Environmental and Experimental Botany 139 (2017) 79–90

Contents lists available at ScienceDirect

Environmental and Experimental Botany

journal homepage: www.elsevier.com/locate/envexpbot

Review

Light quality manipulation improves vegetable quality at harvest and postharvest: A review

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ARTICLE INFO

Keywords:
colour shade nets
Harvest time
Quality attributes
Storage
Vegetable production

ABSTRACT

Modification of spectral quality via coloured shade nets can act as a physiological tool to modify the crop microenvironment and advance plant growth and yield. This literature review presents data on the physiological responses in vegetables linked to light quality under different coloured shade nets. The physiological parameters discussed in the review include: vegetable growth parameters (leaf area, leaf chlorophyll), tissue structure, fruit ripening, physiological disorders, pest and disease incidence, fruit quality parameters (soluble solids content and titratable acidity), phytochemicals (antioxidant activity, ascorbic acid, carotenoid and flavonoid contents) and aroma volatile compounds at harvest. Also, it is evident in the reviewed literature that light quality influences the biosynthesis, accumulation and retention of vegetable phytochemicals, as well as the decay development during storage. These new strategies to modulate light quality should be conveyed to vegetable producing farmers, thus allowing them to preserve the freshness and post-harvest quality of vegetables for an extended period of time, and to meet the consumers demand for vegetables with high nutritional value all year round. Research on light manipulation in horticultural systems is necessary for a sustainable and market-oriented open field and greenhouse vegetable production in the future.

1. Introduction

Consumption of vegetables has rapidly increased due to their high nutritional value and positive health effects. However, growers are unable to produce good quality vegetables with high productivity due to various biotic and abiotic factors that are influenced by climate change (Prasad and Chakravorty, 2015). The global warming effects that are already setting in are likely to increase the incidence of abiotic disorders in vegetables (Ilić et al., 2012). Therefore, active manipulation of the growth environment of plants is commonly used to optimize plant production and quality (Dueck et al., 2016). In order to improve crop yield and quality, current knowledge about how plants respond to light is being applied in horticulture. To that end and as a result of recent technological inventions, such as the development of photo-selective nets (Demotes-Mainard et al., 2016), it is now possible to manipulate light quality. The maximum net CO_2 assimilation of most C_3 species saturates at a relatively low irradiance (600–900 μmol m^{-2} s^{-1}), corresponding to 30–40% of full sunlight (1500–2000 μmol m^{-2} s^{-1}) on a typical season growing day. The resulting excess radiant energy predisposes plants to photo-inhibition, heat stress and stomatal closure, leading to a reduction in net photosynthesis (Pn), which is the ultimate source of carbohydrate substrate for growth. In addition, sustained high temperatures (35–40 °C) as a result of high solar radiation can impair cell division, leaf expansion and reproductive development (Flaishman et al., 2015).

Manipulation of light quality is currently applied in horticulture via photo-selective netting or films to improve the yield, quality and phytochemical composition of cultivated plants. It is a technology that can be used as an alternative to protect crops from adverse environmental conditions such as excessive solar radiation (Ilić et al., 2011), heat and drought (Meena et al., 2014; Tinyane et al., 2015), wind and hail (Teitel et al., 2008), and flying pests (Shahak, 2008a), thus improving the production, yield and quality of crops. This technology has the ability to lengthen the shelf-life of produce, thereby lowering postharvest losses.

In recent years, the use of shade netting, regarded as a common agro-technological approach, has been evaluated with ornamentals (Nissim-Levi et al., 2008; Shahak, 2008a), vegetables (Fallik et al., 2009) and fruit trees (Shahak et al., 2004a,b). Shade nets are characterized by different structures, radiometric and physical properties and mechanical characteristics (Castanello et al., 2008). These nets do not alter the light spectral composition (Ben-Yakir et al., 2008; Elad

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http://dx.doi.org/10.1016/j.envexpbot.2017.04.006
Received 24 January 2017; Received in revised form 20 April 2017; Accepted 20 April 2017
Available online 26 April 2017
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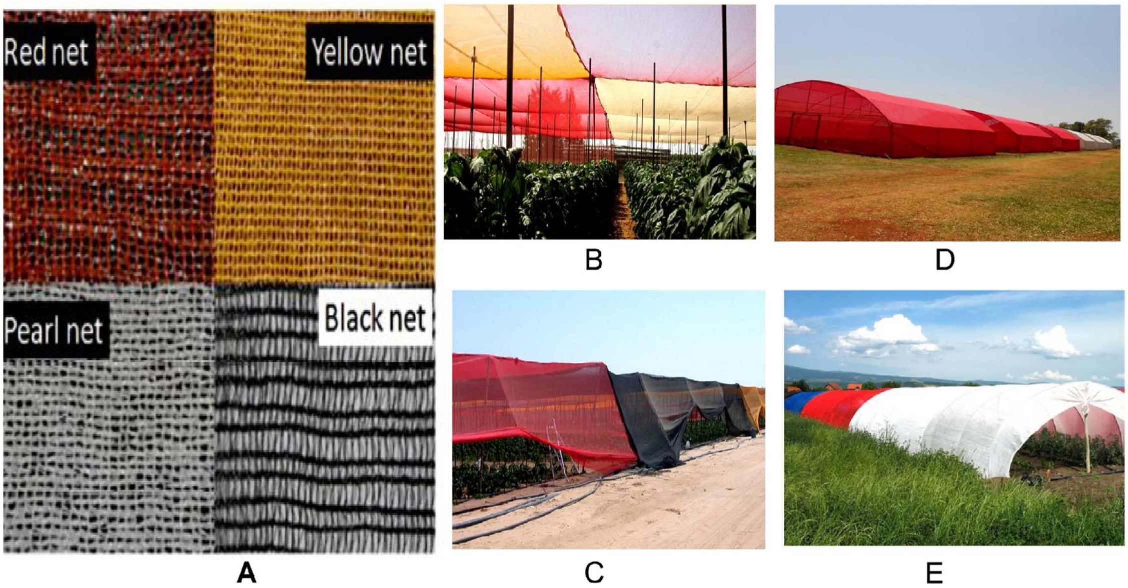

Picture 1. (**A**) Knitting pattern of photo-selective red, yellow and pearl shade nets (40% shading) and the commercial black net (25% shading) *Adapted from:* Sivakumar et al. (2017). Application of colour shade nets in Israel (B, C) – *Adapted from*: Fallik et al. (2009). South Africa (D)- *Adapted from*: Buthelezi et al. (2016). Serbia (E) - *Adapted from*: Ilić et al. (2015). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2007). Modern shade nets are manufactured from woven polypropylene or knitted polyethylene materials, with different dimensions of fibres and holes to achieve specific shade levels (Castellano, 2008a; Appling, 2012) Picture 1.

The fraction of light that passes through the holes in the shade cloth remains unchanged in its quality, while the light hitting the threads is spectrally modified and scattered on exit (Appling, 2012).

Colored shade nets can also increase light scattering by 50% or more (Fig. 1**A**). Colored shade nets are being intensively tested primarily because of their ability to manipulate the spectra of radiation reaching the crops below (Fig. 1**B**). They can be used to change red to far-red light ratios that are detected by phytochromes, the amounts of radiation available to activate the blue/ultraviolet-A photoreceptors, blue light involved in phototropic responses mediated by phototropins, and radiation at other wavelengths that can influence plant growth and development (Stamps, 2009).

