EFFECT OF CLIMATE CHANGE IN INDIAN HORTICULTURAL CROPS: A SYNTHESIS

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ABSTRACT: Global warming and climate change is the greatest concern of mankind in 21st century. The established commercial varieties of fruits, vegetables and flowers will perform poorly in an unpredictable manner due to aberration of climate. Melting of ice cap in the Himalayan regions will reduce chilling effect required for the flowering of many of the horticultural crops like Apple, Saffron, Rhododendron, Orchid, etc. If agriculture is the main stay towards the emission of greenhouse gases induced climate change, horticultural crops have a much bigger role to play in countering the negative consequences of climate change by providing a better carbon trade and carbon sink. The most effective way is to adopt conservation agriculture, using renewable
energy, forest and water conservation, reforestation etc. To sustain the productivity, modification of present horticultural practices and greater use of greenhouse technology are some of the solutions to minimize the effect of climate change. Commercial production of horticultural plants particularly grown under open field conditions will be severely affected. Due to high temperature physiological disorder of horticultural crops will be more pronounced eg. Spongy tissue of mango, fruit cracking of litchi, flower and fruit abscission in solanaceous fruit and vegetables, etc. Development of new cultivars of horticultural 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 will be the main strategies to meet this challenge. Crop-based adaptation strategies are needed keeping in view the nature of crop, its sensitivity level and the agro-ecological region. Simultaneously, keeping an eye on carbon sink potential of different horticultural crops vis-à-vis annual field crops will further aid in developing a blue print for redressed of climate change related issues.

Keyword: Climate, carbon trade, carbon sink disorder, horticultural crop, India and yield.

Fruit and vegetables are 'living' structures. One readily accepts that a fruit or vegetable is a living, biological entity when it is attached to the growing plant in its agricultural environment, but even after harvest the commodity is still living as it continues to perform most of its metabolic reactions and maintain the physiological systems that were present when it was attached to the mother plant. An important feature of plants and by extension vegetables, fruits and ornamentals, is that they respire by taking up oxygen (O_2) and giving off carbon dioxide (CO_2) and heat. While attached to the plant, losses due to respiration and transpiration are replaced from the flow of sap, which contains water, photosynthetic (mainly sucrose and amino acids) and minerals. Respiration and transpiration continue after harvest, and since the fruit, vegetable or ornamental is now removed from its normal source of water, photosynthetic and minerals, the commodity is dependent entirely on its own food reserves and moisture content. Therefore, losses of respiratable substrates and moisture are not replenished and deterioration commences. In other words, harvested vegetables and fruit and ornamentals are perishable. Thus the harvested plant part or organ must.

i. Continue normal respiratory activity to provide the energy for maintenance of basic life processes.

ii. Continue normal growth and developmental processes associated with its stage of maturation.

iii. Undergo metabolic responses to changing physical environments depending on handling and storage systems utilized.

iv. Respond to pathological invasion.

POSTHARVEST LOSSES ASSOCIATED WITH PERISHABLE CROPS

Direct losses: Those caused by waste or consumption by non-human agents, such as insects, rodents, birds, fungi, bacteria etc.

Indirect losses: Those due to deterioration in quality or acceptability of the product up to the point of complete rejection by the consumer, eg. changes in its appearance, texture, and colour caused by climate, improper handling, transportation, or infrastructure.

Economic losses. Those losses brought about by changes in market conditions and expressed in economic terms, eg. losses due to changes in demand and supply.

CAUSES OF POSTHARVEST LOSSES

Physical or mechanical: Physical losses can be caused by improper harvest methods, poor packaging, and transportation resulting in cuts, abrasions, bruises, breakage or leakage. Physical damage can be normal or abnormal. Normal deterioration is due to the natural aging process or senescence of the products. Abnormal deterioration is that which occurs due to adverse conditions such as un-favourable temperatures at either extremes, i.e. too low but above freezing (above 0^0C but below 10-12^0C) resulting in chilling injury or too high (above 30-32^0C) resulting in heat injury. Other examples of physiological damage include sprouting in yams during storage, blossom end rot in tomatoes, internal rind spot on watermelons, tip burn in lettuce etc.

