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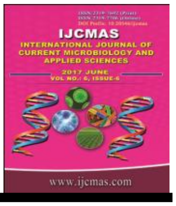

Review Article

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Management Strategies of Sun Burn in Fruit Crops-A Review

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ABSTRACT

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Sunburn injury is common on fruits in due to high solar radiation levels and air temperatures, low relative humidity, and high elevations. The incidence and severity of sunburn depends upon climatic factor, cultivars, hormonal, nutritional and soil moisture. Fruit production losses due to sunburn may be 6 to30 per cent depending on seasons and the type of fruit. Grower must follow best management practices to minimise sunburn and grow tolerant cultivars, efficient irrigation, appropriate canopy management, cover or intercropping, over tree sprinkler, shade netting, fruit bagging, suppressants (Kaolin or calcium carbonate) and chemical protectants.

Introduction

Sunlight is the primary source of energy used in photosynthesis by plants to convert carbon dioxide and water into carbohydrates, which the plant uses to make stems, leaves, roots, and fruits. Without this source of energy, life is not possible. Besides, sun light up to certain level is very much helpful to improve quality and production, and also reduces incidence of pest and diseases. If the intensity of sun light is beyond the optimum, plants suffer from many physiological problems and sun burn is one of them. Sunburn injury is common on fruits in due to high solar radiation levels and air temperatures, low relative humidity, and high elevations. Ultraviolet (UV) radiation is greater at higher elevations and is the greatest contributor to damage. Excess absorbed energy is the greatest contributor to cell death and sunburn. The incidence and severity of sunburn depends upon climatic factor, cultivars, hormonal, nutritional and soil moisture (Schrader *et al.*, 2003). The damage caused due to sun burning which occurs up to 0.9-19.13% in different varieties (Singh *et al.*, 2012). Sunburn occurs mainly where air temperature and the number of sunny hours are high during the ripening period. Sunburn also occurs when cool or mild weather is abruptly followed by hot, sunny weather. Severe sunburn alters the cuticle even more, and damages both the epidermal and sub epidermal tissues. Cell walls get thicker. Intercellular phenols increase, and the structures of plastids and thylakoids change (Barber and Sharpe, 1971; Andrews and Johnson, 1996, 1997).Concurrent water stress can intensify the damage (Brooks and Fisher, 1926; Ware, 1932; Meyer, 1932; Whittaker and McDonald, 1941; Moore and Rogers, 1942; Barber and Sharpe, 1971). Some plant pathogens such as *Alternaria tenuis*, *Physalospora obtusa*, *Monilinia fructicola* (=*Monilia fructicola*), *Monilinia laxa* (=*Monilia laxa*), *Monilinia fructigena* (=*Monilia fructigena*), *Glomerella cingulata*, and *Venturia inaequalis* can infect the fruit through the injured epidermal tissue, making it unmarketable (Holb, 2002 and Leeuwen *et al.*, 2000, 2002). The quality of the fruits is affected by sun burn (Schrader *et al.*, 2001 and Racskó *et al.*, 2005). Therefore, sunburn can cause serious economic losses in many crops with heavy losses in apple (Brooks and Fisher, 1926; Ware, 1932; Meyer, 1932; Whittaker and McDonald, 1941; Moore and Rogers, 1942; Barber and Sharpe, 1971; Bergh *et al.*, 1980; Simpson *et al.*, 1988; Warner, 1997; Schrader *et al.*, 2001).