The spectral manipulation of coloured shade nets is aimed at specifically promoting photomorphogenetic/physiological responses, while light scattering improves light penetration into the inner canopy. The relative enrichment of intercepted light with productive components of the spectrum may allow better utilization of the sun light, while reducing the less productive ones. Black shade nets differ from colour nets in that they merely reduce light intensity, while having no effect on light quality (Shahak, 2008). Compared with black nets with the same shading factor, as determined by the photosynthetically active radiation (PAR), red and yellow nets were found to specifically stimulate the vegetative growth rate and vigour of foliage and cut-flower crops, while the blue nets caused dwarfing, and the grey nets enhanced branching and bushiness, in conjunction with reduction of leaf size and variegation due to their distinct absorption in the IR range. The effects of the blue, yellow and red nets result from their relative enrichment/reduction of blue, yellow and red spectral bands of the transmitted light. Pearl nets have the greatest light-scattering capability in the visible range and also absorb light in the ultra-violet (UV_{A+B}) range, thus found to best increase fruit size and yield in fruit tree crops, as well as postharvest quality of fresh produce (Shahak, 2008; Goren et al., 2011; Kong et al., 2013; Alkalai-Tuvia et al., 2014).

The application of photo-selective netting technology is gaining popularity around the world, especially in Israel (Goren et al., 2011; Kong et al., 2013), South Africa (Selahle et al., 2015; Mashabela et al.,

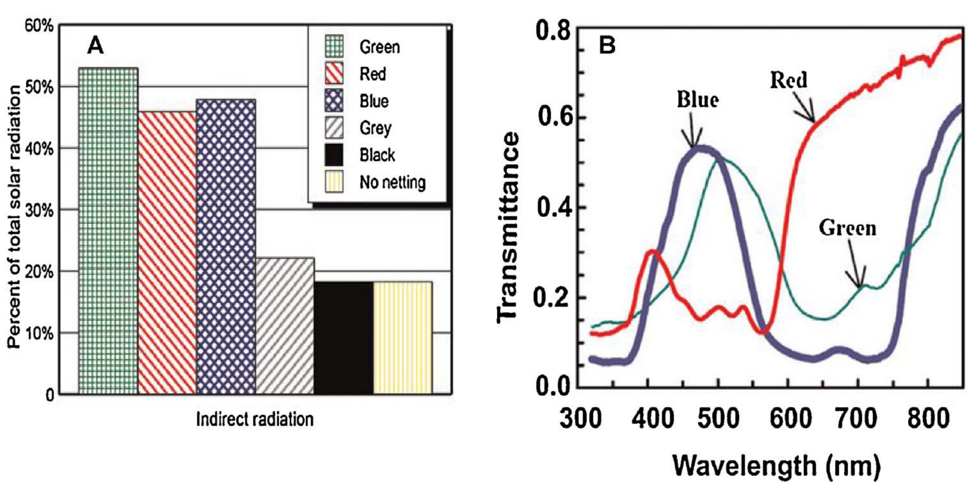

Fig. 1. Light scattering under coloured shade nets compared with no net (A) and spectra of transmittance for three coloured shade nets (**B**).Spectra were measured by LiCor LI-1800 spectroradiometer under each net at midday of a clear day, in August. Adapted from Oren-Shamir et al. (2001).

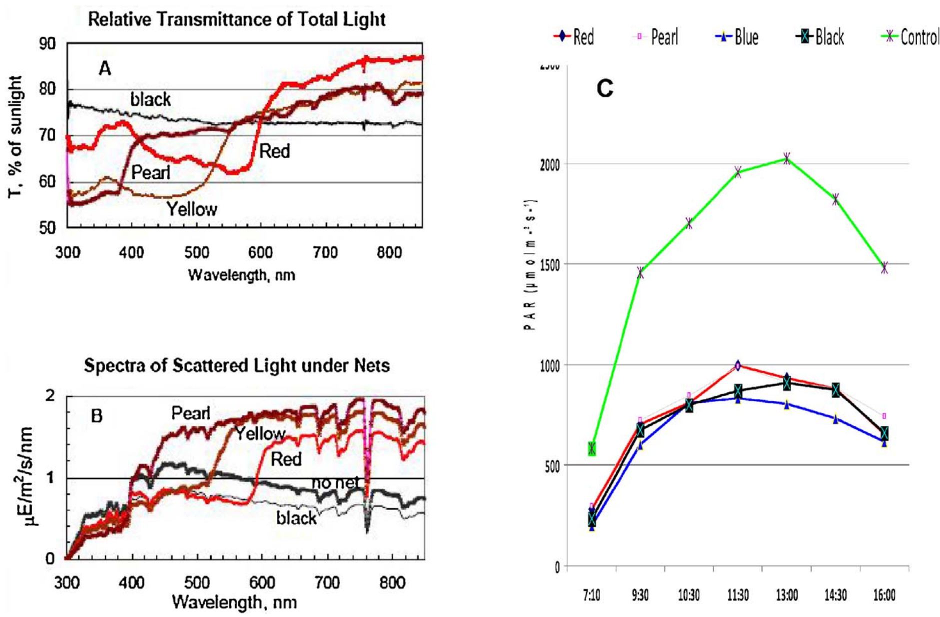

Fig. 2. Spectra of transmittance of total (direct + scattered) and scattered light intensity under coloured nets.(A) The trasmittance spectra were derived from spectra of total light under each net divided by the spectrum with no net.Adapted from Shahak et al. (2008).(B) Scatered PAR intensity was 1894 and 285 (no-net), 1379 and 482 (pearl), 1382 and 221 (black) μmol/m^2/s/nm, respectively, measured at mid, clear day on 06/07.Adapted from Shahak et al. (2008).(C) Photosynthetically active radiation PAR (μmol m^{-2} s^{-1}) under different coloured nets.Adapted from Ilić et al. (2017a).

2015) and India (Swamy et al., 2015), but also in other countries such as the United States (Stamps, 2009), Mexico (Moreno-Reséndez et al., 2015) and Brazil (Santana et al., 2012). This practice is already popular in the Mediterranean countries – Spain (Díaz-Pérez, 2014; Lopez-Marin et al., 2012), Italy (Basile et al., 2008) and Greece (Kitta et al., 2014a,b; Kittas et al., 2009, 2012), but equally in Serbia (Ilić et al., 2012, 2015; Milenković et al., 2012) and Hungary (Ambrózy et al., 2016; Ledóné, 2014; Ombódi et al., 2016).

The shade nets can be placed directly over the plants (net-house) or in combination with plastic tunnels. They can be movable or fixed (Ilić et al., 2015). Milenkovic et al. (2012) and Ilic et al. (2015) found that the same shade nets have different effects on for example pepper compared to tomato, and that the effects can be further modulated by applying shade nets alone or in combination with plastic sheet covering.

Spectral modification promotes physiological responses, while scattering improves the penetration of spectrally modified light into the inner plant canopy (Shahak et al., 2008a,b; Rajapakse and Shahak, 2007) Fig. 2. illustrates the spectra of transmittance of total light, and the spectra of scattered (diffused) light under red, yellow and pearl nets compared with traditional black shade nets.