Pathological: Pathological damage can be to fungal, bacterial or viral infections, e.g. Anthracnose in tomato, pepper, cucumber or watermelon, bacterial soft rot in melongene, mango, papaya or cucumber, or gemini virus in pepper, melongena or tomato (Sekhar*et al.,* 2013).

Entomological: Entomological damageis caused by mole crickets, fruit flies, white flies or mealy bugs.

Biological factors: This manual identifies the major biological factors which affect the postharvest behaviour of horticultural produce, recognising that knowledge of those factors is necessary for the development of successful postharvest management/handling and storage systems that would lead to postharvest maintenance of quality through extension of shelf life. In addition, it briefly examines important interactions between biological and environmental factors, and their effects on modification of postharvest behaviour.

i. Respiratory metabolism: Respiration is the process by which stored organic materials (carbohydrates, proteins, and fats) are broken into simple end products with a release of energy. Oxygen is used in this process, and CO_2 is produced. The loss of food reserves during respiration results in: hastening of senescence or aging, as this energy supplies are exhausted to maintain the commodity's living status; reduced nutritional value; loss of flavour quality, especially sweetness; and loss of salable weight and by extension profits to the producer and or marketer. The energy released as heat, known as vital heat, affects postharvest technology consideration, such as estimations of refrigeration and ventilation requirements. The rate of perishability of harvested commodities is generally proportional to the respiration rate. Based on their respiration and ethylene production patterns during maturation and ripening, commodities are classified either as climacteric or non-climacteric. Climacteric commodities, such as hot pepper, tomato,

bitter melon, mango, banana, passion fruit etc., show a large increase in CO_2 and ethylene production rates coincident with ripening, while non-climacteric commodities, such as melongene, cucumber, yard long beans, okra, lettuce etc., show no change in their generally low carbon and ethylene production rates during ripening. More details on respiratory metabolism are provided i) postharvest factors affecting respiration such as temperature, atmosphere composition, and physical stress, ii) stages in development of a typical climacteric curve, iii) significance of respiration, iv) respiratory biochemistry.

ii. Ethylene production: Ethylene (C_2H_4) a naturally occurring, gaseous plant hormone is produced in a range of plant parts of various physiological ages. Rate and extent of ethylene produced varies considerably and is dependent on several factors such as i) species and cultivar ii) plant part iii) stage of maturation iv) temperature v) physical, physiological or pathological stress, vi) presence of ethylene itself and other hydrocarbons. Ethylene production plays a particularly important role in postharvest behaviour determination. Although more importantly recognized as the ripening hormone, ethylene is also known for its effects on senescence. Storage of high ethylene commodities such as mango, banana, tomatoes or bitter melons can be detrimental to the quality of ethylene sensitive commodities such as yard long beans and okra resulting in chlorophyll degradation (green to yellow colour and eventual darkening of skin), toughening of tissues, poor flavour and rapid deterioration. Ethylene sources include ripened and decayed fruits and produce, volatiles from internal combustion engines, propane powered equipment, decomposed or wounded commodities, cigarette smoke and rubber materials exposed to ultra violet light.

iii. Transpiration or water loss: Control of water loss is very important in maintaining freshness of fruits and vegetables after harvest. The moisture content of the air in the intercellular spaces of most commodities remains close to 100%. Moisture loss is influenced most by the difference between vapour pressures inside and outside of the commodities. When vapour pressures are almost equal, little water is lost. Since water vapour moves from areas of higher to areas of lower concentration, water is lost from commodities when they are subjected to most marketing conditions. Water loss can be reduced by i) maintaining high moisture content in the air around the vegetables, ii) precooling, iii) reducing air movement, iv) protective packaging, v) applying a surface coating, vi) trimming, vii) Curing, eg. Root crops. Water loss or transpiration results in the following effects on harvested vegetables.