Sun burn in fruit crops

Some modern fruit production techniques can increase the risk of sunburn. Rootstock is becoming popular in fruit production and dwarfing rootstocks growing on trellis and using training systems that allows direct sunlight to penetrate throughout the canopy of tree and this can increase fruit yields and improve colour development but can increase the risk of sunburn. Fruit production losses due to sunburn may be 6 to30 per cent depending on seasons and the type of fruit. Estimates of recent losses in susceptible orchards vary from 10 to 40 per cent in Granny Smith apples, 15 to more than 50 per cent in Gala apples, 10 to 25per cent in Pink Lady apples and 10 to 15 per cent in Williams's pears. When air temperatures rise above 30 to 35ºC during the day time, photosynthesis is likely to slow which will reduce potential fruit yield. The energy of sunlight can cause damage to the sun-exposed surface of the fruit. Sunburn is more due to the direct force of the sun than air temperature. The temperature of sun-exposed of apples is often 10 to 18ºC higher than the maximum shaded air temperature (Schrader *et al.*, 2003a). Unlike leaves, many types of fruits like apples and pears have very limited cooling capacity via transpiration from the skin of the fruit. Heat stress on fruit can also increase the incidence of other skin disorders in apples *e.g.* Lenticel Marking, Bitterpit, Splitting and Watercore (Schrader *et al.*, 2003b). Sunburn risk is also affected by tree factors, like variety, canopy density and fruit size (Schrader *et al.*, 2003b). Larger fruit are more likely to sunburn than smaller fruit. Position of fruit on the tree also affects sunburn risk. For example, fruit at the outer edge of the canopy and fruit positioned with a westerly aspect will be more prone to sunburn. Sun burn in apple are entry points for fungi such as Alternaria spp. (Barber and Sharpe, 1971; Bergh *et al.*, 1980; Simpson *et al.*, 1988; Holb, 2002; Leeuwen *et al.*, 2000, 2002). Maximum fruit surface temperatures are normally attained between 2pm and 5pm, in the hottest part of summer. Fruit damage usually becomes most apparent after a prolonged hot period.

Like human skin, fruit skin can become acclimatised to sun heat. The natural sun protection in apple is associated with the presence of antioxidants and 'heat shock proteins' (Brown, 2009). Fruit that has been exposed to direct sunlight earlier in the season will be more tolerant of direct sunlight and high temperatures later in the season. Apples exposed to ultraviolet radiation and high temperatures will usually reach maximum levels of skin antioxidants and 'heat shock proteins' after about three days. Different types of sunburn (Sunburn necrosis, Sunburn browning and Photo-oxidative sunburn) have been identified and characterised in apples (Schrader *et al.*, 2003b; Felicetti and Schrader, 2008). Sunburn necrosis is caused by heat, when the fruit surface temperature of an apple reaches 52 ± 1ºC for 10 minutes. Cells die and later a sunken dark brown or black (necrotic) patch may appear. Sunburn browning is the most common type of sunburn and results in a yellow, brown or dark tan patch on the sun-exposed side of the apple. The minimum threshold fruit surface temperature that will cause sunburn browning varies from46 to 49ºC for one hour, depending on different varieties. Photo-oxidative sunburn is found when shaded or partially-shaded apples are moved in to strong direct sunlight and they are prone to sunburn, even when the fruit surface temperature is relatively low (less than 45ºC). Often the sun-exposed patch of skin will become white-bleached, indicating that skin cells have died. Usually after a few days the patch will gradually become brown and then black and necrotic. Felicetti and Schrader (2008) showed this type of sunburn is mainly due to direct exposure of fruit to visible radiation and it does not require the other main components of solar radiation, i.e. infrared and ultraviolet. Sunburn necrosis in apple happens when the fruit surface reaches 52±1ºC, which damages the permeability of cell membranes. Sunburn browning happens when the fruit surface reaches 46º to 49º C, but sunlight also plays a decisive role in its formation.

It was found that untreated trees gave the highest percentages of sunburn fruits, while generally kaolin and silica gel sprays after fruit setting and before the first anticipated reduced the percentages of fruit sunburn (Aly *et al.*, 2010). Furthermore, it was reported that, plants use several protective mechanisms to avoid sunburn) dissipation of excess energy through the xanthophylls cycle (Demmig-Adams *et al.*, 1995 and Muller *et al.*, 2001) induction of antioxidants to minimize oxidative damage (Ma and Cheng, 2003) UV-B attenuation by reflecting pigments (Merzlyak and Solovchenko, 2002) and production of heat shock proteins (Ritenour *et al.*, 2001). Sunburn on fruit surfaces occurs under conditions of both high temperature and high irradiance (Rabinowitch *et al.*, 1974 and Schrader, *et al.*, 2003). Aly *et al.*, (2010) reported that total anthocyanin isolated from apple skin significantly increased with spraying 1 and 2% kaolin clay and0.5% silica gel compared to control and (Dong *et al.*, 1995; Faragher and Chalmers, 1997; Miller and Greene, 2003 and Toye, 1995) also reported that anthocyanin content increased. There may be two different ways that light enhances anthocyanin synthesis and accumulation in apples. One is to increase canopy photosynthesis and assimilate supply to the fruit, and, thus, indirectly stimulate anthocyanin synthesis by providing substrate. Another possibility is that the film treatments directly stimulated anthocyanin synthesis (Ju, *et al.*, 1999).