Depending on the thread pigmentation and knitting design with different fibres and density to create specific shade indices (Castellano, 2008; Appling, 2012), the photo-selective coloured shade nets provide diverse mixtures of natural, unmodified light and scattered, spectrally-modified light (Shahak et al., 2004a, 2009; Rajapakse and Shahak, 2007).

Traditional black shade nets differ from coloured nets in that they merely reduce light intensity, whilst having no effect on light quality. They do not scatter light (Shahak et al., 2004b, 2008, 2012) or are completely opaque, and as the spectral quality of radiation is not modified by black nets, the shading factor is almost directly proportional to net porosity (Castellano et al., 2008; Appling, 2012). Light quality modification (light transmittance and scattering) by different shade nets is illustrated in Table 1.

It is possible to modify desirable plant growth characteristics with the combination of light-scattering and spectral manipulation. In addition to light, shade nets can modify environmental variables such as temperature, wind speed, or relative humidity inside the canopy

Table 1
Light quality modification in the UV-B to far-red spectral range by coloured nets showing distinct effects on vegetable crops.
Source: Shahak, 2008

Net	Absorption	Transmittance	Scattering
Blue	UV + Y + R + FR	B + G	+ +
Red	UV + B + G	R + FR	+ +
Yellow	UV + B	G + Y + R + FR	+ +
White	UV	B + G + Y + R + FR	+ +
Pearl	UV	B + G+ Y + R + FR	+ + +
Grey	all (+IR)	–	+
Black	all	–	–

(Arthurs et al., 2013).

Photo-selective nets are also used to prolong harvest in conditions of excess light, (Castellano et al., 2008) by protecting the vegetables from sunburns and blossom-end rot, and by reducing the water use, all of which result in higher marketable vegetable yields (Moller and Assouline, 2007). Photo-selective nettings were reported to influence plant growth and morphology in different vegetable plants such as *Capsicum annuum*, *Solanum lycopersicum*, *Lactuca sativa*, and *Brassica oleracea* (McElhannon, 2007). The black nets and open field conditions demonstrated a smaller growth index, whilst the plants under pearl nets (white) consistently showed a larger growth index. The findings reported by McElhannon (2007) demonstrate that the grey and pearl nets influence the production of less compact plants, as determined by the texture and structural parameters of the leaves. According to the literature, photoselective shading nets of red, pearl and yellow colour markedly increase productivity (Fallik et al., 2009), improve the fruit quality (Goren et al., 2011; Kong et al., 2013) and reduce the crop infestation by pests and diseases (Díaz-Pérez, 2014). Color shade nets have been shown to reduce light intensity by at least 50% relative to the outside (2000 μmol m^{-2} s^{-1}) during the summer months, resulting in light intensity levels similar to fall and spring (Ilić et al., 2017a).

Sweet pepper has been proven to be well-adaptable to a shaded environment (Kitta et al., 2014b). The shade net slows fruit ripening during its growth, as assessed by external colour. For instance, photo-selective nettings have been shown to influence the biosynthesis of bioactive compounds in sweet peppers (Selahle et al., 2015; Mashabela et al., 2015). Red and pearl coloured shading nets have been shown to improve tomato fruit quality (Ilić et al., 2012, 2015) and carotenoid content (Tinyane et al., 2013; Selahle et al., 2014). Light modification and micro climate conditions under the pearl photo-selective nets provide better crop yields (Ilić et al., 2011), reduce fruit susceptibility to fungal infection in the field (Goren et al., 2011) and lower susceptibility to decay during post-harvest storage compared to traditional black nets (Stamps, 2009; Fallik et al., 2009; Goren et al., 2011; Shahak, 2014). Pearl shade nets improve not only yield and quality, but also postharvest shelf-life of the bell pepper fruit (Goren et al., 2011; Kong et al., 2013; Díaz-Pérez, 2014; Alkalai-Tuvia et al., 2014; Selahle et al., 2015).

Spectral manipulation can trigger a wide range of physiological responses in vegetables, while the efficiency of light-dependent processes, the series of biochemical reactions in photosynthesis that require light energy, has a large impact on pepper (Ilić et al., 2011, 2017a; Mashabela et al., 2015; Selahle et al., 2015), tomato (Tinyane et al., 2013; Ilić et al., 2015), fresh herbs (Buthelezi et al., 2016) and lettuce (Ntsoane et al., 2015) production. Nettings have also been shown to influence the retention of sensory qualities such as flavor, texture and appearance and vegetable phytochemicals at harvest and postharvest.

The aim of this review is to elucidate the latest information on light quality manipulation by colour shade-nets and on their possible modes of action. It summarizes recently accumulated information regarding shade treatments, applied either individually as net-house or in combination with plastic tunnels. We hope to provide useful recommendations to vegetable growers on how to control or improve vegetative plant development (leaf area index, photosynthetic pigments), fruit development and maturity, colour development and how to reducephysiological disorders, such as rot development during production and how to maintain overall external, biochemical and sensory fruit parameters after harvest and during prolonged storage.

1.1. Leaf area index (LAI)

LAI has an important role in determining the photosynthetic/net assimilation rates and yield. Besides light condition and canopy structure other factors e.g. climate and nutrients have an effect on LAI. Lower light intensities increase stem elongation, leaf blade area and total plant leaf area. The plant leaf area, individual leaf area, dry weight and leaf weight ratio have all been found to increase with increased shade level, whereas the specific leaf weight(SLW;leaf weight per unit leaf area) as an estimator of leaf thickness decreases with increased shade level (Dıaz-Perez, 2013). Rajapakse and Shahak (2007) suggest a shading rate of 30% or less, instead of 40%, as a way to limit the impact on vegetable development caused by excessive shading. Many vegetable species present leaf and stem morphological and physiological adaptations in response to shade.

Ilic et al. (2017) found that all shade nets significantly increase the LAI, compared to the LAI values obtained from control plants (plastic tunnel). Generally, pepper under plastic tunnels integrated with coloured shade-nets have a higher LAI in comparison to the plant LAI obtained under net house (only coloured nets) conditions.

Santana et al. (2010) reported minor differences in LAI values of pepper plants cultivated under shading nets compared with pepper plants grown in the open field. Red screen netting (40% shading) promotes slight increase in the LAI values (1.13–1.15) compared to open field conditions (0.94–1.04). Plants grown in the shade tend to have thinner leaf blades and larger leaf areas, because cells expand more under low light intensities in order to increase photosynthesis.

Ilić et al. (2017a) reported that the spongy parenchyma leaf thickness is higher in control pepper plants from open field and plastic tunnels, compared to coloured nets treatment. No significant differences in upper and lower epidermis leaf thickness between control plants and plants from coloured net houses have been reported.

Compared to black nets, red and yellow nets have been found to specifically stimulate the vegetative growth rate and foliage vigour i.e. plant height, width and number of branches on cilantro-coriander, parsley and basil herbs (Appling, 2012). Blue netting has been reported to cause dwarfing, reduce branching and decreasing yield of commercial branching (cut foliage) and reducing leaf size (Oren-Shamir et al., 2001; Shahak et al., 2008a,b). Based on spectra created by different coloured nets it can be concluded that various plant species respond differently to growth and development.

