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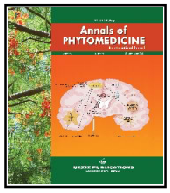

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Unveiling the potential: Colour enhancement and pharmaceutical properties of Crimson Seedless grapes

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Abstract

In warm climates, 'Crimson Seedless' may fail to develop an appropriate red colour, despite being a high-quality, red table grape (*Vitis vinifera* L.). Green berries also persist in most bunches even when the rest of the bunch has turned red. The plant hormone abscisic acid (ABA) is involved in the accumulation of anthocyanins in grape berry skin during maturation. Temperature increases are negatively affecting anthocyanin biosynthesis and other fruit quality characteristics in warmer regions of the world, making high-quality table grapes challenging to cultivate. Crop productivity and sustainability can be improved with nanotechnology. Table grapes are marketed based on their red colour, which is one of the most significant criteria for fruit quality. Several chemicals and practices were evaluated in this review to determine their effect on the bunch colour and metabolic profile of the grapevine variety, Crimson Seedless.

1. Introduction

An attractive and red seedless grape cultivar, Crimson Seedless grapes appear late in the growing season. A late-season market can be supplied by harvesting it between mid-September and mid-November. There is a high demand around the world for Crimson Seedless table grape cultivars. There are elongated, pink berries and a distinctively sweet, juicy flavour that contribute to “Crimson Seedless” popularity. It is crunchy, firm skin, a juicy pulp, and high sugar levels. Glucose and fructose are equally distributed in the fruit. A good amount of potassium and vitamin A are also present in berries, along with some dietary fibres and vitamin C (Ramteke *et al.,* 2021). In some cases, red skin colour cannot be achieved when harvesting Crimson Seedless grapes, Ripening may be compromised by high summer daily temperatures as well as narrow temperature ranges during the day or night during the summer (Koyama *et al.,* 2018). Because some bunches are unevenly coloured, the grape quality is adversely affected, the result is higher production costs for grape growers as they have to perform multiple harvests. Therefore, several strategies are being developed to resolve and prevent these issues, Ethephon and/or abscisic acid have been used as growth regulators during berry ripening. Crimson Seedless makes extensive use of these substances. Due to their suitability for the fresh market and the quality parameters associated with their seedless-ness, seedless table grapes have taken over the market, particularly in the last few decades. As well as the overall look of the cluster, the size, texture, and colour of individual berries determine the quality and value of table grapes (Crupi *et al.,* 2016).

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Various factors influence berry colour development, including temperature, light, and plant growth substances, as well as external factors like environmental, physiological, and chemical factors (Lavado *et al.,* 2019). Crimson Seedless berries tend to have insufficient colour and small size, and cultivars that increase their size further decrease their colour, Vine growth is highly vigorous in fertile soils and becomes excessively vegetative. It is; therefore, recommended to plant vines in soils with moderate vaporosity (Blanckenberg *et al.,* 2021). There is a relationship between anthocyanins and grape coloration, since anthocyanins accumulate during veraison and also appear to be responsible for controlling grape coloration. Abscisic acid plays a partial role (Koyama *et al.,* 2018). In grape peel, anthocyanins, which combine anthocyanidins and sugar molecules through glycosidic bonds, contribute most of the colour. In three to four layers nearest to the epidermis, anthocyanins are stored in the vacuoles of cells (Dong *et al.,* 2019). Recent studies have found that S-ABA increases the content of anthocyanins and flavanols in muscadine grapes (Pessenti *et al.,* 2022). Like ethylene or ethephon is capable of enhancing colour development in table grapes and improving their quality (Samaan *et al.,* 2020). A triazole with growth-regulating properties, paclobutrazol belongs to the triazole family. Gibberellins, abscisic acid, and cytokinin levels, which affect paclobutrazol regulation, threaten its regulation properties. By inhibiting gibberellin synthesis and increasing cytokinin levels, paclobutrazol affects the isoprenoid pathway and shifts plant hormone levels.

As gibberellin synthesis is halted, more precursors in the terpenoid pathway accumulate, leading to abscisic acid production (Soumya *et al.,* 2017). Among its many functions, Ethephon helps promote fruit ripening, abscission, and other responses in plants. It enhances the development of colour in table grapes and improves fruit quality in a similar manner to ethylene (Samaan *et al.,* 2020). The appearance of fruit quality can be affected by phosphorus and potassium,

according to a variety of studies, since potassium increases the volume of grapes, extends shelf-life, increases hardness, and produces beautiful colours, as well as an effective antibrowning effect (Saletnik *et al.,* 2022).