Changes in carbohydrates include

a. Starch to sugar conversion (undesirable in potatoes, desirable in fruits).

b.Sugar to starch conversion (undesirable in peas and sweet corn).

c.Conversion of starch and sugars to CO_2 and water through respiration. Breakdown in pectins and other polysaccharides results in softening of fruits and consequent increase in susceptibility to physical injuries. Changes in organic acids, proteins, amino-acids and liquids can influence flavour quality of the commodity. Loss of vitamin content, especially Vitamin C, is detrimental to nutritional quality.

HARVESTING AND MATURITY INDICES

Harvesting and rough handling at the farm directly affects market quality. Bruises and injuries show up as brown and black patches making the commodities unattractive. Injuries to the peel serve as avenues for microorganisms and lead to rotting. Moreover, respiration is increased markedly by the damage, and storage life is shortened. Lack of knowledge about the principles of proper harvesting will result in a waste of vegetables and fruits. After all, harvest means an abrupt termination of life: in the field or human law, this would be called ‘murder’. The necessity of shipping mature fruit-vegetableslong distances has often encouraged harvesting them at less than ideal maturity,resulting in suboptimal taste quality to the consumer (Kader, 1995).Several factors in addition to maturity at harvest have major impacts on postharvestbehaviour and quality of fruit-vegetables. Fruits of group (1) normally produce onlyvery small quantities of ethylene. However, they are very responsive to ethylene andcan be damaged by exposure to 1 ppm or higher concentrations. Ethylene exposureaccelerates chlorophyll degradation, induces yellowing of green tissues, encouragescalyx abscission (eggplant), and accelerates fruit softening. Most of the fruits ingroup (2) produce larger quantities of ethylene in association with their ripening,and exposure to ethylene treatment will result in faster and more uniform ripeningas indicated by loss of chlorophyll (green color), increase of carotenoids (red, yellow, and orange colors), flesh softening and increased intensity of characteristic aromavolatiles

Harvest indices: Good quality is obtained when harvesting is done at the proper stage of maturity. Immature melon gene or bitter melons when harvested will give poor quality and erratic ripening. On the other hand, delayed harvesting of vegetables and fruits may increase their susceptibility to decay, resulting in poor quality and hence low market value. The specific

harvesting and maturity indices for the six vegetables selected for this course will be presented in the section dealing with postharvest handling systems for each commodity.

Horticultural maturity: This is the stage of development at which a plant or plant part possesses the prerequisites for use by consumers for a particular purpose. It refers to the stage of development when plant and plant part possesses the pre-requisites for use by consumers for a particular purpose i.e. ready for harvest (Dhatt and Mahajan, 2007).

(i) Mature: It is derived from Latin word '*Maturus*' which means ripen. It is thatstage of fruit development, which ensures attainment of maximum edible qualityat the completion of ripening process.

(ii) Maturation: It is the developmental process by which the fruit attains maturity.It is the transient phase of development from near completion of physicalgrowth to attainment of physiological maturity. There are different stages ofmaturation e.g. immature, mature, optimally mature, over mature.

(iii) Ripe: It is derived from Saxon word '*Ripi*', which means gather or reap. Thisis the condition of maximum edible quality attained by the fruit followingharvest. Only fruit which becomes mature before harvest can become ripe.

(iv) Ripening: Ripening involves a series of changes occurring during early stagesof senescence of fruits in which structure and composition of unripe fruit is soaltered that it becomes acceptable to eat. Ripening is a complex physiologicalprocess resulting in softening, coloring, sweetening and increase in aromacompounds so that ripening fruits is ready to eat or process. The associatedphysiological or biochemical changes are increased rate of respiration andethylene production, loss of chlorophyll and continued expansion of cellsand conversion of complex metabolites into simple molecules.

