Research & Reviews: Journal of Agriculture and Allied Sciences
e-ISSN: E 2347-226X
p-ISSN: 2319-9857

Recent Advances in Pre-Harvest Factors Affecting Post-Harvest Life of Fruits

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Research Article

Received: 17/09/2021
Accepted: 01/10/2021
Published: 08/10/2021

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Keywords: Quality; Pre-harvest; Maturity; Post-harvest; Harvesting

ABSTRACT

The overall quality and condition of fresh produce cannot be improved after harvest. Maximum fruit quality can be achieved only by understanding the roles of pre- harvest factors in fruit quality. Pre-harvest factors affect both fruit growth during its development by changing the accumulation of water and dry matter, including biochemical and mineral compounds and fruit behaviour during its storage. Fruit quality consists of many attributes, both intrinsic, including texture, sweetness, acidity, aroma, shelf life and nutritional value and extrinsic such as colour or size. Therefore, the final fruit quality at the consumer level depends not only on the maturity stage at harvest and postharvest conditions during storage and marketing but on environmental factors as well. These factors can be controlled by various cultural practices i.e., light and temperature through tree pruning, carbon availability through irrigation management.

INTRODUCTION

The overall quality and condition of fresh produce cannot be improved after harvest. The final potential market value of the produce depends on the grower's decisions on what and when to plant and on the subsequent cultivating and harvesting practices. Growers in general rely on their own experience and local traditions in selecting crops and in cultivation practices, but if they want or need assistance, they may need to be referred to agricultural extension officers or possibly to research and development specialists of their national department of agriculture or its equivalent.

Maximum fruit quality can be achieved only by understanding the roles of pre- harvest factors in fruit quality. For example, in case of Mango it is a climacteric fruit generally harvested green, which ripens during the marketing process (storage, transport etc.) with an irregular storage period between harvest and consumption [1]. In addition to these market constraints, we must also take the high variability of pre- harvest and post-harvest factors into account, as well as the difficulty to harvest fruit at an optimal maturity stage. All of these factors are involved in providing strong heterogeneous batches of mango in the supply chain in terms of fruit size, gustatory quality and post-harvest behavior. Studies on mango dealing with the factors that determine the final quality of fruits at the consumer level have generally focused on maturity at harvest and on post-harvest management. However, as is the case with other stone fruits, pre- harvest cultural practices, which affect the environmental conditions of fruit development, profoundly influence post-harvest performance and final quality.

Fruit quality consists of many attributes, both intrinsic, including texture, sweetness, acidity, aroma, shelf life and nutritional value and extrinsic such as colour or size. Mango is a fleshy fruit containing more than 80% water. Its size depends on the accumulation of water and dry matter in the various compartments during fruit growth. The skin the flesh and the stone have specific compositions that appear to accumulate water and dry matter at different rates, depending on environment conditions [2]. The patterns of these compounds during mango development and maturation are well described, even if many studies deal with the evolution of fruit flesh composition during ripening according to harvest date. Therefore, the final fruit quality at the consumer level depends not only on the maturity stage at harvest and postharvest conditions during storage and marketing but on environmental factors as well. These factors can be controlled by various cultural practices i.e., light and temperature through tree pruning, carbon availability through irrigation management.

MATERIALS AND METHODS

Quality of horticultural produce

The word "quality" is used in various ways with reference to fresh horticultural produce. 'Quality' does not have a complete and objective definition in post – harvest technology of horticultural crops, but it may be defined in terms of end use. 'Quality' of fresh horticultural commodities is a combination of characteristics, attributes and properties that give the commodity value to humans for food (fruits, plantation crops, vegetables, etc.) and enjoyment (ornamentals) as defined.

Consumers consider good quality fruits and vegetables to be those that have fresh market quality, i.e., good colour, firm or tender, good flavour and nutritive value. Although, consumers buy on the basis of appearance and feel, their satisfaction and repeat purchase are dependent upon edible quality. Several quality components including appearance, texture, flavour (taste and smell), nutritive value and safety are used to evaluate quality of the commodities for trade or in specifications for grade and standard, selection in breeding programme and evaluation of responses to various environmental factors and pre- and post- harvest treatments. Quality and safety are the two most important factors in the international marketing of horticultural commodities in the present scenario of liberalized world trade. Nutritional loss (loss of vitamins, antioxidant, and health-promoting substances) or decreased market value is another important loss that occurs in fresh produce. Quality of fresh produce is governed by many factors. The combined effect of all decides the rate of deterioration and spoilage.

There is no universal set of quality standards for any given commodity. Each country has its own criteria depending on local circumstances. Different standards may apply for produce for home consumption and for export. Generally, only the better/higher quality produce is exported, because of longer time it has to survive before consumption and to excel in the international market competition.

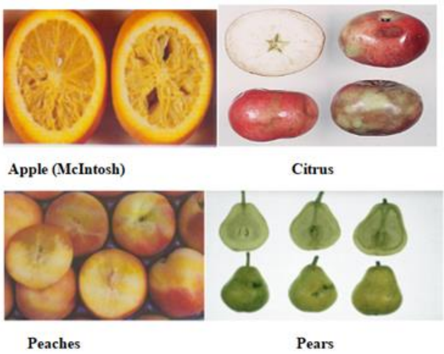
Pre- harvest factors and practices

There are numerous pre-harvest practices involved in deciding the quality of a horticultural crop at harvest, which has a major influence on its post- harvest life, and quality. The pre-harvest factors not only include the genetical make up/variety and maturity at harvest , but also the climate(temperature, humidity, rainfall, sunshine and wind) and soil in which the product was grown and the horticulture procedures. Several of these factors often interact giving complex inter-relationships. Pre-harvest factors may interact with the practices like fertilizer application, irrigation or chemical sprays.

Environmental factors

Temperature: It is commonly accepted that the temperature during production affects growth and development. Temperature has a direct influence on metabolism and, thus, indirectly affects cellular structure and other components which determine texture. There is a correlation between fruit temperature and firmness. This relationship is not necessarily measured in all fruits and vegetables, this probably holds true for most non- chilling sensitive fruits and vegetables because tissue density would be higher at lower temperatures. According to low temperature conditioning is more effective than heat treatment to prevent chilling injuries and increase the quality of fruits. Water content of plants has a direct influence on cell turgor and the degree of cellular hydration is known to result in marked changes in plant texture. This is particularly important to texture of leafy vegetables. It is generally accepted that small changes in percent water can result in undesirable texture changes. A 3% water loss in spinach and a 5 % water loss in apples result in a product unmarketable due to loss of texture. Although changes in osmotic conditions are not known to be associated with changes in texture during fruit ripening some evidence in tomato fruit suggest that turgor changes may be involved. It has been suggested in other species, including Satsuma mandarin and apples (Figure 1).