2. Grapes morphology

A fruit crop, grapes (*Vitis vinifera* L.), are valuable crops that possess bioactive compounds, are considered nutraceuticals, and also contribute significantly to human metabolism. Grape is a food known for its components that protect the body against infections, cancer, obesity, diabetes, and various joint disorders can also be fought with it by strengthening the immune and nervous systems, as a result, ageing is also delayed (Li mallet *et al.,* 2016). Grape berries consist of fruit flesh and seeds, along with their husks. Approximately 80% to 90% of the weight of a grape berry is composed of its fleshy portion; however, the size and shape vary depending on the varietal. A number of intermediate shapes exist, including round, flat, oval, cylindrical, inverted oval, pointed oval, sickle, and a variety of other forms. There are 0-6 seeds per berry depending on the cultivar. The wild grape has an average diameter of 4 mm and a length of 30-35 mm. Colour is determined by the skin of the grape, and white, yellow, green-yellow, red, blue-violet, and red-black grape varieties exist (Abiri *et al.,* 2020).

It is possible to determine the maturity stage of grapes by their size. In order to segment a natural environment, one must first segment the background of a bunch of grapes. In morphology, properties such as the colour, density, shape, and number of the seed are primarily observed, as well as the size, number, and weight of the shoot, bud, leaf, bunch, and berry are also examined. It is also possible to find valuable characteristics when identifying reproductive organs like flowers, bunches, and berries. During the vegetation season, they are available, but only temporarily (Ramteke *et al.,* 2021). Annual harvest fluctuations have a great impact on grapes. Changes in the number of inflorescences, flowers per inflorescence, fruit set, and fruit weight of grapevines cause these yield variations, which highly impact berry quality (Lavado *et al.,* 2019).

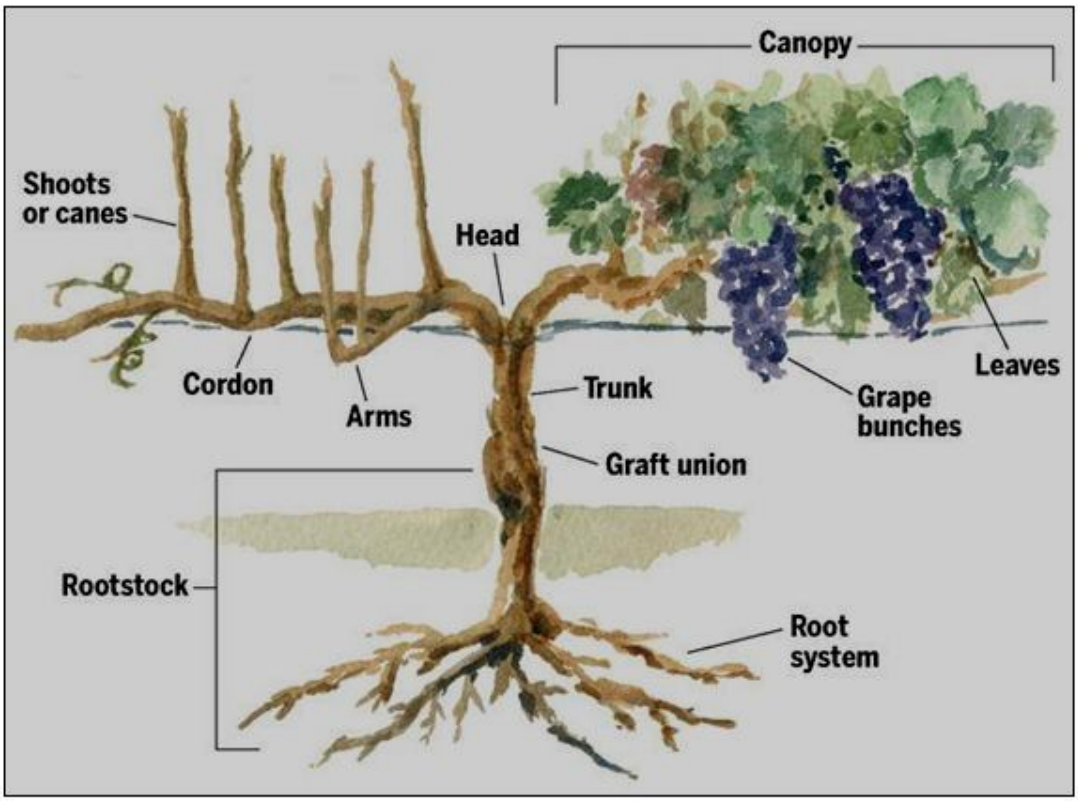

Figure 1: Typical morphology of grapevine.