(v) Senescence: Senescence can be defined as the final phase in the ontogeny of theplant organ during which a series of essentially irreversible events occur whichultimately leads to cellular breakdown and death (Dhatt and Mahajan 2007).

MINIMISING CHANGES IN COMMODITIES AFTER HARVEST

In order to minimise changes that occur in agricultural produce after harvest it is imperative that the following practices be adopted. Both immaturity and over maturity cause quality problems. Another point to remember is that the loss of value ofa downgraded product is likely to be substantially greater for highly differentiatedbranded products which sell at a premium in the

market. All the hard work that hasgone into promoting and raising the profile of a branded product can be quicklyeroded if there are postharvest quality problems with some lines of that product (Jobling, 2002). Immaturity increases water loss and shrivelling. When harvested too immature, some fruits such as tomatoes may never ripen satisfactorily others such as watermelons and sweet corn may be low in sugars. When harvested over mature most crops such as beans, maize and celery become tough. Over mature sweet corn will be low in sugars and starch, but immature and over mature produce are more susceptible to decay.

Harvest during the coolest part of the day: To minimise the spread of certain diseases, harvest should begin as soon as the foliage has dried. This practice is most important for highly perishable products, because high temperatures lead to rapid deterioration. Harvesting continuously during the day decreases the importance of this factor.

Keep harvested products in the shade: This simple practice will minimise wilting, sunburn damage, and prevent unnecessary heating of the produce. On a sunny hot day, tomato fruit in the sun for an hour can be as must 14^0C hotter than fruit in the shade.

Handle all produce gently: Many fruits and vegetables have a natural protective surface. Careful handling helps maintain this surface and results in a more attractive, better quality product. Watermelons that have been handled roughly may appear undamaged but internal bruising may have occurred. Bruises, punctures, and other wounds increase susceptibility to decay and water loss.

PRE-COOLING METHODS AND TECHNIQUES TO OPTIMISE QUALITY

The primary objective in pre-cooling perishable commodities is to remove field heat prior to shipment, storage and display. All fresh horticultural crops are high in water content and aresubjected to desiccation (wilting, shriveling) and to mechanical injury. Variousauthorities have estimated that 20–30 % of fresh horticultural produce is lost afterharvest and these losses can assume considerable economic and social importance. Perishable commodities need very careful handling at everystage so that deterioration of produce is restricted as much as possible during theperiod between harvest and consumption (Dhatt and Mahajan, 2007).Proper pre-cooling of freshly harvested commodities can.

i. Suppress enzymatic degradation and respiratory activity (softening).

ii. Slow or inhibit water loss (wilting).

iii. Slow or inhibit the growth of decay-producing microorganisms.

iv. Reduce production of ethylene.

v. Provide market flexibility by making it possible to market at an optimum time.

Packinghouse: Following harvest, most crops must be cleaned, sorted, sized, and packaged if they are to be sold in the fresh produce market. These procedures are normally done in packinghouses which could be a small shelter located in the field or an automated packing line located in a centralized area.

Purpose of packinghouses: They serve as a sheltered working site for the produce and the packers, and should create an orderly assembly and flow of produce which can be well managed and centrally supervised. They can also serve as a storage point for packing equipment and materials and, if large enough, can house office and communication facilities. For export of fresh commodities, packinghouses are an essential part of the operation where selection, grading, and quality control must be implemented and monitored.

(A)*Non-climacteric fruit* ripen only while still attached to the parent plant. Theireating quality suffers if they are harvested before they are fully ripe because theirsugar and acid contents do not increase further. Their respiration rate graduallydeclines during growth and after harvesting. Maturation and ripening are agradual process. Examples of non-climacteric fruit include: cherries, cucumbers,grapes, lemons and pineapples (Sirivatanapa, 2006).