Figure 1. Freezing injury symptoms.



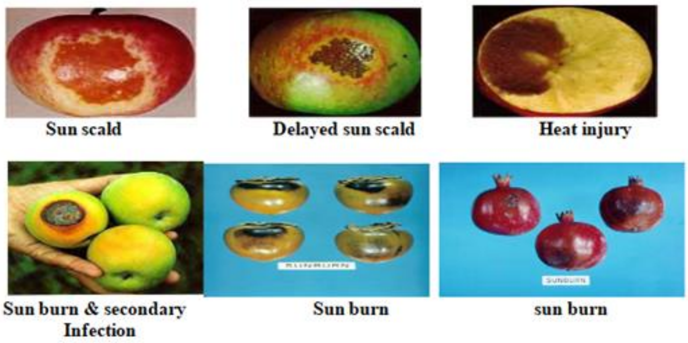
Light environment

Light exposure is a factor that varies with the position and of the fruit itself. The effect of light on photosynthesis includes both a direct effect of the photosynthetic photon flux on the rate of electron flow and an indirect effect of light on leaf photosynthetic capacity, since plants allocate nitrogen resources within the canopy to enhance photosynthetic capacity in portions of the tree receiving high irradiances. Lower carbon assimilation in shaded leaves. Fruit size and dry matter content decrease in 'Kensington' fruit from upper to lower positions in the canopy. Another quality criterion, soluble solids content and total sugars, which can be related to dry matter content, were determined to be lower in mango fruit from the lower portion of the canopy.

Another effect of light exposure on mango quality deals with its attractive trait, especially the red pigmentation of skin through the influence of light on anthocyanin production [3]. Mangoes inside the canopy retain a greater skin colour due to the decrease of fruit exposure to sunlight. Bagging of fruit a cultural practice used to reduce fruit disease diminishes light received on the skin and reduces the area of red colour on the peel and its intensity. Intensity of solar radiation affects fruit texture.

Exposure to excessive sunlight can result in sun scald or sun burn. A loss in apple fruit quality associated with sunscald. Fruit in interior shaded areas of apple trees were not as firm as fruit produced in the outer regions of the canopy which had better exposure to sunlight. Light is required for proper fruit development and can improve fruit texture, but light above photosynthetic saturation levels, especially intense exposure can increase fruit temperature and may result in fruit damage and a loss of firmness. Increased exposure to light increases fruit size, total soluble solids and flesh firmness. In South Africa, soluble solid content in pears was improved under conditions with higher heat unit accumulation, as a result of high photosynthetic rates and carbohydrate reserves (Figure 2).

Figure 2. Effect of light on photosynthesis.



Carbon availability

It is a recognized fact that fruit growth is mainly affected by the availability of carbohydrates. For mango it would be useful to be able to determine the leaf to fruit ratio of a girdled branch or the crop load of a tree required to obtain optimum fruit size, since biennial bearing, which can be due to depletion of carbohydrates, occurs in many mango cultivars. Several studies have shown that mango fruit size increased with increasing leaf to fruit ratio. In addition to produce larger fruit at harvest on branches with the highest leaf to fruit ratio, changing carbohydrates supply to the fruit increased the proportion of fresh mass in the flesh to the rest of the fruit. This relationship between fruit size and the fraction of fruit mesocarp as observed at the tree level by effectively managing cultural practices that affect crop load [4]. The amount of carbohydrates supplied to tree fruits depends on source size and activity and on sink demand, according to the stimulation in the mango growth. Changing the number of leaves per fruit directly affected source size as well as source activity. Changing carbon availability to fruit influenced both the dry mass and the water mass of its three main compartments: skin, pulp and stone. In mango it is observed that increase in fruit size with increasing availability of assimilate supply. Expressed per unit of structural dry mass, the concentrations of calcium were higher in flesh from low leaf to fruit ratios. Effects of carbon availability on key components involved in the perception of mango flavor, measurement of useful indices such as total soluble solids and titrable acidity confirmed that an increase in leaf to fruit ratio had a positive effect on sweetnes and a negative one on sourness.

Water supply (irrigation)

Growing plants need a continuous water supply for both photosynthesis (the process by which plants convert light to chemical energy and produce carbohydrates from carbon dioxide and water) and transpiration (the giving off by a plant of vapour containing waste products). Bad effects can be caused by:

- Too much rain or irrigation, which can lead to brittle and easy damage in leafy vegetables and to increased tendency to decay.
- Lack of rain or irrigation, which can lead to low juice content and thick skin in citrus fruit.
- Dry conditions followed by rain or irrigation, which can give rise to growth cracks or secondary growth in potatoes or to growth cracks in tomatoes.

In Bartlett pear, size and TSS were closely related to the level of water stress experienced by the tree. Increased tree water stress was associated with increases in fruit TSS, firmness, and yellow fruit colour and in decreased fruit size and vegetative growth. There were no evident effects on post-harvest disorders such as softening, internal breakdown, scald or decay.

There is considerable evidence that water stress at the end of the season, which may be achieved by irrigation cutoff or deficit irrigation relative to evapotranspirative demand for generally more than 20 days prior to harvest, may markedly improve TSS in tomatoes. Irrigation cutoff may also facilitate harvests and minimize soil compaction from mechanical harvest operations. Late season irrigations with saline water have also been shown to increase tomato SSC. Although a higher TSS may result in premiums paid to producers, because of the link between applied water and yield, irrigation practices typically aim at the best overall economic balance between productivity and quality.