There is no seed in Crimson grape varieties, but Red Globe has the most seeds of any grape variety. An economically produced grape's appearance is one of its most important quality parameters. The hardness, softness, color, taste, and aroma of grapes are all affected by phenolic compounds. Their properties are heavily influenced by them. In terms of color, grapes are generally divided into three main group's white, red, and black (Bedrech *et al.,* 2022). A major factor in consumer demands is how the grape berries and clusters taste, smell, shape, color, and size. These factors play an important role in grape variety and in the development of the grape variety (Ribeiro *et al.,* 2022). It is important to distinguish between table grapes and grapes used for wine, juice, or raisins, which are grown for different purposes. Their appearance should be attractive, their berries large and elongated, and their pulp should be crisp with thin, soft skin. The grapes are also seedless, which makes them desirable. The sugar content and pulpiness of table grapes are generally lower compared to wine grapes. They are brightly colored, globular-oval, cylinder-shaped, and seedless. The flesh is crisp,

with a neutral taste and thick, tough skin. Medium-sized bunches are conical in shape, well-filled to compact, and conical in shape. From the time of pruning, this variety takes 120 to 130 days to ripen. Indian markets usually harvest fruits at a sugar, acid ratio greater than 25. It is possible to store the fruits cold for 18-20 weeks (Petoumenou *et al.,* 2021).

The clusters of Crimson Seeds are conical, well-filled, and slightly compact with a shoulder. They are medium in size (0.5 kg), well-filled, and slightly compact, in terms of size and shape, these berries are cylindrical to oval in shape and medium in size (3-4 grams). Translucent, firm to crisp flesh, and medium skin thickness. Due to its excellent eating characteristics, the cultivar has been welcomed favorably by the retail sector. Its flavor is described as sweet, neutral, and very good.

