post-harvest quality of strawberry [3]. Total soluble solids were decreased with increasing plant density in muskmelon [30]. Poor management of fertilizers will increase physiological disorders in fruit crops due to deficiencies of some minerals or increase of other leading to toxicity. Increasing planting density decreased fruit quality (fruit weight, colour, soluble solids, sucrose, glucose, fructose, sorbitol, malic and citric acid) in apple [31]. Since availability of solar radiation in HDP is the most important factor as it governs photosynthesis and ultimately accumulation of carbohydrates in its efficient utilization under abundant availability conditions will determine the final yield and quality to a great extant. Therefore, maintenance of suitable plant density to properly utilize the available solar radiation, is essential for optimum production.

2.3.5 Plant growth regulators

Application of PGRs can provide significant economic advantage to the growers when used in appropriate concentration, as these have proven effective in stimulating a number of yield and quality parameters. The pathway to increase is yield to increase the fruit set. The growth regulators also contribute towards fruit growth and development. Some of the PGRs and chemicals are synthesized endogenously but occasionally they need to be supply minted exogenously for the intended purpose of improving fruit set, quality and yield. Application of synthetic gibberellins is widely known to improve fruit set in apple and pear Gill et al. [32]. Gill et al. [32] observed that the application of GA_3at 20 ppm reduced the seed number in pear fruits by 61 per cent over control (Table 8). Gibberellins are used for increasing fruit size and firmness of cherries and peaches [33]. Fruit treated with the optimum dose of BA + GA4+7 (50 mg·L-1) were larger and firmer than untreated fruit in cherry at harvest [34]. Increase in flowering may lead to more fruit and coupled with increasing in fruit size may be determine by cell increased, cell layer formation and cell division with increase sink strength of fruit. Fruit size increase due to cytokine and gibberellins application to apple and grapes was suggested to be cause by increased cell division and elongation and cell wall extensibility [35,36]. GA_3 permotes the cell expansion and elongation, so improve shape and quality of fruits. Sembok et al. [37] reported that GA_3 was able to delay the climacteric peak of banana and also retard the peel color changes, fruit softening and extend its shelf life up to 16 days. Kinetin delay chlorophyll degration resulting lower total anthocynanin. Auxin increase fruit size in citrus etc. It simulates cell expansion, especially of juice vesicles and cell expansion increase beside capacity for juice accumulation and finally fruit grow faster.

2.3.6 Pre-harvest packaging

Pre-harvest packaging in fruit crops protects the fruit from the attack of pest such as fruit fly and guava weevil. Different types of bagging material are used like Kraft type paper, baking paper, polyethylene, poly propylene spun bond fabrics (PSF), Bio degraded films. The variation in temperature, humidity, wind and sunlight are main factor responsible for mechanical injury and the increase in film rigidity, probably due to degradation of cross links. Photo degradation and cross linking are main causes of structural changes, the loss of resistance, increase in fragility of films. Poly propylene spun bond fabrics (PSF) having good mechanical resistance and bio-degradility. Kudachikar et al. [38] reviewed that the shelf life of ber fruits can be extend by coating the fruits in wax followed by packing in polythene bags. Maniwara et al. [39] observed that the MAP-2 plastic showed the best results in maintaining fruit quality, gas composition, and extension of storage life (up to 51 days) in passion fruit.

2.3.7 Irrigation

Water stress is of great concern in fruit production, because trees are not irrigated in many production areas around the world. It is well documented that water stress not only reduces crop productivity but also tends to accelerate fruit ripening [40]. Pre-harvest water stress caused increased post-harvest browning potential in avocado and also interacted adversely with restricted ventilation [41]. Decreasing fruit moisture loss during storage significantly decreased the incidence of pathological and physiological disorders [41]. Moisture stress also increase sunburn and cracking in apples, apricot and cherries and increase in temperature at maturity will lead to fruit cracking and burning in litchi [7]. Irrigation influences the water and nutrient supply to the plant and can affect the nutritional and antioxidant capacity of fruit. In the case of peaches, it has been shown that lower levels of irrigation results in higher density of fruit surface trichomes and consequent lower weight losses in storage [42].

