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Review Article
COLD STRESS MITIGATION IN HORTICULTURAL CROPS

Manpreetkaur and Deepika Saxena*
Department of Horticulture, School of Agriculture, Lovely Professional University,
Phagwara, Punjab-144411, India
*Corresponding author: deepika.20662@lpu.co.in

Abstract

Cold stress (chilling and freezing injury) hampers production and productivity of the horticultural crops. Injury in plants induced by cold stress may appear after 48 to 72 h of stress exposure. It can be alleviated by various methods like heat treatment, intermittent warming, packaging, waxing, growth regulators, some natural compounds (methyl-jasmonate, polyamines, oils), rootstocks, controlled atmosphere, site selection, mulching, irrigation, soil banking, nutrient management, row covers, wind machines. No one treatment promising to reducing the injury completely. The adequacy of every treatment differs as indicated by the fruits and duration of treatment. Rootstocks for cold resistant are limited with some horticultural crops, heat treatment suppresses the oxidative activity and induces the membrane stability, natural compounds act as anti-oxidants and reduce the damage, application of Potassium to improve the uptake of water similarly, all the processes work to reduce cold injury in horticultural crops.

Keywords **:** Cold stress, chilling injury, freezing injury, alleviation.

Introduction

Stress is a negative power, or condition, which repress the typical working and well- being of a biological system. Biotic and abiotic stresses, including drought, extreme temperature, scarcity of water, reducing quality of irrigation water and salinity in soil and water, are problems which are becoming really acute (Flowers, 2004). These stresses can affect both the quality and quantity of fruits. It is basic to improve pressure resilience of the harvest plant to upgrade crop yield under pressure conditions and diminishing the yield holes by extending plant crops resistance to stresses (Helaly, 2003).

Among all the stresses, cold stress is the oldest environmental and horticultural problem also, serves as a challenge to scientist as well as for the growers hampering production and productivity. Cold pressure (chilling and freezing injury) happens at temperatures under 20ºC and varies with the level of temperature range and plant type. Chilling (<20ºC) or freezing (<0ºC) temperatures can trigger the progression of ice jewel in plant tissues, which causes cell parchedness (Chinnusamy *et al*., 2007).

At the point when yields are presented to chilling temperatures underneath 10 to 15°C however over their freezing focuses brings about injury after a timeframe. Some temperate origin horticultural crops are also prone to low temperature injury (Bramlage and Meir, 1990). These mild harvests have lower critical threshold temperatures. At critical chilling temperatures, the tissues debilitate in manners that they can't carry on common metabolic strategies typically (Wang, 2010). Freezing injury, which impacts endurance and production of numerous plants, is of extraordinary monetary significance to mild zone cultivation (Quamme, 1987). Cold stress-instigated injury in plants may show up after 48 to 72 h of stress exposure.

Chilling and freezing injury

Chilling injury	Freezing injury
It occurs when temperature drop below 10-15℃.	It occurs below 0℃.
Main site is plasma membrane.	It occurs first in cell wall, then in intercellular spaces.
Main symptom surface pitting.	Main symptom water-soaked appearance.

Effect of cold stress on different fruit crops

1. Pollen development is affected.
2. Disruption of the conversion of starch to sugar.
3. Decrease carbon dioxide rate.
4. Alteration in photosynthesis.
5. Deferred Development, lengthening of growing season. (Skrudlik and Kosceilnaik, 1996).
6. It decreases rate and consistency of germination, hamper seedling energy and postponements. Ontogenic plant improvement (Oliver *et al*., 2007), bringing about serious harvest yield misfortunes (Ruelland *et al*., 2009).
7. Slow growth of chilling sensitive plants (Venema *et al*.,1999).
8. Loss of vigour (potato lose the ability to sprout if chilled)
9. Off-flavor, rot and inability to mature ordinarily (Saltveit and Morris, 1990).

Methods to alleviate cold stress

Heat treatment

Heat treatments have been found in many cases to defer or forestall the improvement of chilling injury (Lurie, 1998).

Time of the heat treatment can depend upon several factors and it can be vary from hours to days (Fallik, 2004). In tomatoes (40°C for 7 min) prior to 2.5℃, demonstrated good quality and advanced ripening scores after storage (Luengwilai *et al.,* 2012). Kinnow (35-45^0 for 10 min.) before store at 0℃ improve fruit quality. (Ma *et al.*, 2014). Bassal *et al.* (2011) have reported that treating 'Navel' and 'Valencia' oranges with heated water inundation (20 min at 41°C) diminished chilling injury, diminished weight reduction and expanded or kept up juice rate. Vapour heat treatment has been found to brings down affectability of tomatoes (Lurie and Klein, 1991) and mangoes (McCollum *et al*., 1993) to low temperatures. In Avocado, VHT for (at 40 °C for .5 and 3 h) prior to 3.5℃ results in product with less external darkening and mash spot, without postponing aging time after storage (Wolestonehome, 2015). Li *et al*., (2013) found in papaya that treating fruit with high temp water controlled *Colletotrichum gloeosporioides* in peel by actuating the nearby articulation of barrier related proteins. Likewise, heat liquified the natural product wax, making a mechanical obstacle against pathogen entrance.