1.2. Chlorophyll and carotenoid contents

Light is an environmental factor that significantly affects plant growth and development, not only as the sole energy source of photosynthesis (acting on chlorophyll) but also by mediating photomorphogenesis (Liu, 2012).

At high light intensities, the degradation rate of chlorophyll in plant leaves is higher than the synthesis rate, leading to a decrease in chlorophyll concentration as a result of chloroplast formation inhibition. Consequently, shade leaves in comparison with sun leaves tend to show higher chlorophyll concentrations per unit of leaf weight (Gonçalves et al., 2001; Fu et al., 2012; Kosma et al., 2013). Shaded lettuce leaves generally have larger total chlorophyll (chlorophyll *a* and chlorophyll *b*) content than leaves from the open field (control). Leaves of lettuce plants, cultivated under blue and black shade nets have the highest total chlorophyll content in comparison to plants cultivated under other colour shade nets. Un-shaded control plants exhibited the lowest total chlorophyll level (Ilić et al., 2017a,b).

Shade-grown leaves harvest lower levels of light, and thus contain more chlorophyll than leaves exposed to direct sun. A strong and negative relationship was noted between the intensity of shading and the relative chlorophyll content (SPAD value) of leaves. Although shade-grown leaves are not directly exposed to sunlight, they produce additional chlorophyll *a* and *b* to capture diffuse radiation to produce the carbohydrates needed for the plant to grow, as supported by the results of Beneragama and Goto (2010).

The green colour of leafy vegetables is an important quality parameter for consumer preference (Kasim and Kasim, 2012), and chlorophyll content has been reported to decrease after several storage days (Perucka et al., 2013). The extent of reduction of these pigments depends on the species, variety and temperature, and is due to degradation of chlorophylls and carotenoids. This catabolism of leaf pigments is strongly connected with storage conditions (Ferrante et al., 2004).

A strong positive linear relationship has been described between the chlorophyll content of the leaves and the fruit yield (Ombódi et al., 2016). The chlorophyll content of pepper fruits grown under pearl nets is significantly higher than the chlorophyll level of fruits grown under black nets (Alkalai-Tuvia et al., 2014). This has been observed in ginger plants as well (Ghasemzadeh et al., 2010). Carotenoids serve to protect the chlorophylls from too much light or the wrong wave lengths thereof, and thus act as a selective filter. Increased temperature and solar radiation during tomato production reduced lycopene and ß–carotene levels, resulting in induction of sunscald (Díaz-Pérez, 2014).

Carotenoids are able to absorb energy that may otherwise lead to singlet oxygen formation from excited chlorophyll molecules. Carotenoids may also scavenge any singlet oxygen that forms during photosynthesis (Bergquist, 2006). The excess radiation can generate reactive oxygen species that, if not scavenged, may cause photo inhibition (Bergquist et al., 2007). The carotenoid content was lowest in plants from open fields and highest in plants covered by black nets (Ilić et al., 2017a,b).

1.3. Tissue structure

During the hot summer months, cool-season vegetables like lettuce can be grown only under shaded conditions. In warmer months, more heat units accumulate faster and growth, development and maturity are accelerated. Craker and Seibert (1983) have suggested a light-dependent photo-regulatory mechanism within the plants that controls the development of leaf size.

Only limited data can be found in the literature dealing with the texture in lettuce as a response to growing conditions, particularly variations in solar radiation and temperature. For lettuce to properly form heads, individual leaves need to be sufficiently large, petioles short, rate of stem elongation slow, and production of the leaves adequately fast. Lettuce heads under shade nets developed soft, partially open heads with frequent bolting. Studies have suggested that the high temperature tolerance observed in plants grown under colour shading is primarily linked to the improved leaf texture. Ilić et al. (2017b) found that colour shade nets improved the leaves structural parameters, by altering the texture to become soft-buttery. By contrast, lettuce grown in the open field was characterized by a hard, crisp leaf texture.

The fruits from plants grown under coloured nets contain about 20% more seeds per fruit, and as much as 29% of the fruit has more than 400 seeds per fruit, compared to fruit from plants cultivated in open field conditions (Ilić et al., 2017a). Plants grown under colour nets in optimal growing conditions, develop firmer fruits with thicker pericarp and a better tolerance to transport and storage. Pericarp thickness (exocarp, mesocarp and endocarp) is significantly higher in tomato plants covered by pearl and red nets compared to open field tomatoes (Ilić et al., 2015). Moreover, pericarp fruit thickness is significantly higher in plants from plastic tunnels covered by colour nets, compared to pericarp fruit thickness in plants from net-houses and the open field. In pepper plants, the pericarp fruit thickness is significantly higher in peppers from red net-houses compared to control and other treatments (Ilić et al., 2017a).

Therefore, the mechanical properties of pepper tissues can be used to create optimal growing conditions to achieve fruits with thicker pericarp, firmness and longer postharvest life (Ilić et al., 2017a).

1.4. Physiological disorders

A physiological disorder is the breakdown of tissue that is not caused by either invasion by pathogens or by mechanical damage, but develops due to an adverse environment, especially extreme temperature or to nutritional deficiency during growth and development.

If shade were applied only during periods of intense sunlight, by using a moveable shade system, it would have a less adverse effect on yield, but the shading would still have a positive effect on the marketable fraction (Gent, 2007). Sunscald is a solar radiation injury that causes fruit tissue necrosis or browning and is accompanied by changes in fruit pigments (Schrader, 2011). When tomatoes are exposed to direct solar radiation, fruit temperature may increase by 10 °C or more above the ambient. When the temperature of an exposed fruit portion exceeds 40 °C, it becomes white and sunken (sunscald or sunburn), (Ilić, unpublished data).

The beneficial effects of shading, increased marketable yield and reduced sunscald, are associated with a reduction of light, air and soil temperature resulting in alleviation of heat stress in the plants. The number of sunscalded fruit decreases with the shade level (Dıaz-Perez, 2014).

Several studies have demonstrated improvement in fruit quality and an increase in commercial fruit production when coloured shading screens have been used (Rajapakse and Shahak, 2007; Stamps, 2009; Ilić et al., 2012, 2015). All shading nets have been shown to have a protective effect against sunburn compared with the unshaded control plants (Ambrózy et al., 2016). Losses due to sunscald and rotting are estimated to be greater than 35% under field conditions, while screen houses reduce these losses to less than 5% (Santana et al., 2012).

Cracks in the skin is one of the most common defects in vegetables, especially in tomato (Peet, 2009; Savvas et al., 2008), cherry tomato (Matas et al., 2004), pepper (Ilić et al., 2017a) and melon fruit (Fernández-Trujillo et al., 2013). Fruit cracking is a problem that may be associated with a number of environmental, genetic and anatomical factors. Factors thought to promote this problem include high temperatures and high irradiance (Gent, 2008), irregular watering, excessive growth rates, hight differentials between day and night temperature, high humidity and poor calcium nutrition. Cracking occurs when there is rapid influx of water solutes into the fruit concurrent with other factors that interact to reduce the strength and elasticity of the fruit skin. Fruit cracking not only reduces the appeal and market value of the fruit, but can also increase the fruit's susceptibility to decay and thus shorten its shelf life. Fruit surfaces affected by sunscald and cracking are followed by infection with microbes such as *Alternaria* (Ilić et al., 2012) and *Cladosporium* rot (Fernández-Trujillo et al., 2013).