2.3.8 Nutrition

Nutrients are important components of commercial fruit production. These have significant impacts on fruit quality. These include effects on fruit color, texture, disease susceptibility, juice composition, and the development of physiological disorders [45]. Fruit quality usually improves as soil moisture and nutrients increase from deficient to optimum, levels that produce maximum yield may not always correspond to those that result in the highest fruit quality and maximum quality retention [43]. Poor management of fertilizers will increase physiological disorders due to deficiencies of some nutrients or increase of other leading to toxicity. Deficiency of ‘K’ detoriates the quality of fruit and cause heavy flower and fruit drop. Zn deficiency is most wide spread and foliar spray of zinc sulphate 0.5% improved the general condition of plants and decreased the die back of twing and leaf chlorosis in kinnow. K application increased the photosynthesis, which lead to accumulation of carbohydrates and increased fruit yield and quality. The increase in juice content due to zinc application can be attributed because it has regulated the water relation in plants. Zincand potassium regulate the enzymatic activities, and would have activated the enzymes involved in the conservation of polysaccharide into simple sugars that increase the TSS of fruits [44]. Pre harvest application of calcium compound have good impact on the storage life if supplemented with correct and appropriate packaging materials in ber. Singh et al. [45] observed that the pre harvest spray of $CaCl_2$ and boric acid coupled with completely packed poly bags is able to prolonged shelf life of ber fruits. High Ca uptake in fruits reduces respiration rate and ethylene production. So delay ripening, increase firmness, and reduce the incidence of physiological disorders in fruit crops resulting increase post-harvest life. Improvement in banana due to nitrogen and potassium nutrition has also been observed by [54] (Table 9). High N content reduce post-harvest life due to increase susceptibility to mechanical damage, physiological disorders and decay.

2.3.9 Use of organic materials

Organic farming is a form of agriculture which excludes the use of synthetic fertilizers and pesticides, plant growth regulators and genetically modified organisms [46,47]. Continues use of chemical fertilizers without organic manures cause problems to soil health and decrease the quality of produce. Bulk density increase –herbicide compare to living or straw mulch. Living mulch and straw mulch increase earth worm and increase cation exchange capacity. Earthworms are important for their role in mixing fertilizers, insecticides and organic residues into the soil. Therefore, earthworms can play a good role in quality improvement of fruit crops. A sawdust mulch reduced physiological disorders in apple fruit and increased the Ca and K concentrations in the leaves [48]. Organic management in apple may delay on-tree fruit ripening and also improve the fruit eating quality [44]. Singh et al. [50] observed that the application of FYM, cakes, CPP and NPK in different combination improved the soil physiochemical properties and nutrient availability to the plants which resulted into better growth, yield and quality attributes of aonla (Table 10). The increasing demand of consumers for fruit quality coupled with unsustainable productivity, organic farming is claimed to be most alternative. In this situation, the use of organic manures and biodynamic become important for quality improvement of fruits.

2.4 Physiological Factors

Fruit size in general is negatively correlated with firmness and amount of berry phenolics [51]. Fruit size can be improved either by increasing carbohydrates availability to fruit or by increasing fruit sink strength [52]. When the synthetic auxins are applied at the onset of cell enlargement stage fruit sink strength is increased and carbohydrates accumulation in the fruit enhanced [52]. Smaller fruits are firmer as they have the same number of cells as larger fruit, giving a greater density to the plant tissue [51]. The relationship between ripening period and temperature is due to fruit respiration. Fruit respiration depends on many enzymatic reactions, and the rate of these reactions increases exponentially with increase in temperature. Fruit bearing order may also have a significant effect on the bioactive compounds in berry crops like mulberry [51]. The phenolic content is reported to be increased by 10-25% from primary to tertiary fruits [53]. Water loss may affect fruit

Table 7. Effect of cluster thinning on biochemical parameters of berry juice in grape cv. Jumbo seedless

Treatments (No. of clusters per vine)	TSS (°Brix)	Acidity (%)	pH	Reducing sugar (mg/g)	Total phenols (mg/g)	Total proteins (mg/g)	Total carbohydrates (mg/g)
23	17.35	0.47	3.43	71.16	11.42	25.90	50.1
27	16.40	0.46	3.46	67.25	11.18	22.60	47.82
33	15.50	0.49	3.38	67.53	09.40	21.42	45.49
37	15.00	0.48	3.43	44.25	08.26	19.18	43.08
45	14.85	0.48	3.39	39.89	08.64	18.6	44.25
50	14.70	0.40	3.42	31.89	7.4	18.5	42.44
$CD_{0.05}$	0.48	0.05	0.27	1.56	0.18	0.39	2.09
CV%	5.83	7.58	5.95	5.38	5.22	5.58	5.20

Source: Somkuwar et al. [26].