How Heat Treatment works

Fruit decay is controlled by heat treatments by means of three systems: a) direct germicidal impact, b) inciting barrier components in host and c) liquefying the cuticular waxes on the fruit surface (fixing open stomata, micro cracks and wounds), in this manner compelling the locales of pathogen infiltration. The three system have been as of late concentrated in a few products (Escribano *et al*., 2014).

Packaging

Using plastic packaging material to package the fruits and vegetables maintain the relative humidity in high percentage and helps to modify the surrounding atmospheric composition of oxygen and carbon the commodity (Wang 2010), likewise postpone chilling injury in numerous natural products like bananas, pineapples, Japanese apricots and lemons. Bundling with low thickness PE film and products covered with heat-shrinkable film were likewise answered to decreased pit development and singe in chilled grapefruit (Wang and Qi, 1997). Bundling with low thickness polyethylene film relieved chilling injury in cucumber product (Wang and Qi, 1997). Properties pertaining antioxidant activity and free radical scavengers are exhibited by certain chemicals reported to reduce chilling injury. (Yadav *et al*., 2015) Showed that Active packaging treatment coated with chitosan on banana at (5±1℃) reduced the softness and chilling injury in fruits. Tomato fruits are also protected by accumulatedCO2 in polyethylene bags from chilling injury at 2^o (Hibson 1981, 1987). Sealing Japanese Apricot in polyethylene packs significantly supressed injury at 0o (Itawa and Yoshida 1979).

Waxing

Surface coating with different types of waxes are widely used to increase the quality of fruits and vegetables as it Retard the loss of water. It act as semi-permiable barrier to lower the cold injury (Meng *et al.*, 2008; Ahmed *et al*., 2009). Waxing reported to lessen chilling harm in oranges, cucumbers, grapefruit and pineapples. Use of Sta-Fresh 2952 wax in pineapple also improve the total sugar and ascorbic acid (Huigang *et al.*, 2011). Intermittent film wrapping and coating in pomegranate (Nanda *et al.,* 2001; D'Aquino *et al*., 2009).

Discontinuous warming

Sporadic warming is the impedance of low-temperature aggregating with in any occasion on various occasions of warm temperature. The bringing temperature up sincerely busy chilling presentation brings about higher metabolic exercises and permits dangerous materials to get aggregated during chilling. This moving prompts a fast metabolic correction to happen that increments polyunsaturated unsaturated fat amalgamation. Changing temperature from high to low can results in fatty acid elongation and desaturation. This change likely influences layer smoothness and builds resilience to low temperature (Patel *et al*., 2016). Arming of chilled tissues for brief periods helps with fixing harm to movies, organelles, or metabolic pathways (Lyons and Breidenbach, 1987). Chilling injury in lemons can be diminished by providing warm temperature for 7 days at 13 °C after at regular intervals in cool stockpiling at 2°C. Irregular warming has been found to ease chilling mischief in lime (Harhash and Al-Obeed, 2006), grapefruit and lemon fruit (Safizadeh *et al*., 2007).

Growth regulators and Chemicals

Among all plant growth regulators, Cytokinins and ABA were most effective (Duncun, Widholm, 1991; Anderson *et al*., 1994; Lukatkin *et al.,* 2003; Lukatkin and Zauralov, 2009). Non-hormonal development controllers are utilized additionally so as to improve the chilling resistance of developed plants. These include paclobutrazol, chlorocholin chloride, mefluided, unikonazol and other triazoles (Feng *et al.,* 2003). SA application have been found effective in reducing the chilling (Miura and Tada, 2014) and freezing injury (Tasgin *et al*., 2003). Salicyclic treatment in pomegranate (Sayyari *et al.,* 2009). Polyamine application as best treatment by immersion at (25℃ for 4 min), (Mirdehghan *et al*., 2007). Use of BRs incited broad overhauls in plant versatility against chilling worry regarding plant development, photosynthesis and cell reinforcement framework in tomato plants (Khan *et al*., 2015). Postharvest treatment with safflower oil, or mineral oil hindered chilling-began underpeel recoloring of bananas (Jones *et al*., 1978). These blends may go about as agents preventing cancer and diminish oxidative harm activated by chilling temperature. Lime with the most minimal content of calcium in juice build up the most noteworthy level of chilling damage (Slutzky *et al*., 1981). Postharvest utilization of methyl jasmonate was found to diminish chilling harm of grapefruit, avocados and zucchini squash. (Meir *et al*., 1996; Wang and Buta, 1994).