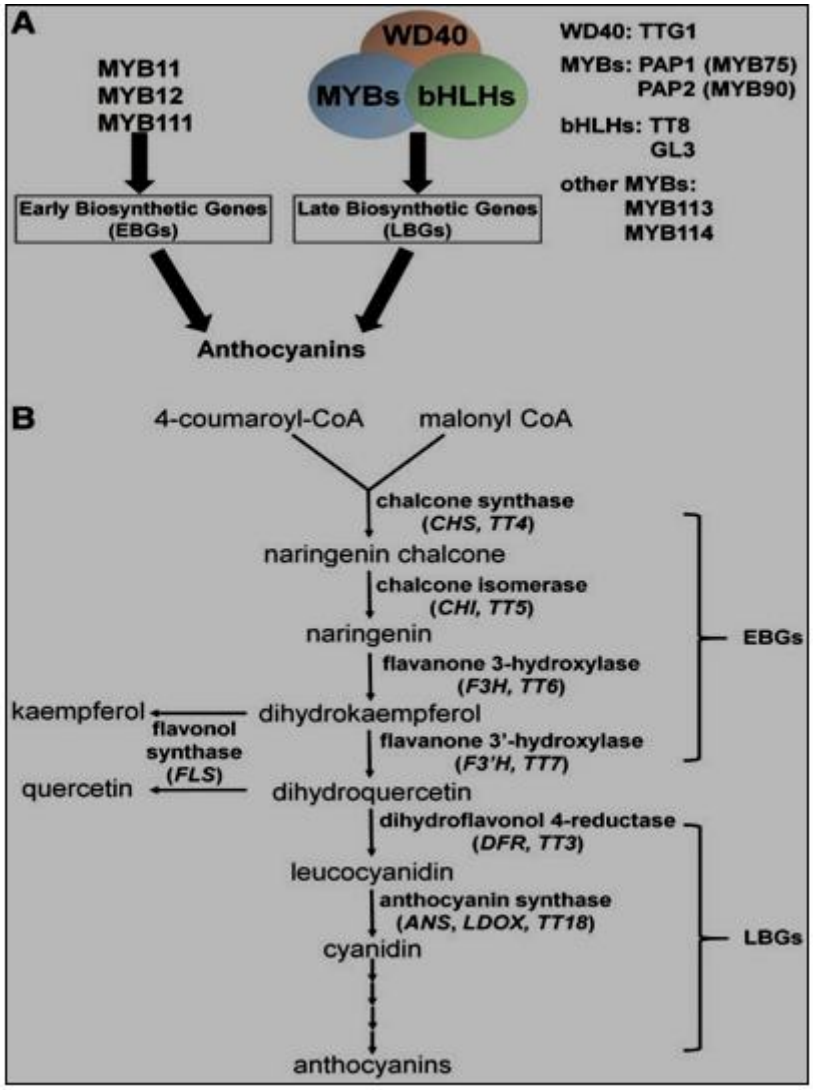

Figure 2: Biosynthetic pathway of anthocyanins in grapes.

3. Grapes anatomy

Grapevines are classified as Dicotyledonae under class Dicotyledonae due to their membership in the kingdom Plantae and the phylum Angiospermae. Vitaceae is the family and is the order of the grapes. Due to their common name, grapevines are members of the Vitaceae family. A total of 1000 species are found in 17 genera within the Vitaceae family. There are seventeen genera with two chromosomes each, but Vitis is one of the most important genera. The grape-growing regions of the world mostly cultivate three main species of grapes called pinot noir, merlot, and white wine grapes vines (*V. vinifera*) are ideal for cultivating in subtropical climates due to their thick skin and sweet pulp. Because American grapes (*V. labressca*) and Muscadine grapes (*V. rotundifolia*) require high chilling hours to break bud dormancy, they are particularly suitable for temperate climates. There is an acidic pulp in the pulp of both these species, as well as a thin skin on the fruits. A one-year cane of a grapevine has compound buds. Whether it is a seeded or seedless berry, flowers have a perfect appearance (Keller, 2015).

4. Effect of climate change

The metabolic processes, physiological structure, and yield of plants are all affected by these biotic and abiotic stresses. Plant economic yield is directly influenced by these adverse effects. Temperature, water availability, radiation intensities, and extent all play a crucial role in vine development. The growing, yield, and quality of the plant may be compromised by these factors (Dinis *et al.,* 2018). Temperatures of fruit can also be reduced by reducing tree temperatures. In plastic greenhouses, low-temperature cultivation can induce colour development in fruit species that develop colour before midsummer, such as grapes (Sugiura *et al.,* 2019). Increasing air temperature will affect grape production since air temperature is the primary climatic factor affecting grape quality. Most grape studies have been conducted on wine grapes, with fewer studies on table grapes. Future changes to suitable land, yield, and berry quality have been calculated for grapes (Nemoto *et al.,* 2016). Grapevines have a reasonable tolerance to drought, moderate drought may alter the relationship between source and sink (competition for carbon resources), resulting in smaller shoots and smaller berries and a higher skin surface/mass berry ratio. It is possible to affect the ratio of older and younger leaves during berry softening by increasing daylight penetration into the canopy structure. Environmental thresholds are mostly reached when this occurs. Vegetative growth and reproductive development and function may be adversely affected as a result of these consequences (Fraga *et al.,* 2016). Stresses caused by abiotic factors, such as high temperatures, may affect the chemical composition of grapes. There is a shift as well as a change in aroma and colour that can be seen in overripe fruits, which have a low acidity, high sugar, and therefore high alcohol content (Pons *et al.,* 2017).

4.1 Heat stress and grapevines

Grapevines are extremely sensitive to high temperatures, which is why heat stress is considered one of the most critical factors. Grapevine photosynthesis is disturbed by temperatures over 35°C. There are usually temperatures above 40°C in grapevine production regions. If, plants are exposed to these conditions without adopting internal and external tolerances in grapevines, this will result in superior quality fruit and reduced grape production. There is a possible link between high-temperature stress and changes in grapevine development, including budburst, flowering, veraison, and fruit burn (Torregrosa *et al.,* 2017).

4.2 Salt stress on grapevines

The physiology of grapevines is adversely affected by salt stress. As a result of permanent drought conditions, roots struggle to absorb and transport nutrients from the soil. A grapevine's root zone is very sensitive to Na^+ accumulation, which can cause Na^+ to accumulate over time. Grapevine biological processes are adversely affected by Na^+ ions, resulting in death. It is through the reduction of ion absorption, the diffusion of ions from the roots, and the lowering of photosynthesis that vines adapt to salinity (Baneh *et al.,* 2014).