Exposure of fruit to sunlight can change the water potential of the fruit directly and cause the skin to crack as a result of heating of the fruit surface. Field-grown fruits exposed to sunlight are more than twice as likely to develop cracks as shaded fruits (Ilić et al., 2012). (Table 2**).**

Various other physiological disorders of tomato fruit (puffiness, irregular shapes, uneven ripening, yellow shoulders) have been related to sunlight intensity. Therefore, growers should learn to positively identify the various physiological disorders that occur in their agro-ecological zones/areas and be able to manipulate the environment and to use locally available resources/colour shade nets to control particular disorders.

Intensive light and high temperatures can be detrimental to lettuce, resulting in reduced head yield and increased incidences of leaf physiological disorders such as rib discolouration, tip burn, bolting and bitterness (Ilić et al., 2017b).

Tipburn, a physiological disorder caused by localized calcium deficiency in the foliage, develops under hot weather and fast growing conditions. Saure (1998) reviewed the mechanism of tipburn, which results from the plant's inability to supply sufficient calcium (Ca) to rapidly developing leaves. Many packing companies reject entire fields of lettuce with a tipburn incidence greater than 5% (Jenni and Hayes, 2010).

1.5. Fruit ripening

High temperature in conjunction with high irradiance contributes to blotchy or uneven fruit ripening. The spectrum of transmitted light influences fruit growth by affecting cell proliferation and fruit ripening, and thereby changes the sensory perceptions of fruit appearance, taste, and texture. Ripening of fruits is associated with the biosynthesis of carotenoid and loss of chlorophyll pigments. Finlayson et al. (1999) reported that higher far red/red (FR/R) radiation influences fruit ripening. The findings of Mashabela et al. (2015) revealed that pearl photo-selective nets have higher transmittance of B/FR and R/FR ratios (proportion of blue and red is greater than far-red). Exposure of green peppers to higher R/FR photon ratios during growth probably may play a role in suppressing the conversion of biologically active phytochrome, thereby reducing the expression of genes involved in ripening-related changes including colour and biosynthesis of β-carotene and lycopene.

Light quality and different wavelengths have been reported to affect fruit colour and maturation in different vegetable plants (Shahak et al., 2004c; Lopez et al., 2007; Solomakhin and Blanke, 2010). Pepper fruits harvested under pearl shade nets for example, have a lighter red colour compared to pepper fruits grown under the black shade nets, which has been associated with higher chlorophyll content. To the naked eye, fruit pigmentation between the two nets was not markedly different (Goren et al., 2011), however; chlorophyll values were higher under pearl net, while carotenoid values were higher under black netting. Bell pepper

Table 2
Common physiological disorders of vegetables crops.

Fruit	Physiological disorders	Causes of formation	Reference
Tomato	Catfacing, boat fruit, rough fruit, puffiness, sunscald, sunburn Blossom-end rot, gold fleck or speck, Blotchy ripening, greywall Cracking, russeting, rain check, shoulder check Green or yellow shoulder	Environmental factors (temperature extremes and solar radiation) Deficiencies of a single nutrient (calcium amount or movement into the fruit) Nutrient imbalances, especially between potassium and nitrogen or magnesium Soil moisture status; watering practices Genetic predisposition	Ilić et al. (2012); Peet (2009); Peet (2005); Savvas et al. (2008); Adegoroye and Jolliffe (1987); Taylor and Locascio (2004); Peet (2009)
Pepper	Blossom-end rot Fruit cracking Colour spots and flacks yelloe spots Abortion of the reproductive organs	Restrict the traslocation Ca to a certain part of the fruit Restriction of night transpiration under low air temperature and high relative humidity Rate of nitrogen fertilization Reduction solar radiation intensity (shading) Heat stress, low solar radiation, insufficient nutrition and/or water supply	Ilić et al., (2017a); Ombody et al. (2015); Ambrózy et al. (2016); Savvas et al. (2013); Aloni et al. (1999); Jovicich et al. (2007); Bosland and Votava (2000); Marcelis et al. (2004)
Lettuce	Ribbiness Rib discoloration Tipburn Bolting (seeders)	High temperature conditions Induced by heat stress It usually occurs during hot weather when lettuce is growing rapidly. Temperatures and radiation levels. Calcium deficiency. Inability to supply sufficient calcium to rapidly developing leaves. Lettuce maturing during long days and high temperature,Elongated core inside and bolting	Jenni et al. (2013); Zandstra et al. (1983); Jenni (2010); Ilić et al. (2017a); Olle and Bender (2009); Murdoch et al. (2003); Saure, 1998; Murdoch et al. (2003); Kosma et al. (2013); Ilić et al. (2017b)

decay reduction could also be influenced by the fruit ripening process, as shown by colour development, and antioxidant contents that are affected by the light quality (Liu et al., 2004; Giliberto et al., 2005). Fruits became deeper yellow in colour with lower $h°$ and higher *chroma* and $b*$ values after postharvest storage (Selahle et al., 2015). Also, sweet peppers 'Celaya' produced under black nets showed higher incidence of *Alternaria* rot after postharvest at 7.5 °C for 21 days.

Similarly, red sweet pepper cv. 'HTSP-3′ grown under commercial black nets, showed a dark red skin colour after postharvest (Selahle et al., 2015). Exposure of fruits to higher photosynthetically active radiation (PAR) inside the nets and higher fruit surface temperatures under the black nets (Mashabela et al., 2015; Tinyane et al., 2013) during production affected ripening related colour changes in tomatoes and sweet peppers after postharvest storage. Under the yellow net, significantly more scattered red light penetrates into the plant and fruit, which in turn inhibits fruit ripening and/or, indirectly, induces resistance against *Alternaria alternata* infection after harvest. Moreover, results have revealed high amounts of chlorophyll in fruit harvested under pearl and yellow nets and relatively low amounts of carotenoids, which might indicate slow fruit ripening (Alkalai-Tuvia et al., 2014). Ripening inhibition can be associated with less fruit susceptibility to decay (Barkai-Golan, 2001; Goren et al., 2011).

1.6. Pest and disease

Photo-selective filtration of sunlight is reported also to affect plant pests and diseases (Shahak et al., 2008a). Therefore, crops grown under these shade nets could potentially be at a higher or lower risk for pest infestation. Although the holes of the shade nets might be large enough to allow free pass of aphids, whiteflies and thrips, these pests respond differently to different photo-selective shade nets (Makled et al., 2012). Yellow or blue colour nets are known to attract whiteflies and thrips, respectively (Ben-Yakir et al., 2012).

The use of coloured cladding materials appears to be a promising technology that could improve both crop production and pest management. Using cladding materials that optically repel or arrest pests can enhance crop protection and reduce the use of insecticides. This technology is compatible with other methods of plant protection and can be included in integrated pest management programs for pepper and tomato crops.