Sunburn also known as lesion browning or pericarp necrosis is a serious problem in litchi. This disorder is physiologically related with PPO (Poly-phenol Oxidize) activities in litchi and it also varies with cultivars. Sunburn is pronounced in ill managed orchards having sandy or sandy loam soils or light soils receiving/exposed to high temperature (>40ºC) and very less RH (<50%). It is a type of direct thermal injury and in case of higher temperature, the tissue coming in contact/exposure gets sunburnt/ sun scalded. Sunburn problem is also seen more in early ripening cultivars of litchi. Fruits on shaded branches suffer less damage than those more exposed to sun. Lower translocation of calcium in the pericarp region also found to favour sunburn disorder. In case of sunburn light brown blotches appear on the portion of the fruit skin facing direct sun rays. In severe cases more than half of the surface area becomes discoloured, blotchy light brown. The blotches become intense in few days and the blotchy area dries up blocking of the aril growth. The symptoms appear more on the south west side than the north-east side as on the latter side fruits remain almost in shade except during early hours of the day, which is not harmful.

Pineapples are susceptible to heat stress and sun damage, which can significantly reduce marketable yield. Extreme sun intensity can limit overall plant production and directly damage fruit. In many cases, damage is not realized until after the fruit is harvested. Early symptoms of sunburn exhibit as yellowing, “bleached” skin that turns pale grey/brown as the tissue deteriorates. This damaged tissue is susceptible to disease and infestation. Internal damage occurs when the fruit overheats and ends up “cooking” on the inside. There are some conditions which increases the risk of sunburn:

Modern intensive orchard production systems on dwarfing rootstocks growing on trellis and, training systems that allow good light-penetration through the orchard canopy

Fruit positioned with southerly and westerly aspect in direct sunlight

Sudden movement of fruit from shade to strong and direct sunlight

Hot, sunny and calm days

Cool, cloudy weather followed by clear-sky day’s greater than 30ºC

Plant water stress on hot days

Convection heat

Management of sunburn in fruit crops

Grower must firstly follow best management practices to minimise sunburn on fruit before considering investment in expensive sunburn protection products and infrastructure such as spray-on sun protection, shade netting or evaporative cooling. Grower should identify which fruit blocks are more susceptible to sunburn, what control strategies can be employed in each block and which blocks have the best chance of achieving good returns on the additional investment (Brown, 2009). Shade netting and over tree sprinkler cooling systems are best but it has high set-up costs.

Climate ameliorating techniques

Best Management Practices for sun protection

Use fruit varieties that are more tolerant of sunburn

Granny Smith and Royal Gala are considered to be most susceptible. Other apple varieties that are susceptible to sunburn are Jonagold, Braeburn, Golden Supreme, Ginger Gold and Fuji (Evans, 2004). Pink Lady® is more tolerant than Cameo and Honeycrisp (Schrader *et al.*, 2003a).

Schedule irrigations to avoid tree water stress

Healthy, fully irrigated trees receive the maximum cooling benefit from transpiration. Irrigation scheduling techniques based on weather forecasts and soil moisture measurements should be used to ensure irrigation is well-matched with the crop’s water requirements. Irrigation should be used just before or during heat waves to avoid tree stress and sunburn. Proper irrigation helps to create congenial microclimate for fruit production.

Train fruit trees to develop an appropriate canopy

Fruit crops which are highly susceptible to sun burn should not be trained on the system which directly exposes the fruits to sun. Apple and pear fruit sunburn is often associated with thin exposed canopies when branches move under the weight of the developing crop.

Avoid branch movement by training young trees with less fruit developing at the ends of branches and with scaffold branches that can support the fruit load. Supporting the limbs and branches of free standing trees with bands tied two-thirds of the way up the trees.