Table 8. Effect of chemicals sprayed at different flowering stages of semi-soft pear cultivar 'Punjab Beauty' on seed number

Treatment	Seed number		
	Full bloom	Petal fall	Mean
GA3 10 ppm	2.17	2.29	2.23
GA3 20 ppm	2.00	2.00	2.00
GA3 30 ppm	2.49	2.29	2.39
Sucrose 5%	4.17	4.43	4.30
Sucrose 10%	4.67	4.87	4.77
Sucrose 15%	4.67	4.87	4.77
Boric acid 100 ppm	4.67	4.67	4.67
Boric acid 200 ppm	4.67	4.73	4.70
Boric acid 300 ppm	5.17	5.17	5.17
Control	5.17	5.17	5.17

Source: Gill et al. [32]

Table 9. Fruit quality of micro propagated Robusta banana at different NPK doses

Quality characters	Bunch weight (kg)		Finger weight (g)		TSS (%)		Pulp/peel ratio	
Nutrient dose (g/plant/ crop)	**First crop A**	**Second crop B**	**First crop A**	**Second crop B**	**First crop A**	**Second crop B**	**First crop A**	**Second crop B**
Nitrogen								
0	6.5	3.4	109.7	69.8	22.5	22.4	3.46	3.41
100	8.7	7.3	136.6	106.1	23.1	22.6	3.49	3.46
200	13.1	10.4	193.1	134.1	23.2	22.8	3.76	3.61
300	16.6	12.0	234.0	139.5	23.8	23.1	3.76	3.76
CD at 5%	2.3	1.2	21.1	15.7	0.07	0.12	-	-
Phosphorus								
0	8.1	5.3	141.9	91.4	23.0	22.7	3.56	3.51
50	11.6	9.3	171.7	121.6	23.1	22.7	3.63	3.56
100	13.9	10.3	191.3	124.0	23.4	22.8	3.65	3.61
CD at 5%	2.6	1.4	24.3	18.2	0.08	0.14	-	-
Potassium								
0	8.2	5.4	135.3	91.4	22.9	22.4	3.53	3.48
100	11.1	8.7	170.6	120.3	23.1	22.6	3.61	3.53
200	12.2	9.1	181.5	117.9	23.3	22.8	3.65	3.59
300	13.5	9.9	186.0	119.9	23.4	23.0	3.67	3.64
CD at 5%	2.3	1.2	21.1	15.7	0.07	0.12	-	-

Source: Panday et al. [54]

Table 10. Effect of various sources of nutrients on yield and quality attributes of aonla

Treatment	TSS (°Brix)	Total sugars (%)	Acidity (%)	Vitamin C (mg /100 g)	Fruit pulp (g)	Fruit weight (g)	Yield/ plant (kg)
T_1(Neem cake + FYM + CPP)	8.50	4.8	2.00	390.40	39.21	41.19	30.00
T_2(castor cake + FYM + CPP)	8.30	4.7	2.05	385.15	36.95	39.00	27.68
T_3 (groundnut cake + FYM + CPP)	8.25	4.5	2.15	384.68	37.90	40.00	29.00
T_4 (Mahua cake + FYM + CPP)	8.20	4.3	2.10	384.32	35.98	38.18	28.16
T_5(FYM + standard dose of NPK)	8.25	4.6	2.10	388.17	40.35	42.50	32.15
T_6 (FYM + half of standard dose of NPK)	8.20	4.7	2.20	384.00	40.00	41.50	30.30
CD at 5%	NS	NS	NS	5.12	1.02	1.10	3.15

Source: Singh et al. [50]

physiology during its ripening, i.e. earlier ethylene synthesis [55], or a rise in membrane deterioration. Water loss causes fruit to lose its firmness, the peel or pulp becomes soft and shriveled, and ripening period reduces.

3. CONCLUSIONS

The pre –harvest factors, such climate change and cultural regime are directly and indirectly affect the production and quality of fruit crops grown in different climates around the world. Lack of cultural practices leading to undesirable fruit quality with non-uniform maturation. Temperature can directly affect crop photosynthesis, and a rise in global temperatures can be expected to have significant impact on postharvest quality by altering important quality parameters such as synthesis of sugars, organic acids, antioxidant compounds and firmness. Rising levels of carbon dioxide and Increased levels of ozone in the atmosphere can lead to detrimental effects on postharvest quality of fruit crops. Nutrition management and organic fertilisation in fruit crops significantly influences the level of different bioactive compounds in fruits, so optimised fertilisation is very important for marketability of fruits after harvest. Finally, the use of new cultivars of fruits crops tolerant to high temperature, resistant to pests and diseases, short duration and producing good yield under stress conditions, as well as adoption of hi–tech horticulture and judicious management of natural resources can be good strategy for improvement in post-quality of fruit crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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