Goren et al. (2011) found that red pepper grown under 35% pearl and yellow shade nets significantly maintained better pepper fruit quality after 16 days at 7 °C and three days at 20 °C, mainly by reducing decay incidence caused by *Alternaria alternata*, during two consecutive years, compared to commercial black and red nets. No significant differences were observed in percentage of weight loss, firmness and total soluble solids in fruit harvested under the different coloured shade nets. Moreover, pearl and yellow shade nets significantly reduced *Alternaria* spp. population in the field, which was evaluated with *Alternaria*-selective growing medium. The highest *Alternaria* population was found under the red shade net. The significant low decay incidence in fruit harvested under pearl and yellow shade nets was due to the low inoculum level of *Alternaria* spp. in the field, and inhibition of fungal sporulation, and/or by a slowing of fruit ripening during its growth as shown by fruit skin colour which was lighter, thus reducing fruit susceptibility to fungal infection in the field. The significant low decay incidence after harvest was additionally explained by the scattered light, its quality and the ratio between the light spectrum under the two shade nets in the range of blue/UV and the red/far red (Goren et al., 2011). Alkalai-Tuvia et al. (2014), reported that the lower decay incidence in red pepper under pearl shade net was due to high level of antioxidant activity and carotenoids content that are known to be involved in fruit defense mechanism against decay causing agents. Similar results were reported by Kong et al. (2013) with red pepper grown under pearl shade net. However, in previous work, opposite results were reported by Gent (2007) and Sandri et al. (2003).

1.7. Nutritional quality

1.7.1. Soluble solids content and titratable acidity

Light intensity and temperature greatly impact the sugar accumulation in vegetables. Therefore, exposing fruit to higher temperatures, especially during fruit cell division and ripening, leads to an increase in the total soluble solids content (SSC), predominantly due to an increase in carbohydrate biosynthetic enzyme activity and increased transpiration (Guillen et al., 2007). Light quality and different wavelengths can also affect fruit SSC. The SSC of tomato fruit ranged between 3.59 and 4.40%. These values are similar to those reported by Lumpkin (2005), Gupta et al. (2011) and Ilić et al. (2012). During cooler days SSC levels decrease (Aldrich et al., 2010). The SSC levels did not change significantly for different cultivars during postharvest as reported by Guillen et al. (2007).

Under the black net, the blue light transmittance is significantly higher than under the other nets, whereas under the red nets the red light transmittance was higher and thus one would expect a higher production of photosynthates resulting in an increase of SSC. All tomato cultivars grown under black nets had the highest SSC. The SSC was reported to increase with fruit ripening as a result of greater degradation of polysaccharides and accumulation of sugars (Molinari et al., 1999).

Titratable acidity (TA) in tomato fruits is used along with SSC content as an indicator of maturity (Gonzalez-Cebrino et al., 2011). Among the cultivars studied, 'Irit' showed significantly higher TA than the other two cultivars, and the black nets gave higher TA in all fruits, which suggests that the cooler temperatures (under black nets) favoured the accumulation of acids (Aldrich et al., 2010). There is contradicting literature regarding the shading effect and TA levels in tomato fruits. According to El-Gizawy et al. (1992), increasing shading levels from 35% to 63% increased the TA in tomato fruits, while Riga et al. (2008) reported that shading tomato plants by 50% did not affect the concentration of titratable acidity. The increase in TA content of pepper fruits under black nets may be associated with fruit senescence (Nyanjage et al., 2005; Antoniali et al., 2007; Fernandez-Trujillo et al., 2009). Fruits grown under pearl and yellow nets showed moderate SSC/TA ratios after postharvest storage (Tinyane et al., 2013). Decay incidence during postharvest storage of pepper fruits obtained from black nets may have increased the SSC/TA ratio (Selahle et al., 2014).

The SSC/TA ratio was higher in lettuce produced under yellow and pearl nets. On the contrary, the SSC/TA level was lower in lettuce produced under red and black nets. No significant difference was observed among the varieties (Nsoante, 2015).

1.8. Phytochemicals

A number of environmental stresses can affect the phytochemical content of plants including high radiation, UV, water stress, extremes of temperature, and nutrient stress. Of the abiotic stresses, high light may play a dominant role in enchancing the phytochemical content of plants (Oh et al., 2009).

The accumulation of phytochemicals during the production of plants depends on many factors such as light quantity and quality, type of varieties or cultivars, growing season and metabolic factors. It would be more economical to use modified light quality from solar radiation via the coloured shade nettings during summer to improve the phytochemical quality of vegetables at harvest compared to commercial black nets.

Vegetable plants acumulate a number of phenolic compounds and other antioxidants as a protective measure against damaging high light and UV. In fact, light plays an important role in the synthesis of many antioxidants such as carotenoids, flavonoids, anthocyanins and α-tocopherol (Lester, 2006).

The colour of the fruit forms an important property from the consumers point of view. It is the first quality attribute that stimulates them to purchase, consume and enjoy the fruit and the most important quality attribute to tomato processing (Barrett and Anthon, 2008; Shi and Le Maguer, 2000). Apart from the influence of the light spectrum, the species specific responses can also vary and be influenced by the light quality (Taulavuori et al., 2015).

The biosynthesis of lycopene is affected by environmental conditions such as air temperature and sunlight (Dumas et al., 2003). Exposure of fruits to excessive sunlight has been reported to inhibit the synthesis of lycopene (Brandt et al., 2006). Growing methods, open field or greenhouse conditions are known to affect lycopene levels in tomatoes (Brandt et al., 2003), in addition to lycopene content variations between cultivar types (Dumas et al., 2003; Martinez-Valverde et al., 2002).

The optimal temperature for lycopene biosynthesis is around 22–26 °C. Temperatures above 30–35 °C and excessive solar radiation have been reported to inhibit lycopene biosynthesis (Rosello et al., 2011; Gautier et al., 2005) and stimulate the oxidation of lycopene to *β*-carotene (Dumas et al., 2003). In cherry tomatoes high solar radiation and high temperature (36 °C) were shown to reduce the lycopene and β-carotene contents (Rosales et al., 2006).

Tomatoes covered by red nets showed higher lycopene contents than tomatoes grown under pearl nets (Tinyane et al., 2013). Similar observations were reported by Lopez et al. (2007) and Ilić et al. (2012). The observed differences between the lycopene content in tomatoes under the red and pearl nets could be due to the stimulation of lycopene accumulation in tomatoes under the red net due to the slight variation in red light as explained by Ilić et al. (2012) stating that lycopene synthesis is mediated by phytochromes. The lycopene contents of tomatoes in the study by Tinyane et al. (2013) were lower than those reported for newly bred tomatoes by Gupta et al. (2011) and for the cv. Vedeta (Ilić et al., 2012). The values are however, higher than what has been reported for cherry tomatoes (Rosale et al., 2006) and are within the range reported for Savoura tomatoes (Bui et al., 2010).

Photosynthetically active radiation (400–700 nm) and temperature can affect β-carotene accumulation. For example, significantly higher *β*-carotene content was observed in tomato fruits grown under black nets compared to fruits from tomato plants covered with other colour nets. However, according to investigations by Tinyane et al. (2013), the *β*-carotene content is also determined by the cultivar itself. Cultivars 'AlfaV' and 'Irit' grown under black nets and the 'SCX 248′ cultivar produced under red net nets produced tomatoes with significantly higher *β*-carotene content compared to controls. Based on these observations, it appears that the red nets can improve lycopene and *β*-carotene contents in tomato cultivars (genotypes) that are genetically predisposed to produce lower lycopene and *β*-carotene contents (Tinyane et al., 2013).