Avoid excessive summer pruning and leaf stripping

This is often done to allow light into shaded parts of many fruit trees to enhance colour development. This should be done carefully to avoid limb movements and sudden exposure of fruit to direct sunlight, especially during hot weather.

Cover cropping

The bare earth and dead vegetation in the inter row space is likely to reflect more sunlight into the orchard canopy than green vegetation. In the hottest part of summer this is likely to increase the heat load on fruit and increase the probability of sunburn. Inter row space should be utilized and grow inter crops as per crop specific. Maize or pigeon pea is most useful in pineapple orchard to protect from sunburn/sunscald.

Improve air movement through the fruit block

The temperature of fruit skin in direct sunlight is higher than the temperature of the surrounding air. Air movement around the fruit helps to remove some of its heat and tends to equalise the temperature of fruit and air.

Over-tree sprinkler cooling systems

Over-tree sprinkler cooling systems are designed to reduce sunburn by delivering sprinkled water over the tree canopy to cool fruit during the hottest part of the day. The same cooling systems can be used to enhance colour development of ’red’ or ‘red-blushed’ apples close to harvest. Over-tree sprinkler cooling systems rely on the cooling properties of water to reduce temperature extremes on the fruit’s surface. All types of over-tree cooling systems rely to varying degrees on three possible water cooling mechanisms (Evans and Van der Gulik, 2011). These are listed below in order of increasing effectiveness, from least to most effective:

Aerial evaporative cooling

Orchard air can be cooled by water evaporating from fine droplets as they come from misting sprinklers and travel through the air. This creates cool air currents that move through the orchard by convection. This process is very inefficient and not effective for reducing fruit surface temperatures and sunburn, especially when there is wind.

Hydro-cooling

Water droplets emitted from the over-tree sprinkler system are cooled through evaporation. The cool water runs continuously over the fruit and the rest of the tree, absorbing and carrying away some of the heat. This can be effective, but it tends to use excessive amounts of water and greatly increase the risk of the orchard floor becoming water logged.

Surface evaporative cooling

Emitters spray droplets over the tree canopy, thoroughly wetting all surfaces to the point of run-off. Fruit is cooled by water continuously evaporating directly from its skin. This is the most efficient way to reduce fruit surface temperatures. In this approach, fruit surface is wet during the day time and water losses can be minimized which was being applied on the orchard floor. Using the same amount of water, evaporation can remove50 times more heat energy than the heat carried away inflowing water.

Every over-tree sprinkler cooling system should be carefully designed to ensure adequate water can be delivered when and where it is required. The heat energy coming into anorchard in the middle of a hot summer’s day (35°C) is approximately 800 Watts per square metre. The amount of water that can be evaporated with that amount of heat energy is estimated to be about 3.1 litres per second perha. However, heat energy is also carried into the orchard by wind and is estimated to be almost as much as the energy from sunlight, so the flow of water to neutralise the total heat load on the orchard is estimated to be approximately 6.2 litres per second per ha (Evans, 2004).

Aerial evaporative cooling uses application rates up to 6litres per second per ha. Very little or no water reaches the ground. With swirling air currents and wind, water droplet and cool air distribution is often not uniform. This process is not very effective at lowering fruit surface temperatures (Evans and Van der Gulik, 2011).

Hydro-cooling uses application rates that are significantly greater than 6.5 litres per second per ha. The amount of water entering the root zone must be carefully co-ordinated with irrigation to ensure the crop’s water needs are met and to prevent waterlogging. Normal irrigation applications should be reduced to take into account the volume of water reaching the orchard floor and entering the root zone. It may be very difficult to prevent waterlogging. The soil surface often becomes saturated, with some runoff (Evans and Van der Gulik, 2011).

Surface Evaporative Cooling uses application rates around6.0 to 6.5 litres per second per ha. This is the most effective way to achieve cooling for sunburn protection while minimising water use.