Post-harvest losses due to storage diseases such as neck rot, black rot, basal rot and bacterial rot of onions can be influenced by irrigation management. Selecting the proper irrigation system relative to the crop stage of growth, reducing the number of irrigations applied and assuring that onions cure adequately prior to harvest can help prevent storage losses. Management of water frequently poses a dilemma between yield and post-harvest quality. A deficiency or excess of water mar influence post-harvest quality of berry crops. Extreme water stress reduces yield and quality; mild water stress reduces crop yield but may improve some quality attributes in the fruit; and no water stress increases yield but may reduce post-harvest quality. In strawberries, reduction of water stress by natural rainfall or irrigation during maturation and ripening decreases firmness and sugar content and provides more favorable conditions for mechanical fruit injury and rot. If strawberry plants are over irrigated, especially at harvest, the fruit is softer and more susceptible to bruising and decay.

Plant roots under drought stress often produce ABA as a hormonal signal to the shoot to reduce the stomatal aperture. In the rainy season, the fruit reaches senescence faster than in dry season, becoming its skin yellow and soft. This makes the fruit more susceptible to mechanical damage, such as bruises, cuts, and wounds, increasing the risk of deterioration during its post-harvest handling. Moreover, in this season, the humidity increases, supporting conditions for the propagation of fungal, bacterial and viral diseases which are expressed later on during post-harvest phase. Therefore, the post-harvest requires more demanding and careful handling during rainy season compared to the dry season, to keep Tahiti lime quality and increase its shelf life.

Cultivar and rootstock genotype

Cultivar and rootstock genotype have an important role in determining the taste, quality, yield, nutrient composition and post- harvest life of fruits and vegetables. The incidence and security of decay, insect damage and physiological disorders can be reduced by choosing the correct genotype for given environmental conditions. Breeding programs are constantly creating new cultivars and rootstocks with improved quality and better adaptability to various environmental and crop pest conditions. Some experts consider the most important cultivar characteristic for fruits and vegetables to be disease resistant including resistance to disease that diminish post-harvest quality. Control of some post-harvest disease may include breeding for resistance to the vector (e.g., aphid, nematode, leafhopper or mite), rather than just for the pathogen. In Australia, it has been claimed that the rootstock of the avocado tree has a major influence on the amount of post-harvest rots that avocado fruit develop when ripe [5].

RESULTS AND DISCUSSION

Cultivation practices

Good crop husbandry is important in achieving good yields and quality of fresh produce. Certain aspects are particularly important, such as:
Weed control: Weeds are commonly alternate or alternative hosts for crop diseases and pests and those growing in fallow land near crops are as important as those growing among the crops. Weeds also compete with crops for nutrients and soil moisture.

Crop hygiene

Decaying plant residue, dead wood and decaying or mummified fruits are all reservoirs of infection causing post-harvest decay. Their collection and removal are crucial factors in the reduction of post-harvest losses.

Crop load: In most fruits, fruit let thinning increases fruit size while also reducing total yield; a balance between yield and fruit size must be achieved. Generally, maximum profit does not occur at maximum marketable yield since larger fruits bring a higher market price. For example, leaving too many fruits on a tree reduces fruit size and SSC in the early ripening May Glo nectarine and the late ripening O'Henry peach. Crop load on O'Henry peach trees affected the incidence of internal breakdown measured after 1, 2 and 3 weeks at 5°C. Despite a large amount of mealy fruits in all lots, the overall incidence of mealiness and flesh browning in fruit from the high crop load was low, intermediate in fruit from the commercial crop load and the highest in fruit from the low crop load.

Also, it is well known that the fruit count: leaf count ratio (F:L) influences high bush blueberry fruit quality more than mineral nutrition. A high F:L results in later ripening lower TSS and smaller berries. During the harvest season, as berries are picked, TSS increased when the F:L drops to between 1:1 and 2:1. In general, berry crops have better post-harvest fruit quality when the plant microclimate is improved by having an open canopy and maximum air circulation.

Fruit canopy position

Large differences in SSC, acidity and fruit size were detected between fruit obtained from the outside versus inside canopy positions of open- vase trained peach , nectarine and plum trees. Peaches grown under a low light environment (outside canopy) have a longer storage and market life than peaches grown under a low light environment (inside canopy). The use of more efficient training system that allows sunlight penetration into the center and lower canopy areas is recommended to reduce the number of shaded fruit.

Numerous studies have shown that improving light penetration into the canopy improves fruit composition of grapes, including increased TSS, aroma, anthocyanins and total soluble phenols; but it reduced titrable acidity and potassium content. In kiwifruit, shading reduces fruit count rather than individual fruit weight, delays harvest maturity, decreases SSC and accelerates the rate of fruit softening during storage.

In grape vines, open canopies and optimal air circulation can be attained by the proper combination of plant spacing, vegetative thinning and training. Vine vigor can be controlled by stem training and by avoiding high levels of nitrogen. This improves light penetration to leaves ensuring that they continue to produce photosynthesis and do not prematurely senesce and become pathogen hosts. An open canopy lowers the humidity around the plant, reduces wetting periods and improves spray penetration, which reduces disease and insect problems and improves foliar nutrient application. An open canopy also enables the pickers to harvest more rapidly, decreasing the likelihood of overripe fruit.

Leaf removal: Summer pruning and leaf pulling around the fruit increases fruit light exposure and, when performed properly, can increase fruit colour without affecting fruit size and SS. Excessive leaf pulling or leaf pulling did too close to harvest, however, can reduce both fruit size and SSC in peaches and nectarines.

Girdling

Girdling (a commercial practice in which the phloem of the tree or vine is removed) 4 to 6 weeks before harvest can increase peach and nectarine fruit size and advances and synchronize maturity. In some cases, girdling increases fruit SSC but also increases fruit acidity and phenolics so that the taste resulting from the additional sugars may be masked.

Girdling can also cause the pits of peach and nectarine fruits to split, especially if it is done too early during pit hardening. Fruits with split- pits soften more quickly than intact fruit. Split-pits, as a consequence of girdling have not been observed in Black Amber, Santa Rosa, Friar or Royal Diamond plum cultivars; however rapid fruit softening and severe tree weakening have been noted.

In grapes, the balance between vegetative and fruit growth can be altered by girdling vines that have excessive vigor and a history of poor berry and bunch size. In cases, girdling may improve bunch shape and berry size.

Crop rotations

Crop rotation may be an effective management practices for minimizing post-harvest losses by reducing decay inoculums in a production field. Because soil borne fungi, bacteria and nematodes can build up to damaging levels with repeated cropping of a single vegetable crop, rotations out of certain vegetables are commonly recommended in intensive vegetable production regions.