Higher PAR inside the nets, due to the knitting pattern in the black nets, is favourable for *β*-carotene and lycopene accumulation in peppers at harvest. Similar observations have been reported for tomatoes by Tinyane et al. (2013).

Although the temperatures for β-carotene biosynthesis (25–26 °C) were favourable under all nets studied, it is possible that the leaf surface temperature was higher under the black nets due to the higher FR in the light spectrum. Coriander leaves revealed higher total carotenoid and β-carotene contents than marjoram and oregano, which could be species specific (Buthelezi, 2016).

1.9. Antioxidant activity

The accumulation of antioxidant compounds during the production of vegetables depends on many factors such as temperature, light quantity and quality, type of varieties or cultivars, growing season and metabolic factors. Environmental conditions such as elevated temperatures and a decrease in plant growth can enhance the antioxidant scavenging activity. If antioxidant activity is increased, it usually leads to decrease in reactive oxygen species levels (Miller et al., 2010). Blue light especially increases the amount of phenolic compounds, e.g. anthocyanins (Johkan et al., 2010). A higher transmittance of blue light through black nets increases the production of antioxidants and the antioxidant scavenging activity in vegetables produced under black nets. The oregano leaves obtained from plants grown under black and yellow nets showed a significantly higher content of total antioxidant activity at harvest, Table 3.

Even though there is a slight decline in antioxidant scavenging activity after postharvest storage, a trend similar to the retention of

Table 3
Influence of coloured shade nets on improved vegetables quality at harvest and during postharvest storage.

Colour nets	Special finding	Reference
Shade nets	Increasing water use efficiency − decreasing plant transpiration Increasing in biomass (leaf area index, structure of a pepper leafs, chlorophyll concentration, leaf pigments, etc) Protected fruits from sunburns Resulted in high yields of good quality of tomato fruit	Ahemd et al. (2016); Zhu et al. (2012); Ombodi et al. (2015); Ilić et al. (2015); Ilić et al. (2012);
Pearl and yellow nets	Extending plant physiological activity Produced a higher marketable yield of lettuce	Ilahy et al. (2013); Ntsoane et al. (2016)
Red, pearl and yellow	Improved fruit quality and increased productivity Reduced infestation by pests and diseases	D & az-Pérez (2013); Goren et al. (2011);
Pearl nets	Improved fruit colour Retard fruit ripening Reduce fruit susceptibility to fungal infection in the field Ripening inhibition, AOX activity and carotenoids content	Ambrózy et al. (2016); Goren et al. (2011); D & az-Pérez (2014); Kong et al. (2013);
Pearl nets Red nets	Increase antioxidant activity Increase total phenols and flavonoids content in lettuce Increase antioxidant activity	Díaz-Pérez, 2014; Ilić et al. (2017a,b); Milenković et al. (2012);
Pearl and red nets Yellow net nets	Improve taste index of tomato fruit Higher number of odor active aroma compounds in the pepper fruit	Ilić et al. (2012, 2015); Selahle et al. (2015); Fallik et al. (2009);
Red nets	The characteristic leaf aroma compound decanal was higher in leaves from the herb plants under the red nets	Buthelezi et al. (2016)
Blue nets	Reduction number of fruits and total yield/plant	Santana et al. (2012);
Black nets	Improved total phenols, flavonoid (quercetin) content, ascorbic acid content, and total antioxidant activity in coriander leaves Higher fresh mass, total soluble solid content, chlorophyll, ascorbic acid, β-carotene, and flavonoid (Isorhamntein,quercetin, myricetin, anthocyanin) contents and antioxidant activity at harvest in lettuce	Buthelezi et al. (2016); Ntsoane et al. (2016)
Postharvest storage		
Pearl and red nets	Retention of bioactive compounds in tomatoes and sweet peppers. Maintain quality and AA during storage and exted marketing simulation	Selahle et al. (2014); Selahle et al. (2015); Mashabela et al. (2015);
Pearl nets	Maintain better fruit quality after harvest Green sweet peppers maintained green colour longer, fruit mass, firmness, and nutritional composition	Kong et al. (2013); Mashabela et al. (2015);
Pearl and yelow nets	Lower the fruit's susceptibility to decay during post-harvest storage	Shahak (2014); Selahle et al. (2015); Goren et al. (2011); Fallik et al. (2009);
Pearl nets	Retained the odor active aroma compounds Retained the sensory properties	Selahle et al. (2015);
Pearl nets	Lettuce showed less weight loss, higher sensory properties and higher ascorbic acid and moderate antioxidant activity after postharvest storage. Retained a higher ascorbic acid content	Ntsoane et al. (2015): Selahle et al. (2015);
Pearl nets	Retained overall quality, ascorbic acid content and aroma volatile compounds in fresh coriander leaves	Buthelezi et al. (2016)
Pearl nets	Oregano and marjoram showed retention of antioxidants (ascorbic acid), total phenols and flavonoids (quercetin) during postharvest storage.	Buthelezi et al. (2016)
Black nets	Larger weight loss in oregano and marjoram	Buthelezi et al. (2016)

antioxidants such as total phenols and ascorbic acid has been noted. Growing lettuce varieties under the black net retained the antioxidant scavenging activity postharvest (Ntsoane, 2015).

The antioxidant activity in tomato and pepper fruit increases during postharvest storage, and is due to coloured net cultivation. This activity is related to metabolic pathways involved during ripening and the production of lipophilic antioxidants (carotenoids, lycopene and phenolic compounds). Light conditions during production, and genotype differences have been shown to affect the fruit antioxidant activity during postharvest storage. Significantly higher antioxidant scavenging activity was obtained during postharvest storage in tomatoes cvs 'AlfaV' and 'Irit' grown under black and pearl shade nets. Another cultivar 'SCX 248′ produced higher antioxidant activity when grown under red shade nets (Selahle et al., 2014).

Spectral quality control under the photo-selective red and pearl nets led to retention of antioxidant activity in vegetables postharvest. Increased antioxidant levels, which are induced by the light environment manipulation by the pearl netting, could be involved in improving the postharvest fruit quality maintenance (Kong et al., 2013). Pepper fruits produced under pearl nets show higher ascorbic acid content and antioxidant activity after harvest (Alkalai-Tuvia et al., 2014). Results by Mashabela et al. (2015) show the impact of modified light quality on the bioactive compounds of green sweet pepper during postharvest. Pearl nets were reported to increase the antioxidant activity and ascorbic acid content in harvested red sweet peppers (Kong et al., 2013), and also to preserve the antioxidant activity during storage (Selahle et al., 2015)

Antioxidant activity was higher in fresh herbs grown under the yellow and red nets after postharvest storage. Also, no significant differences were noted in leaves from the plants grown under the different nets with respect to antioxidant content after postharvest (Buthelezi et al., 2016).

Our observation confirms that the antioxidant scavenging activity of vegetables during postharvest also depends on the genotype, quality of the light, PAR and temperature during cultivation.

1.10. Vitamin C

The vitamin C content in plants is affected both by biotic (Navarro et al., 2006; Topuz and Ozdemir 2007) and abiotic factors (López-Marín et al., 2011, 2012). Ascorbic acid content was higher in the presence of a high light intensity during the production period of fresh produce (Lee and Kader, 2000).