Shade netting

Shade netting is made from woven synthetic fibres to provide protection from high radiation. In recent years, its use in horticulture has increased because netting materials that are stronger and longer-lasting. It can be used for at least 10 years under natural sunlight. Netting is used for sun, hail, wind and bird protection. Shade netting reduces the adverse effects of climatic extremes, including intense sunlight, wind and hail. Direct sunlight is the primary cause of sunburn. Shade netting is usually designed to reduce mid-day sunlight by about 20 per cent. This reduces the heat loading on trees and fruit from visible and infrared radiation and reduces the amount of damaging ultraviolet radiation. Different net designs are available providing a range of 12 to25 per cent reduced sunlight. In some situations wind speeds can be reduced by 50per cent. This reduction varies depending on the type of netting, whether it is gabled or flat and whether or not side netting is used as a windbreak or to exclude birds. Anecdotal evidence indicates that wind could either reduce or increase sunburn. There is a complex interaction between fruit surface temperature, tree water status, humidity and wind.

For example, wind in a well-watered orchard will reduce temperature of sun exposed fruit, however, if drying winds raise tree water demand above a rate that can be supplied by the roots, then the tree will become stressed and probably also more prone to sunburn.

Different management under shade netting

Shade netting increases more vegetative growth and excessive shoot growth could reduce fruit set and fruit skin colour development. However, with well-managed apple trees grown on dwarf and semi-dwarf rootstocks, excessive vigour should not be a significant problem (Middleton, 2010).

It is generally accepted that fruit tree yield is proportional to the amount of sunlight that is distributed and intercepted by leaves. It is likely that shade netting will reduce photosynthesis of fruit trees. However, during most of the growing season and most of the day there is an excess of sunlight for photosynthesis and a 20 per cent reduction of sunlight due to shade netting is unlikely to reduce the yield potential and fruit quality of a well-managed orchard, provided direct sunlight can penetrate evenly throughout the tree’s canopy.

Under permanent shade netting, with less wind and sunlight, the orchard floor will stay wetter for longer after rainfall and irrigation. Irrigation applications should be reduced to avoid more wet and humid under shade netting. Low air movement and higher humidity under netting can cause fungal diseases. Bound (2010) found that chemical thinning in apple is more effective under shade netting because of lower light levels.

Fruit bagging

Bagging of individual fruits or bunch is used to prevent fruit injury by sun light, insects and diseases. Individual fruit bagging was used in apple to obtain a smooth finish of the apples along with uniform, but uncharacteristic, skin color (Mink, 1973; Proctor and Lougheed, 1976). Bagging was found to protect apple fruit from sunlight-dependent types of sunburn. Bagging significantly decreases fruit borer infestation, sunburn, spotted and cracked fruits with slightly decreases in TSS and acidity in litchi. The physical appearance, weight and vitamin–C of fruits were significantly improved under all type of bagging. Bagging with white butter paper bag gave the best result and recorded 30-35 % less damaged fruit. Bagged fruits produced heavy and longer fruit with 6-16 % more weight over control (Anon, 2015).

Suppressants

Materials that are sprayed on the fruit to suppress sunburn in fruit tree are called suppressants. At least two classes of suppressants exist. There are white particle films that, by definition, are physical inorganic blockers (Antoniou *et al.,* 2008) that block, reflect and scatter solar radiation. A different class of sunburn suppressant is a sunscreen by definition, as it contains organic chemical absorbing agents to further reduce the intensity of high-energy UV radiation by absorption, in addition to physical inorganic constituents.

The suspensions of tiny, white mineral particles (clay or calcium carbonate) or with wax emulsions can be sprayed onto leaves and fruit to create a film that provides some protection from the effects of sunlight.

Particle film

The use of reflective particles on fruits has been suggested as a tool to diminish its thermic charge because it reduces the incident radiation that can be absorbed by the fruits (Glenn *et al.,* 2002; 2003, Wuncshe *et al.,* 2004) and thus reduce the incidence of sunburn (Glenn *et al.,* 2002; Gindaba and Wand., 2005; Wand *et al.,* 2006; Colavita, 2011). Purshade reduces solar stress in crops by protecting the foliage and fruit from damaging ultraviolet (UV) and infrared (IR) radiation while still allowing photosynthesis to occur. The mineral particles form a white film that blocks and reflects some of the direct sunlight to reduce the temperature of fruit surface. The wax-based product forms a film that absorbs some of the damaging UV radiation and reflects a small amount of the incoming radiation. These products must be applied several times during the season to maintain a protective cover on the fruit. All spray-on sun protection products must be applied before severe summer heat wave conditions occur and applications must be maintained throughout the hot season to maintain coverage on the expanding fruit. Resellers usually recommend a minimum of three to four applications, separated by seven to 21 days.