(B)*Climacteric fruit* can be harvested when mature but before the onset of ripening. These fruits may undergo either natural or artificial ripening. Theonset of ripening is accompanied by a rapid rise in respiration rate, generallyreferred to as the respiratory climacteric. After the climacteric, the respirationrate slows down as the fruit ripens and develops good eating quality. Examplesof climacteric fruit include: apples, bananas, melons, papaya and tomatoes(Sirivatanapa, 2006).

Storage: After commodities are packaged they should be immediately placed in chill rooms at the recommended temperature and relative humidity. Please refer to the section on handling systems of the six selected vegetables for these conditions of storage. Ancient (and modern) people often dried fruits such as apples, apricots, figs, and grapes to prolong the storage longevity of these perishable crops (De Long and Prange, 2003).

STORAGE SYSTEMS

i. Slow biological activity of the product by maintaining the lowest temperature that will not cause freezing or chilling injury by controlling atmospheric composition;

ii. Slow the growth and spread of microorganisms by maintaining low temperatures and minimising surface moisture on the product;

iii. Reduce product susceptibility to damage from ethylene.

It is important to note that high quality produce will come out of storage only if it is of high quality on entering the store, and if management of the storage facility is of a high standard (Sharma *et al.,* 2010).

Modified Atmosphere Storage (MAS) and Controlled Atmosphere Storage (CAS): In modified atmospheres or controlled atmospheres, gases are removed or added to create an atmospheric composition around the commodity that is different from that of air (78.08% N_2, 20.95% O_2, and 0.03% CO_2). Usually this involves reduction of O_2, and/or elevations of CO_2 concentrations. MAS and CAS differ only in the degree of control, CAS is more exact.

POSTHARVEST PATHOLOGY

Wastage of horticultural commodities by microorganisms between harvest and consumption can be rapid and severe, particularly in tropical countries where high temperatures and high humidity favour rapid microbial growth. Furthermore, ethylene produced by rotting produce can cause premature ripening and senescence of other produce in the same storage and transport environment, and sound produce can be contaminated by rotting produce. Apart from actual losses due to wastage, further economic loss occurs if the market requirements necessitate sorting and separating partially contaminated consignments. Many bacteria and fungi can cause postharvest decay. Most of these organisms are weak pathogens in that they can only invade damaged produce. A few, such as *Colletotrichum sp.,* are able to penetrate the skin of healthy produce. Often the relationship between the host (fruit or vegetable) and the pathogen is reasonably specific e.g. *Pencillium digitatum* rots only citrus and *P. expansum* rots pears and apples but not citrus. Bacteria gain entry through wounds or natural openings e.g. stomata, lenticels or hydathodes and multiply in the spaces between plant cells. Entry via wounds or natural openings is also characteristic of many fungi. Certain species of fungi, however, are capable of direct penetration of the intact cuticle, the waxy outermost layer possessed by leaves, stems and fruits. The fungi produce a swelling called the appressorium from the underside of which a thin strand grows through the cuticle and into or between plant cells. Penetration is achieved by mechanical pressure and by an array of enzymes specific to the fungus involved.

FACTORS AFFECTING DEVELOPMENT OF INFECTION

1. Environment high temperature and high humidity. Low temperatures can induce chilling injury and secondary infections.

2. Low O_2 and high CO_2 can restrict the rate of decay by either retarding the rate of ripening or senescence, depressing the growth of the pathogen, or both.

3. Host tissue pH of fruit tissue is usually below 4.5 and therefore are mainly attacked and rotted by fungi, but many vegetables where the pH is above 4.5 can highly be susceptible to bacterial rot.

4. Fruit maturity ripening fruits are more susceptible to wastage than immature fruits. Thus treatments aimed at retarding the rate of ripening, such a refrigerated temperature, may also withstand the growth of decay organisms.

5. Formation of periderm layer at the site of injury for underground storage organs such as cassava, potato and sweet potato.

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