Controlled atmosphere

Controlled climate (CA) stockpiling has been seemed to influence the breath, ethylene creation and activity, protein blend and movement, maturing procedure, and senescence of different agricultural items (Kader 1986 and Calderon and Barkai-Golan, 1990). Only some horticultural fruits respond well (Blanpied *et al*., 1993). It alleviates chilling injury of avocados, nectarines, peaches, pears, grapefruit, potatoes etc. (Wang 1993). Some crops like in papaya, lemon, tomatoes no effect of CA has been found.

Rootstocks

Rootstocks are the viable option used for propagation against the abiotic stresses since 2000 years. (Webster 1995).

Crops	Rootstocks	Reference
Apple	G 935, G 11, G 30, G 41, B 9, P 2, M 26, B 9, M 26, MM 106, MM 111 and M 7	Chadha, 2016.
Citrus	Bitters	Federici, 2009.
Pear	Pyrusbetulaefolia seedling	Roper, 2001
Cherry	Mahaleb seedling	Roper, 2001
Plum	Myrobalan seedling	Roper, 2001.

Mulching

Mulching is the addition of material (organic, non-organic) over the plants to protect them from heat, cold. Main purpose of the mulch is to reduce evaporation, to control soil erosion and conservation of moisture.

Types of Mulch

Organic mulch	In-organic mulch
It Include once-living products that will decompose.	are non-living materials applied to the soil Surface.
These are non- competing legume plant that are planted around the desired crop.	These products do not break down and must be removed after each growing season.
Fallen leaves, paddy straw, saw-dust, Hay.	Plastic mulch, rubber mulch, polygene.

Source: (Tyagi, 2017)

Organic mulches usually moderate diurnal soil temperature fluctuations (Asghar *et al.,* 1987). Increasing soil temperature, conserving soil moisture and weed control is effective by applying plastic mulch (Lamont, 2005; Zhang *et al.,* 2007; Brault *et al*., 2002). Best protection is provided by wetting the soil before covering with clear plastic. Mulching act as insulator and aids warming under cool conditions (Facelli and Pickett, 1991 and Chalker-Scott, 2007). Wheat and oat straw mulch in strawberry (2-3''thick),before temperature each -7℃to -9℃. (Fisher, 2004). Ni *et al.* (2016) found that different types of mulches induce the chlorophyll content upto 46.3% which ultimately increase the photosynthetic rate of plants grown under mulches.

Soil banking

It is one of the most capable cold insurance strategies for youthful trees by setting a hill of soil around the tree's trunk. By giving banking, heat conduction through the dirt and into the secured region of the youthful tree can be upgraded. Therefore, banking ensures by conduction and insulation too. It is most gainful when the trees are banked the day going before a freeze or not some time before the occasion of ice is anticipated (Usha *et al.*, 2015).

Surface Irrigation

Surface irrigation (flood or furrow) also protect from frost injury. By converting latent to sensible heat from the cooling water protection is provided. It ought to be begun right on time to guarantee that water shows up toward the completion of the field before the air temperature falls underneath the basic harm temperature. Brewer (1983) admitted that after ice forms on top of the furrow flows there is little heat transferred from the warmer water flowing beneath the ice.

Row covers

There has never been any doubt that covering for frost or freeze protection works (e.g. Bagdona *et al*., 1978, Martsolf and Gerber 1969). Covers, such as foams and blankets which have good insulation qualities, placed over low growing crops and ornamentals are always highly effective.

Nutrient management

Nutrient uptake including N, P and K were reported to be reduced under chilling stress due to poor root system of plants (Panetal, 1985 and Yan *et al*., 2002). Proper application of nutrient are required from the recovery of injury. (Proebsting, 1978) stated, when the plants accumulates photosynthesis in their tissues, it ensure resistance from frost injury. Photosynthesis rate under the temperature stress can be increased by the use of Mg (Waraich *et al*., 2011). A dose of nitrogen fertilizer in potatoes before frost, found to be resistant from injury (Valmari, 1966). Palta, 2000 stated that calcium actuate the plasma film proteins ATPase which siphon back the supplements lost during cell layer harm and recoup from injury.

Wind Machines

Wind machines are one the active method providing protection by mixing the cold air near the plants with warmer air above the plants. Wind machines are suggested only when the difference of temperature in between heights of 1.5m and 10m high (Synder, 2001). Wind machines require fuel of about 12l /h. (Usha *et al*., 2015). In apple, machines reduce flower damage by 60% (Gerber, 1979).

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