Four year rotations with non-cucurbit crops are routinely recommended for cucurbit disease management, as are 4-year rotations for garlic to decrease postharvest disease incidence. There is also evidence that the use of plastic mulches can increase postharvest losses from decay in vegetables such as tomatoes. The impacts of cover crop-derived mulches on postharvest quality have not been well evaluated for vegetable crops.

Sanitation efforts such as working clean fields before entering infested fields and washing equipment and clothes to remove soil and debris when leaving infested fields can help reduce contamination and postharvest losses in crops grown in clean fields.

Pruning and thining

Pruning affects the size, colour, acidity and sugar content of grape, phalsa, ber, peach, apple etc. Thinning in grapes, dates, peaches, plum etc. increases size. Colour, acidity and sugar content of fruits. The reduction in cluster per grape vine resulted in to increase in TSS, acidity, and reducing sugar in berries (Table 1).

Table 1. 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	25.9	50.1
27	16.4	0.46	3.46	67.25	11.18	22.6	47.82
33	15.5	0.49	3.38	67.53	9.4	21.42	45.49
37	15	0.48	3.43	4.25	8.26	19.18	43.08
45	14.85	0.48	3.39	39.89	8.64	18.6	44.25
50	14.7	0.4	3.42	31.89	7.4	18.5	42.44
CD0.05	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	5.2

Mineral nutrition

Among the pre harvest treatments, nutrition of the plant are extensively studied affect as it the postharvest quality. Intake of balanced minerals is the most important pre-harvest factor influencing the postharvest qualities of the horticultural crops. Excess or deficiency of certain elements can affect the quality and postharvest life. Several physiological disorders of horticultural produce are attributed to the deficiency of mineral nutrients. These disorders are minimized or avoided by pre harvest supply/treatments with specified mineral, even though the actual role of the mineral in preventing the disorder has not been established for most disorders [5]. The application of fertilizers to horticultural crops has been shown to influence their post-harvest respiration rate. This has been reported for a variety of fertilizers on several crops including potassium on tomato, nitrogen on oranges and organic fertilizers on mangoes. Plant nutrition is an important factor that potentially affects both the quality and postharvest life of fruit. Optimum plant performance depends on a balanced availability of mineral nutrients that can be limited in many soils around the world. Nitrogen (N) and potassium (K) are the principal nutrients needed by plants.

Nitrogen

In general, pre harvest treatments with higher dosages of nitrogen are reported to reduce the quality and storage life of the horticultural produce. In onion, supply of higher nitrogen reduces the shelf- life. Storage behavior of onion bulbs grown with different treatments of graded levels of nitrogen significantly decreased the dry matter and increased rotting and spouting of the bulbs, thereby reducing their storability.

The increases in nitrogen levels beyond 160 kg/ha caused steep increase in total storage losses of onion bulbs. Higher rates of application of nitrogen fertilizer to apple trees could adversely affect the flavour of the fruit.

High nitrogen increases the susceptibility of apple flesh to core browning during storage. Bunches of Italia grapes from vines treated with 35% nitrogen as urea and 65% as calcium nitrate through fertilizers had less water loss and less decay during storage. Excessive nitrogen fertilization significantly increased the incidence of rot in kiwi fruit in cold storage.

Nitrogen can reduce mango fruit quality by increasing green colour and anthracnose disease in ripe fruit. Application of more than 150 g nitrogen/tree resulted in a higher proportion of green colour in ripe fruits of mango. Anthracnose disease was significantly higher with 300 g nitrogen/tree treatment.

Phosphorus

There is little information in literature on the effects of phosphatic fertilizers on crop storage. Application of 100 kg/ha of phosphorous minimized weight loss, sprouting and rotting of onions compared with lesser application. P nutrition can alter the post-harvest physiology of cucumber by affecting membrane lipid chemistry, membrane integrity and respiratory metabolism. Foliar fertilization of phosphorus and potassium resulted in increased amounts of sugars (glucose, sorbitol, soluble solids) and organic acids (malic and citric acid) in 'Williams' pear.

Potassium

The major mineral in plants is potassium and both high and low levels of potassium have been associated with abnormal metabolism. High levels of potassium have been associated with development of bitter pit in apple. Low potassium is associated with changes in the ripening of tomato and delays the development of a full red colour by inhibiting lycopene biosynthesis. The application of potassium to citrus trees could affect the shape of the fruits and increase their acidity.

Spraying Shamouti orange trees with 9 % 'Bonus', a potassium fertilizer reduced the incidence of rind pitting. Pre-harvest spray of potassium to Jonagold apple trees produces bigger size fruits and increased soluble solids concentrations after storage of fruits than those of control. A strong relationship in fruit potassium and titratable acidity in 'Rocha' pears.

Calcium

Among the mineral nutrients, calcium has been associated with more deficiency disorder than other minerals and some examples are given in table (Table 2).

Table 2: Calcium related disorders of fruits and vegetables.

Apple	**Bitter pit, lenticel blotch, cork spot, lenticel breakdown, cracking, jonathan spot and water core**
Avocado	End point
Cherry	Cracking
Mango	Soft nose
Pear	Cork spot
Strawberry	Leaf tip burn
Watermelon	Blossom- end rot
Bean	Hypocotyls necrosis
Brussels'sprout	Internal browning
Cabbage	Internal tip burn
Carrot	Cavity spot, cracking
Celery	Blackheart
Lettuce	Tip burn
Pepper	Blossom- end rot
Potato	Sprout failure, tip burn
Tomato	Blossom-end rot, black seed, cracking

Some of the disorders such as blossom-end rot of tomatoes can be readily eliminated by the application of calcium salts as pre- harvest spray, while for others such as bitter pit of apples, only partial control is obtained. Pre- harvest foliar spray with calcium followed by post- harvest dip in calcium increased the firmness of tomato fruits. Calcium has been shown to affect the activity of many enzyme systems and metabolic sequences in plant tissues. The activities of enzymes involved in fruit ripening, viz. pectin methyl esterase (PME), poly galacturonase (PG-ase) are increased or inhibited depending on the concentrations of calcium applied. The ability of calcium to regulate the activities of these various systems has led to spectulation that calcium may have a role in the initiation of normal fruit ripening process. It is also possible that calcium prevents or delays the appearance of some physiological disorders.