At harvest, the leaves of herbs grown under the pearl nets showed lower ascorbic acid content, which could be linked to the fact that photo-selective 'coloured' shade nets are densely knitted, resulting in a higher shading effect. Bergquist (2006) reported that shading decreases ascorbic acid concentrations. It was found that ascorbic acid concentrations were most often significantly lower in plants grown under netting (shading) than in un-shaded plants (Bergquist, 2006), supporting the conclusion that a high shading effect decreases ascorbic acid content.

The content of ascorbic acid starts declining with the initiation of ripening (Yahia et al., 2001). Temperatures from 27 °C to 32 °C have been reported to reduce the vitamin C content of cherry tomato in greenhouse conditions (Gautier et al., 2008). Makus and Lester (2002) reported lower vitamin C content in mustard greens planted under a 50% shade environment compared to full sunlight. The ascorbic acid concentration in lettuce was reported to increase under blue light because the blue light increases the photosynthesis accumulation of ascorbic acid precursors, hexose and D-glucose sugars. Although there was a slight decline in the concentration of ascorbic acid after postharvest, all the lettuce varieties produced under the black and pearl nets retained higher concentrations of ascorbic acid (Ntsoane, 2015).

In the investigation by Buthelezi et al. (2016), the higher blue light transmittance under the black nets promoted the increase of ascorbic acid content in herb (coriander, marjoram and oregano). In herbs grown under the black nets, after postharvest, the ascorbic acid was lost rapidly as a result of water loss and due to the ascorbic acid being exposed to oxidation (Nunes et al., 1988).

1.11. Flavonoid content

The influence of UV radiation on the modification of flavonoid composition is well known (Wade et al., 2001).Light intensity or quantity (PAR) has also been reported to favour the production of flavonoid (quercetin), Agati et al. (2013). An influence of the R/FR ratio and higher percentage relative transmission of PAR on the total flavonoid content in red beetroot was reported by Stagnari et al. (2014). The FR light (730 nm) mediates the conversion of biologically active phytochrome (Pfr) to an inactive phytochrome (Pr) form (Favory et al., 2009). Blue light influenced the synthesis of total phenols in red amaranth cultivar 'Roctoalta' (Khandaker et al., 2010).

Most phytochemical biosynthesis is dependent on light quantity and quality as observed in lettuce grown under black nets (Ntsoante, 2015). The blue shifted spectrum also influenced a higher biosynthesis of phenolics and total flavonoids (Son and Oh, 2013). In contrast, higher flavonoid concentrations in baby spinach grown under low transmittance shade nets were reported by Bergquist et al. (2007). According to Bergquist et al. (2007), shade conditions promote or induce some stress, and as a result, an increased flavonoid concentration is observed which explains the increase in flavonoids (quercetin) in oregano, marjoram and coriander under pearl nets after postharvest (Buthelezi et al., 2016). Although there is a slight decline in phytochemical content during postharvest, a higher level of accumulation of phytochemicals at harvest enables the herbs to retain the phytochemical quality during postharvest (Buthelezi et al., 2016).

1.12. Aroma volatiles

Flavor comprises two components: taste (sweet, sour, salty, bitter, and umami) and odor. Volatile compounds, also known as volatile oils, ethereal oils and essential oils (Hedges and Lister, 2007; Burt, 2004), are mixtures of compounds (aromatic oily liquids) obtained from plant material such as spices, herbs, fruits, flowers, leaves, roots, and are responsible for the characteristic aroma of fresh products (Silva et al., 2011; Burt, 2004). Flavor depends on factors that include: weather condition (light and temperature), which affect growth and maturity; natural genetic variability, which results in differences in taste and smell among cultivars; and maturity during harvest and postharvest handling.

The photo-quality and micro climate conditions under the photo-selective netting can affect the essential oil content and aroma compounds in vegetables. Lipoxygenase activity is responsible for the biosynthesis of aroma volatile compounds from unsaturated fatty acids and eventually for the production of unsaturated aldehydes (Luning et al., 1995). Red peppers grown under the yellow net contained an increased number of odor-active aroma compounds in the fruits, whereas black nets significantly affected synthesis of such compounds during storage. After storage, sensory analysis indicated a preference for red pepper fruits from plants grown under pearl nets (Selahle et al., 2015).

The retention of aroma volatiles in green fruits produced under different shade nettings have shown the following trend during post-harvest storage: photo-selective red net > pearl net > yellow net > black net (commercial-control). These results indicate that many aroma volatiles are lost during postharvest and this could be related to fruit maturation (Luning et al., 1994).

Furthermore, in red sweet pepper, the retention of odor active aroma volatiles after postharvest showed the following trend: photo-selective yellow > photo-selective pearl > photo-selective red > commercial black (25%) nets. Tomato production under red and pearl photo selective (40%) nets improved the number of major aroma compounds during postharvest (Selahle et al., 2014).

During the summer season, the pearl nets have been shown to improve the marketable yield and sensory properties of vegetables, as well as retaining higher ascorbic acid content moderate antioxidant activity and moderate aroma compounds after postharvest in these vegetables.

The production of summer herbs under the red and pearl nets is recommended to preserve the aroma which is one of the important parameters for consumer acceptance. Buthelezi (2016) reported that the production of aromatic herbs; coriander, marjoram and oregano leaves for fresh cuts under commercial black nets (25%) affected the leaf colour and limited the shelf life and consumer acceptance of the herbs after postharvest. Although a higher number of aroma compounds was produced in coriander and marjoram leaves grown under photo-selective nets, after postharvest the number and the concentration of aroma compounds slightly declined in coriander and marjoram herbs grown under the different photo-selective nets. Under the red nets coriander and marjoram maintain a higher number and concentration of aroma compounds both at harvest and after postharvest. This was also observed for coriander and marjoram grown under pearl nets (Buthelezi, 2016).

Thus, it is essential to emphasize that good flavor quality is obtainedby selecting the best-tasting genotypes for production, improving micro climate conditions under the photo-selective netting, harvesting at maturity or a ripeness stage that will optimize the eating quality at the time of consumption, and by using postharvest handling procedures that will maintain optimal flavor and nutritional quality of the vegetables.

It is important to point out that light quality manipulation by shade-nets (depends on colour and shading intensity) that has shown very successful management for vegetable quality maintenance in one cultivar and/or in a particular country, might have severely limited commercial potential for quality management in a different country and/or with a different cultivar.

2. Conclusion

High solar radiation and elevated temperatures during summer months affect the quality and storage life of vegetables. Incorporation of various light dispersive and reflective chromatic additives in the photo-selective nets helps transform direct light to scattered light allowing penetration into the inner plant canopy. The radiometric properties of photo-selective nets depend on the porosity and colour of the nets. During production, the light quality under the photo-selective shade nets exerts a positive effect on the yield, quality parameters and phytochemical contents of commonly consumed vegetables such as tomatoes, sweet peppers, lettuce and aromatic herbs at harvest and after storage. This technology has the ability to extend the shelf life of produce, thereby lowering postharvest losses. Overall, photo-selective netting has proven to be a cost-effective approach for manipulating crop microclimate properties in order to regulate not only yield, but also the retail/eating quality as well as functional or bioactive properties of vegetables that are associated with human health and wellbeing.

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