Kaolin based product

The type of clay used is white kaolin, which has many industrial uses. The kaolin used in clay-based sun protection products has been refined and modified to produce awe table powder which can be mixed with water and sprayed onto foliage and fruit to create a white film that will reflect some sunlight. Glenn and Puterka (2005) reported that they can reduce fruit surface temperatures by up to 5 to 10ºC.

Glenn (2009) reported that clay-based coating unaffected photosynthesis or even increased due to reduced heat stress and better distribution of light to lower shaded parts of the tree canopy under highlight intensities. Clay-based products can be easily washed-off the tree and must be re-applied after rainfall and over-tree sprinkler irrigation and evaporative cooling. Glenn and Puterka (2005) reported that these products can act like an insect repellent in fruit crops.

Kaolin and silica gel have been recommended to lower the temperature of the fruit, thereby reducing sunburn and improving red fruit colour in situation when temperatures are supra optimal (Glenn *et al.,* 2001; Heacox, 1999 and Werblow, 1999).

Kaolin reduces fruit surface temperature by increasing the reflection of visible and ultraviolet light (Glenn, *et al.,* 2001; Wunsche *et al.,* 2004). The effectiveness of Kaolin in reducing sunburn in most cultivars and regions may be more strongly ascribed to the reduction in harmful radiation reaching the fruit surface than to the reductions in surface temperature (Gindaba and Wand, 2005), although the latter would lower the threshold for radiation damage. The same results were found by (Schupp *et al.,* 2002) on apple. Aly *et al.,* (2010) reported that kaolin clay particle film produced labeled reduced in sunburn percentages. The same trend was reported by (Melgarejo *et al.,* 2004) on pomegranate fruits.

Calcium carbonate-based product

The main active ingredient is high-grade calcium carbonate or crystalline limestone. These products are marketed as a liquid that is mixed with water and sprayed onto crop foliage and fruit to form a thin crystalline layer that reflects some sunlight. There is also a calcium-based fertiliser product which claims good sun protection quality. It is a high-analysis suspension fertiliser, high in calcium (Ca), zinc (Zn), magnesium (Mg), nitrogen (N) and boron (Bo). Ahmed *et al.,* (2011) reported that untreating the grapevines with CaCO3 or Purshade gave the maximum values of sunburned berries % (20.5. and 22.3 %, in both seasons 2009 and 2010, respectively). Glenn *et al.,* (2002) reported that crimson Seedless grapevines treated with plant protectants and CaCO3 were less prone to sunburn damage than untreated ones and this is due to reducing both fruit temperature and exposure to UV radiation as Purshade and $CaCO_3$ have been found to reflect UV radiation strongly. Melgarejo *et al.,* (2004) found that sunburn damage of pomegranate fruits was depressed from 21.9% in untreated control to 9.4% in the kaolin treated fruits. Curry *et al.,* (2004) reported that anti sunburn compounds effectively reduced solar radiation injury of apple trees. Attra (1999) also reported that Purshade and other plant protectants protected fruits from all stresses by leaving a protective powdery film on the surfaces of the fruits and similar results are also obtained by Melgarejo *et al.,* (2004) and Morsy *et al.,* (2008). Ahmed *et al.,* (2011) found that CaCO3 and Purshade stimulated plant metabolism through enhancing photosynthesis and formation of plant pigments in favour of enhancing quality of the berries and Glenn *et al.,* (2002) and Morsy *et al.,* (2008) are also reported the same.

Talc-based products

Hanrahan *et al.,* (2009) reported that sunburn incidence could be reduced in apples by four applications of Invelop® (Luzenac, Greenwood Village, CO), a talc-based particle film product.