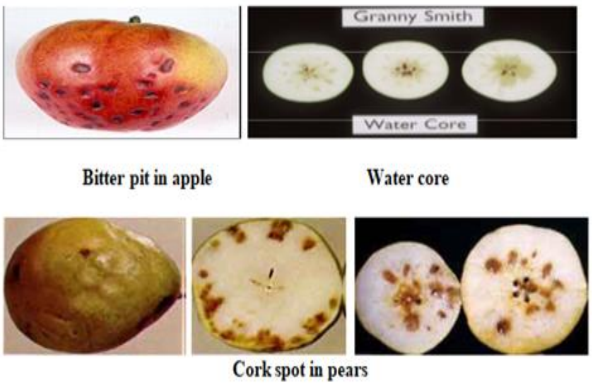
Gypsum applied to sapota trees up to 4 kg/tree, once every week for six weeks prior to harvest, improved the appearance of fruit, pulp, colour, taste, firmness, aroma and texture after storage in ambient conditions. Calcium chloride (2%) pre- harvest spray one month before harvest followed by post-harvest dip in GA3 (100 ppm) extends shelf- life of sapota. Pre-harvest spray with calcium nitrate or calcium chloride to papaya trees fifteen days before harvest extended the shelf-life of the fruits, though TSS and total carotenoids contents decreased. Addition of calcium chloride to irrigation water improved the quality of mushroom by increasing the whiteness at harvest and reduced post-harvest browning. They were also more resistant to the negative effects of excessive handling or bruising.

Pre harvest application of calcium chloride to cactus pear delay the rind colour development and increased fruit resistance to decay after harvest but promoted susceptibility to chilling injury during cold storage. The treatment with application of basal dosage of calcium 150 kg/ha with top- dressing of 100 kg/ha resulted in least internal browning development in pineapple up to 28th day after harvest in cold storage (15°C and 80-85% RH) and showed high level of ascorbic acid, TSS and low percentage of weight loss. Pre- harvest spray with 0.4% to 6% calcium chloride delayed the ripening, reduced the PLW (%) and extended the storage life of tomato fruits.

In citrus, fruit size, weight and ascorbic acid content are increased by higher potash, magnesium and zinc fertilization, while they are decreased by higher nitrogen and phosphorus dosages. Higher levels of nitrogen also promote rind breakdown causing spoilage of fruits after harvest. Patassium application reduces this physiological disorder. Copper deficiency causes Exanthema, which is characterized by dark brown, glossy, gum soaked eruptions occuring as irregular blotches on the rind that turn black as the fruit matures. Exanthema is aggravated by high nitrogen and phosphorus application. Fruits with 'Exanthema' can lose their commercial value.

Ber fruits of cv. Gola treated with calcium nitrate (1.5%), packed in perforated polythene bags recorded lowest PLW during storage at ambient conditions (12-28°C temperature and 65 ± 3% RH) under semiarid environment of Gujrat. Pre harvest sprays of calcium nitrate and potassium nitrate 4 weeks prior to harvest maintained flesh firmness in Fortune mandarin fruits during storage. The application of calcium nitrate in combination with potassium nitrate in Elsanta strawberry contributed to more healthy and firm fruits. The spray of calcium chloride in grapes before harvest increased TSS of fruits during storage (Figure 3).

Figure 3: Disorders associated with calcium deficiency.



Magnesium, zinc and copper

Mg increased size, weight and vitamin C in fruits such as citrus fruits. Zn deficiency causes straggled cluster in grape. Cu deficiency causes irregular blotch on citrus fruits and spoils the appearance. Efects of organic fertilizers and other materials.

The market for organically produced food is increasing. There is conflicting information on the effects of organic production of fruits and vegetables on their post-harvest qualities. Organic production has been shown to result in crops having higher levels of post-harvest diseases. That organically produced grapes were more prone to storage decay. In potatoes, it was reported that organically cultivated ones showed lower levels of dry rot. Organically grown kiwi fruit developed less soft patches on the fruit surface, though there were no differences in the whole fruit softening. Reduced levels of physiological loss in weight in organically produced lettuce. A survey in Japan no effects of organic production on post- harvest quality in Philippine bananas. However in Britian, that imported organically grown Robusta bananas ripened faster at 22 to 25°C than non-organically grown bananas, but ripe fruits had similar TSS.

Pre- harvest treatments with fungicides

Pre- harvest treatments with fungicides are one of the strategies employed to prevent the development of post-harvest diseases and spoilage of horticultural produce. Pre- harvest sprays with fungicides reduce the field innoculum and prevent/eradicate the latent field infections. Resulting in healthy produce with best initial quality and potential for long transport. In tropical and sub-tropical areas, latent infections of colletotrichum are common in banana, mango, papaya, avocado and citrus fruits at harvest. Latent infections at the time of harvest are difficult to eradicate by post- harvest application of fungicides. In recent years, several systemic fungicides have become available, which can be effectively used to eradicate the quiescent infections (benzimidazoles/benomyl and other fungicides like dichloran, imazil, prochloraz etc.). A few, well timed pre- harvest treatments with systemic fungicides could prevent the quiescent infection like anthracnose of mango and papaya, crown rot of banana, stem end rot of citrus, lenticel rot of apple and brown rot of peaches. Pre- harvest treated produce would be safer with less or no residues. Pre- harvest sprays may be the best means to reduce or prevent anthracnose infection in mangoes stored in controlled atmosphere for export, as this malady is a great obstacle for the success of CA storage for export. Pre-harvest fungicide treatments are the best ways to reduce decay in horticultural commodities those are subjected to controlled ripening or other post- harvest treatments practices which induce decay by wound pathogens. Development of resistance to certain specific fungicides by the organism might be a disadvantage of pre- harvest treatments if the same fungicides are to be relied upon for post- harvest treatments.

Chitosan

Pre- harvest sprays of chitosan significantly reduced the post- harvest fungal rot and maintained the keeping quality of strawberries stored up to 4 weeks at 3°C. Fruit from chitosan sprayed plants were firmer and ripened at a slower rate as indicated by anthocyanin content and titrable acidity.

Generally, if a crop has suffered an infection during development, its storage or marketable life may be adversely affected. Bananas may ripen prematurely or abnormally after harvest because of leaf infection by fungi during growth, which cause stress and therefore shorten their storage life. Fungicides applications in the field to control Sigatoka leaf spot were shown to reduce premature ripening.

Pre- harvest sprays with Capton, Dithane M-45 (mancozeb) reduced the incidence of Phoma rot, Geotrichum candidum and Phytopthora sp., and reduced the spoilage in harvested tomato fruits. Several investigators have demonstrated that sprays of dichloran applied to peach orchards one week before harvest reduced wound infection by Rhizopus sp., after harvest. Oranges sprayed with benomyl 30 days before harvest controlled Pencillium. Sprays of benomyl and TDZ in pear and apple orchards reduced post- harvest decay due to Pencillium and Botrytis. Trials carried out on Keitt mangoes in South Africa showed that two pre-flowering application of copper oxychloride than two applications of Bayfidan (Triadimenol) during flowering followed by monthly application of copper oxychloride from fruit set ensured control of anthracnose.

Pre-harvest spray with benomyl

Prevents the post- harvest development of stem-end rot arising from quiescent infection of Dipolodia and Phomopsis in oranges and peaches. Pre- harvest sprays with Bordeaux mixture control Alternaria black rot in tomato and soft rot in capsicum. A major problem in this approach of pre- harvest sprays to post- harvest disease control is their selective fungicides such as benomyl may cause a proliferation of fungicide resistant varieties of the pathogen or related fungicides. For instance, the rapid development of resistance by Pencillinum species to the benzimidazole group of fungicides strongly suggests that pre- harvest sprays of thick fungicides would be unwise, particularly if the same fungicide was being relied upon for post- harvest control of Pencillium.

Induced Systemic Resistance (ISR)

A phenomenon of immunizing plants in the field with heat killed spores of C. musae to control crown rot of banana is known as reduced systemic resistance. It was shown that culture filtrates of cell wall fragments of C. musae could induce the production of antifungal components in the peel of green banana fruits. As a result, conidial germination of C. musae was inhibited on treated skin. Pre- harvest treatments with dead conidia of C. musae reduced the crown rot levels in banana. Antagonistic strain of yeast against anthracnose in mango.

A pre- harvest application of Psuedomonas fluorescens (FP7) with chitin formulation at monthly spray intervals through aerial spray reduced the pre- harvest and post- harvest anthracnose incidence. Its efficiency was superior to standard fungicide carbendazim treatment. Pre-harvest application of food additives to control post- harvest diseases. Pre- harvest application of ethanol at 50% (v/v) to organically grown strawberries one hour before harvest significantly reduced the decay by Botrytis cinerea after storage for 3 days at 1°C followed by 2 days at 24°C.
Growth regulating chemicals.

Polyamines

Investigations the effects of pre- harvest and post- harvest applications of putrescine (one of the polyamines) on fruit ripening, quality and shelf-life of ‘Kensington Pride’ mango revealed that pre- harvest putrescine spray was more effective than post- harvest dip. After 20 days storage at 13°C (85% RH).

Pre-harvest treated fruits exhibited higher firmness, TSS and lower fruit rot, whilst acidity, total and non- reducing sugars were reduced in fruit treated with both methods compared with control. In conclusion, pre- harvest putrescine spray was more effective than post- harvest dip.

In peach, pre- harvest application of putrescine reduced ethylene production of the harvested fruit, delayed loss of firmness, retained titrable acidity and prevented the increase in dry matter and soluble solids concentration. It was also reported that pre- harvest application of polyamines strongly reduced ethylene production and influenced quality traits in peaches. These reports confirm the notion that this naturally occuring growth regulating substance can be a useful tool for controlling fruit ripening. No dose- dependent responses were observed, suggesting that lesser polyamines may open promising perspectives, such as the extension of shelf- life of fruits.

Daminozide

Daminozide, also called Alar, B9 or B995, when applied to apples at 2,500 mg/l, developed more red colour in the skin and were firmer than unsprayed fruits. Sprayed fruits were less susceptible to Gleosporium rot but had more core flesh during storage. There was some indication that sprayed fruits were slower to ripen since daminozide tended to retard the climacteric rise in respiration. Pre-harvest application of alar delayed the ethylene production of apples by 3 days at 15°C. It also reduced the ethylene production by 30% and fruits were less sensitive to ethylene during storage. Daminozide has been withdrawn from the market in several countries.

Maleic hydrazide

Pre- harvest application of MH reduces sprouting of onion during storage and extends the storage life of the bulbs as reported by several workers. Because it is necessary for the chemical to be translocated to the apex of the growing point towards the centre of the bulb, it has to be applied to the leaves of the growing crops as pre-harvest spray.

Reduction in rooting and physiological losses in weight of the bulbs was also observed as a result of the pre-harvest spray with MH. Pre- harvest spray of MH (2000 ppm) along with difolatan (0.2%) was very effective in reducing the storage losses due to sprouting and rotting of onion bulbs. Restriction on the usage and permitted residues of MH. Pre- harvest foliar application of MH (3000 ppm), 15 days prior to harvest, reduced weight loss, rooting and decay and inhibited sprouting during storage for 6 months at 30C, ambient temperature and in soils. Application of MH followed by storage at 30C, significantly improved storability of onion.

Gibberellic acid and cytokinin

Pre- harvest spray with GA3+ carbendazim to mango (cv. Baneshan) trees, 20 days before harvest of the fruits, recorded delayed ripening of 22 days after harvest when they were stored at 10 to 12°C. Pre- harvest sprays of GA3 (50 to 150 ppm) to tomato plants were not found useful delaying the colour development, ripening rate or extending the storage-life of tomato fruits.

Pre-harvest application of GA3 has been reported to delay softening, colour development and occurrence of rind disorders in various citrus fruits. This response has been commercially exploited in Navel Orange to delay rind senescence, and extend harvesting and marketing season. In Nagpur mandarin, GA3 (10 to 20 ppm) treatments delayed colour development and fruit softening with lesser weight loss in storage.

Pre-harvest treatments with GA3 (10, 15 and 20 ppm) delayed rind colour development and fruit softening and minimized fruit drop and puffiness during on- tree storage without adverse effect on TSS/acid ratio. After harvest, fruit weight loss was reduced in storage by the GA3 pre- harvest treatment, but results were inconsistent with respect to fruit decay. Combination of carbendazim reduced storage decay.