Sunscreen

Another sunburn suppressant is a sunscreen by definition (Antoniou *et al.,* 2008), as it contains organic-chemical absorbing agents in addition to physical inorganic constituents. Carnauba wax, the principal component of this sunscreen (RAYNOX®, Pace International, LLC, Seattle, WA), contains cinnamates that absorb high-intensity UV rays with excitation to a higher energy state (Schrader, 2011), but this excess energy is dissipated by emission of longer wavelength light or relaxation by photochemical processes such as isomerization and heat release. RAYNOX® also contains inorganic components that block, reflect and scatter solar radiation, the main active component of the wax-based product is carnauba wax, which is produced on the leaves of a tropical palm tree and also used in cosmetics and car wax. Small amounts of reflective compounds based on clay are also added. The wax-based product is a liquid emulsion sprayed onto fruit trees to form a clear film that filters out a significant proportion of the damaging ultraviolet radiation and a small amount of the visible and infrared radiation. It has been shown to significantly reduce sunburn browning of apples (Schrader, 2011). It has some insect repellent qualities and the distributors claim it has no negative effect on beneficial insects and mites. The applied product is rain fast and can be used in orchards with overhead sprinklers. It is not compatible with other chemicals and a water softener is required when mixing.

Chemical protectants

This group includes certain naturally-occurring metabolites that have shown promise, when sprayed on trees, of protecting fruit from effects of excessive temperatures and/or sunlight. The concept is to increase the concentration of selected metabolites in the fruit and enhance the fruit's ability to avoid damage from stress-induced disorders such as sunburn.

Ascorbic acid

The ascorbate-glutathione cycle is the central antioxidant system that protects fruit from photo oxidative injury (Ma and Cheng, 2004). One of its key components is ascorbic acid (vitamin C), and its level in the peel is positively correlated with susceptibility of the fruit to sunburn (Andrews *et al.,* 1999). Although sunburn incidence was significantly reduced in 'Fuji' apples, ascorbic acid was not effective in 'Granny Smith' (Andrews *et al.,* 1999). Even though 4% concentration reduced sunburn incidence more than lower concentrations, mild phytotoxicity occurred on ‘Fuji’ fruits as darkening of the lenticels. Although ascorbic acid showed promise for controlling sunburn in some apple cultivars, the suggested amount, the frequency of applications and its price make its use impractical commercially.

Abscisic Acid (ABA)

Recently, Iamsub *et al.*, (2009) reported significant reductions in the incidence of SB and SN in ‘Tsugaru’ and ‘Sensyu’ apples in Japan when they applied pure ABA (S-isomer) at 200 ppm concentration or at 400 or 800 ppm rate as a fertilizer. Along with the reduction of sunburn incidence, ABA treatments reduced lipid peroxidation and increased the total antioxidant capacity, phenolics, ascorbic acid, anthocyanin and chlorophyll content of the peel. From these results, the authors concluded that specific ABA-mediated mechanisms contribute to normal cell functions in apples under elevated solar radiation conditions. Considerably more research is needed to establish whether the physiological changes they observed will reduce sunburn in apples grown in areas with higher temperatures and higher solar radiation than experienced in Japan.

Anti-transpirants

The use of anti-transpirants can effectively reduce excessive water loss through transpiration under drought stress conditions (Yuanwen, 1992). A product named VaporGard® (MillerChemical and Fertilizer Corp., Hanover, PA), whose active ingredient is poly-1-P menthene, has been sold for years as a sunburn protectant. Yuri *et al.*, (2000) and Schrader *et al.*, (2008) reported no significant effect of VaporGard® on sunburn or ‘Fuji’ stain, a sunburn-related postharvest disorder (Schrader *et al.*, 2008). Given the fact that transpiration is reduced by an antitranspirant, temperature of leaves and small fruitlets is expected to increase; it is therefore not surprising that VaporGard® did not reduce the incidence of temperature-dependent types of sunburn.

It is concluded that all the available technologies are capable of reducing sunburn, but none alone will completely eliminate it. The sun burn tolerance cultivars of fruit crop must certainly be combined with other means of strategies to minimize sun burn in fruit crops. Grower should identify which fruit blocks are more susceptible to sunburn, what control strategies can be employed in each block and which blocks have the best chance of achieving good returns on the additional investment.

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