Colouration of 'Nagpur' mandarin can be advanced by three weeks with two pre- harvest sprays of ethephon (250 ppm + 1% calcium acetate + 500 ppm carbendazim) at colour break stage with 15 days interval. This treatment improved colour without affecting taste, appearance and shelf-life under ambient and refrigerated condition. Addition of calcium acetate to ethephon, minimized leaf and fruit abscission whereas carbendazim minimized decay losses in storage. That pre- harvest spray in strawberry cv. Chandler with GA3(25 ppm), 2,4-5 (10 ppm) and calcium nitrate (1%) extended shelf life of fruits and reduced the post- harvest decay loss.

BA and PBA cause parthenocarpic fruit. 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. That GA3 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 andcell expansion increase beside capacity for juice accumulation and finally fruit grow faster.

Chloremquat (CCC)

Pre- harvest spray of CCC (250 to 500 ppm) improved the vase life of gladious cvs. American beauty and Agni Rekha. Pre- harvest spray with SADH (Daminozide) delayed the senescence of cut roses and improved the size of cut roses. The chemical growth retardants decrease ethylene production and this might be the reason for improved vase life of flowers obtained from CCC and SADH pre- harvest sprayed plants. Vase life and cut flowers quality of Rakthagandha rose were improved by pre- harvest application of SADH (1000 ppm) and the best results were obtained with CCC (1000 ppm), which gave the longest vase life of 19.74 days compared with 7.4 days in control. CCC also increased flower size, total water uptake and minimized loss of fresh weight after harvest. Pre-harvest sprays of 5 to 10 ppm CCC, kinetin or tridimefon increased longevity of crossandra cut flower after as reported.

Paclobutrazol

According to a latest report, the work carried out at Indian Institute of Horticultural Research, Banglore revealed that pre- harvest treatment of mango cv. Alphonso fruits with paclobutrazol (2000 ppm) reduced the incidence of spongy tissue. Table shows that spongy tissue incidence in the fruits was increased by pre-harvest treatment with GA3, while decreased with paclobutrazol (Table 3).

Table 3: Spongy tissue incidence (%) in pre- harvest and post- harvest treated fruits of Alphonso mango.

Stage of treatment	control	GA3(200 ppm)	Paclobutrazol(2000 ppm)
Pre- harvest			
55-75% mature	51.5	70.2	16.4
Post- harvest			
85% mature	52.5	49.5	45.2
95% mature	54	53	48.5

Auxin

Pre- harvest spraying of pineapple fruits with alpha- NAA or ethral alongwith K_2SO_4 solution (5% w/v) four weeks before harvesting significantly increased the potassium ion- concentrationof the fruits and decreased internal browning symptoms by 60% to 70% in the core tissue and pulp during cold storage.

That dipping of Sardar guava fruits in solutions of 25, 50 and 75 ppm GA3 and NAA and 0.5 and 1.0% $Ca(NO_3)_2$ for 5 minutes maintained the fruit firmness during the storage. The effects of pre- harvest sprays of NAA, 2, 4, 5-T, GA3, Kinetin and cycocel on the storage life of guava cv. Sardar. That pre- harvest spray of strawberry cv. Chandler with NAA (25 ppm) favoured the higher vitamin C content during storage.

Ethylene

Ethephon increases anthocyanin (grape, plum, apple, chillies and brinjal), carotenoids (mango, guava, papaya, citrus, tomato etc.) ascorbic acid and TSS and reduces tannin (grapes, dates etc.) and acidity (grape, mango, tomato etc.). Pre-harvest treatment with ethephon reduces internal browning of pine apple.

Physical treatment

Pre-harvest treatments modifying the micro-climate of the fruits and vegetables are used to obtain better post-harvest qualities. Pre-harvest heat treatment (PRHT) by reducing the ventilation in greenhouse increased the soluble solids and fruit skin colour and reduced the chilling injury of tomatoes.

Banana fruits of better colour and quality are produced by pre-harvest bunch covering with plastic bags of standardized colour and other characteristics. Banana fruits of better colour and quality are produced by pre-harvest bunch covering with polyethylene bags of standardized colour.

Covering bunches of different cultivars of banana with 100- gauge blue polyethylene bags with 15% ventilation at the time of last hand emergence improved finger length and finger girth which ultimately lead to increase in the bunch weight. Bunch covers hastened maturity of fingers by a week. It also resulted in attractive green lustrous fruits without any bruises, signs of biological infestation, thus improving the quality of fruits. Similar benefits resulting in high market demand due to better quality of fruits by bunch bagging in var. That pre- harvest blue plastic bag covering of banana bunches can mitigate the problems of fungicidal toxic residues on fruits due to avoidance of fungicidal sprays.

By this treatment pesticides residue- free, export quality healthy banana can be produced. Similarly, individual bagging of mangoes meant for export, on tree with special paper bags as followed in the Phillipines would produce best quality mangoes and this would help boost export of mangoes from our country.

When is fresh produce to harvest?

A critical time for growers of fruits and vegetables is the period of decision on when to harvest a crop. Normally any type of fresh produce is ready for harvest when it has developed to the ideal condition for consumption. This condition is usually referred to as harvest maturity. Confusion may arise because of the word maturity since, in the botanical sense, this refers to the time when the plant has completed its active growth (vegetative growth) and arrived at the stage of flowering and seed production (physiological maturity). Harvest maturity thus refers to the time when the “fruit” is ready to harvest and must take into account the time required to reach market and how it will be managed in route. This time lag usually means that it is harvested earlier than its ideal maturity.

How is harvest maturity identified?

Most growers decide when to harvest by looking and sampling. Judgments are based on:

- Sight-colour, size and shape
- Touch-texture, hardness or softness
- Smell-odour or aroma
- Taste-sweetness, sourness, bitterness
- Resonance-sound when tapped.

Experience is the best quide for this kind of assessment. Newcomers to fresh produce growing may find that learning takes time. Harvest maturity can readily be observed in some crops: bulb onions when their green tops collapse and potatoes, when the green tops die off. Other crops can be more difficult: avocado remains unripe off the tree after maturity.

Quality and ripening potential of pears is closely related to harvest maturity of the fruit, such that the degree of maturity at harvest has a direct bearing on the period for which it can be stored without losing quality.

Large scale commercial growers combine observation with more sophisticated measurement:

- Time- recording, from flowering to harvest.
- Environmental conditions, measuring accumulated heat units during the growth period.
- Physical properties, including shape, size, specific gravity, weight, skin thickness, hardness etc.
- Chemical properties, (important in fruit processing, less so in vegetables), sugar/acid ratio, soluble solids content, starch and oil content.
- Physiological characteristics, including respiration rate, acidity or alkalinity (pH).

The final decision on harvesting will take account of the current market value of the expected yield and also the time. During which the crop will remain in marketable condition. With seasonal crops, growers are often tempted to harvest too early or too late in order to benefit from higher prices at the beginning and end of the season.
Fruit harvesting at proper stage of maturity has direct effect on quality and market value of the produce. Stage of harvesting also influences the post-harvest enzymatic activities of the horticultural produce, which determines the levels of different sugars, acids, flavours, vitamins, pigments, etc.
In litchi the development of fruit colour is most dependable maturity index, Litchi fruits turn deep red when fully ripe and fruits harvested at this stage possess excellent quality. In pomegranate is a non- climacteric fruit and requires maturity on the tree for its better post- harvest quality attributes (Table 4).

Table 4: Summarized form of pre- harvest factors affecting post- harvest life of fruits.

Factors	Quality affected
A. Environmental	
Temperature	High temperature affects maturity, colour, sugar, acidity, etc. Reduces the quality for e.g. in citrus, radish, spinach etc. and increased the quality in grapes, melons, tomato etc. Low temperature cause chilling and freezing injury which reduces the quality.
Light	Essential for anthocyanin formation. Exposed fruit to sun light, develop lighter weight, thinner peel, lower juice and acids and higher TSS than shaded fruits e.g. citrus, mango etc. High light intensity causes sunscald in citrus.
Rainfall	Causes cracking in grape, dates, litchi, limes, lemon, tomato etc. It reduces appearance and sweetness.
Wind	Causes bruising, scratching and corky scar on citrus fruits e.g. citrus
Humidity	High humidity reduces the colour and TSS and increased acidity in citrus, grapes, tomato, etc. but on the other hand it is needed for better quality of banana, litchi and pineapple.

B. Cultural factors	
Mineral nutrition	
i. Nitrogen	High N reduces ascorbic acid content, TSS/acid ratio and keeping quality but increases thiamine, riboflavin, carotene e.g. citrus and its deficiency reduces size of fruit.
ii. Phosphorus	High phosphorus decreases size, weight and vitamin C in various fruits. Its deficiency causes poor appearance of fruit such as citrus fruits.
iii. Potassium	Increase size, weight, vitamin C and sugars. Its deficiency causes uneven ripening.
iv. Calcium	Increase firmness of many fruits e.g. apple, mango, guava, tomato etc. check physiological disorders in many fruits.
v. Magnesium	Increased size, weight and vitamin C in fruits such as citrus fruits.
vi. Zinc	Deficiency causes straggled cluster in grape.
vii. Boron	Flesh browning (e.g. anola) and gummy discoloration of albedo in citrus. Fruit become hard and mis shapen.
viii. Copper	Deficiency causes irregular blotch on citrus fruits and spoils the appearance.
Growth regulators	
i. Auxins	Increased size in loquat (2, 4, 5-TP), grape (IAA), mandarins (NAA) and TSS in mango (2, 4-D).
ii. Gibberellic acid	Pre-harvest application increases size and weight of grape, apricot, strawberry and Causes parthenocarpic fruit, guava, grape, tomato etc. It reduces disorder of fruits e.g. water spot and corky spot in citrus.
iii. Cytokinin	BA and PBA cause parthenocarpic fruit.
iv. Ethylene	Ethephon increases anthocyanin (grape, plum, apple, chillies and brinjal), carotenoids (mango, guava, papaya, citrus, tomato etc.) ascorbic acid and TSS and reduces tannin (grapes, dates etc.) and acidity (grape, mango, tomato etc.) pre-harvest treatment with ethephon reduces internal browning of pine apple.
v. Growth retardant	Pre- harvest application of Alar (B9) increases colour in apple, cherry, apricot, etc. and MH inhibits sprouting in onion bulb. Foliar application of CCC before harvest resulted higher content of total sugars and TSS in banana fruits.
Rootstock	In citrus Troyer and Carrizo (Citrange) rootstock produce the fruit of excellent quality of oranges, mandarian and lemons. In guava *Psidium pumilum* rootstock increases sugar and *Psidium cujavilis* ascorbic acid content of fruit.
Irrigation	Excess irrigation causes high acidity and deficiency of moisture reduces fruit size, juice content and increases thickness of peal.
Pruning	It affects the size, colour, acidity and sugar content of grape, phalsa, ber, peach, apple etc.
Thinning	Thinning in grapes, dates, peaches, plum etc. increases size. Colour, acidity and sugar content of fruits.
Girdling	It affects the size, colour and sugar in grape berries.
Bunch covering	Pre- harvest bunch covering with plastic bags produced banana fruits of better colour and quality.
Variety	Varieties differ in size, shape, colour and chemical composition. Productiveness, bright appearance and good keeping qualities are most important characters of the varieties.
C. Diseases and pests	Pre- harvest application of systematic fungicides prevents quiescent infection like anthracnose of mango, papaya, crown rot of banana, stem end rot of citrus, lenticel rot of apple and brown rot of peaches. Pre- harvest spray of chitosan reduced the post-harvest fungal rot and maintains the keeping quality of strawberry.
D. Maturity	Fruits when ripe are of higher quality on account of full size, bright colour, sweetness and less acidic.
E. Mechanical injury	Fruits should not be injured or damaged otherwise injury will reduce appearance and may be source of infection for fungal diseases.

e-ISSN: E 2347-226X
p-ISSN: 2319-9857

CONCLUSION

Pre-harvest factors affect both fruit growth during its development by changing the accumulation of water and dry matter, including biochemical and mineral compounds and fruit behaviour during its storage. Having knowledge of and then being able to control changes in fruit quality in response to environmental conditions may be essential to adopting cultural practices that will provide high quality fruits and to defining optimal postharvest procedures that will take fruit production conditions into account e.g. to improve final fruit quality traits such as size, colour, taste, nutritional value and flavour is also to build an integrated approach that links the two categories of factors, pre-harvest and post-harvest, which influence the various components of fruit quality. Evaluation of the influence of pre-harvest factors on fruit quality needs to be conducted through to consumer acceptance and consumption.

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