4.3 Drought stress and grapevines

There are grapevines that can survive short-term droughts and low water availability. In case of long-term droughts, grapevines have difficulty setting fruit and getting enough water during fruit setting and maturity. Fruit quality and quantity are also affected by water deficits. Stomatal conductance, aquaporin, and stomatal conductance are the mechanisms that grapevines use to control water distribution to leaves. Xylem vessel diameter declines with these adjustments, as well as leaf size and shoots growth (Romero *et al.,* 2015).

4.4 Cold stress on grapevines

Under very low temperatures, grapevines can also suffer chilling injury. When the temperature is low, only low-chilling varieties can be grown. A grapevine's soluble sugar concentration changes under cold stress, and proline synthesis is enhanced, proteins are modified, antioxidants are more concentrated, and phenolic compounds and ABA are more abundant (Karimi, 2017).

4.5 Temperature, water potential, and hormonal regulation through kaolin

As a result of hormonal regulation, temperature reduction, and an increase in water potential of plants, kaolin ($Al_2H_4O_9Si_2$) develops tolerance against abiotic stresses in grapevines. The leaves of grapevines are protected from UV radiation and they reflect most of the frequency while not interfering with PAR absorption by the leaves for photosynthesis. We are conducting research on how kaolin can reduce temperatures, regulate hormones, and increase leaves' water potential by treating grapevines with kaolin (Conde *et al.,* 2016).

5. Problem background

Colour development during harvest is not uniform among colour grape cultivars. Table grapes are inspected in terms of uniformity and colour development, as well as firmness, size, and sugar content according to commercial standards. Grape bunches with a deep red colour can attract customers and encourage purchases, while bunches with a dull colour might be forced to sell at a discount or not function as advertised. The harvesting of poor-coloured berries is sometimes not carried out. "Crimson Seedless" production and economic value substantially decrease, if it fails to achieve its desired red colour. Sunlight, temperature, soil type, and nutritional status are all factors that affect the colour development of red table grapes. Most of these factors are under our control, except for temperature, which has the biggest impact. Grapes' poor red colour is caused by anthocyanins, the red pigment, being inhibited by high temperatures, leading to berry development and growth. Temperatures higher than 30°C during the day and over 15°C at night during the ripening season result in lower levels of anthocyanins being synthesized (Vergara *et al.,* 2020).

Among the most important factors defining fruit appearance and attracting consumers is berry colour, especially for red grape cultivars. Because of the narrow range of temperatures between day and night in Mediterranean (hot/dry summer) climates, 'Crimson Seedless' generally exhibits fruit clusters with poor colour development (Petoumenou *et al.,* 2021). There are serious problems with Crimson Seedless cultivar. Its clusters of berries are unevenly coloured, set poorly, and grow in a tropical environment. The use of compounds such as boron, magnesium, potassium, and phosphorus are recommended in order to enhance the biosynthesis of plant pigments and carbohydrates. The use of silicon materials is also beneficial for protecting vines from high temperatures (Ramteke *et al.,* 2021). In skins, anthocyanin content and

composition determine the colour of berries. Fruits, flowers, and leaves are blue or purple thanks to anthocyanins, phenolic compounds found in vegetables. Wine and grapes contain anthocyanin pigments that colour the fruit as well as provide biological benefits. Sensory and therapeutic qualities are dependent on them. These compounds exhibit antioxidant and anti-inflammatory properties that protect DNA from oxidative damage. White grapes contain flavone (quercetin) and flavanol (quercitrin), yellow compounds composed of anthocyanidin (red grapes), and anthocyanidin (black grapes) (Sparrow *et al.,* 2020).

6. Role of anthocyanins in grapes

A grape whose skin is high in anthocyanins is darker and redder than one whose skin is low in anthocyanins. Colour does not depend linearly on pigment content. Colour may be affected by large increases in anthocyanins (Vergara *et al.,* 2020). The loss of chlorophyll, the green pigment, is another noticeable change in red grape varieties as they ripen. Red pigments called anthocyanins replace them. In order to determine the maturity of red grape berries, their colour should change from green to red. It is anthocyanins that contribute to the coloration of Crimson Seedless grapevine cultivar. Day-night temperature difference, air temperature, and sunlight affect this pigment negatively (Ramteke *et al.,* 2021).

Different types of grapes and even cultivars within a single cultivar group have different colouring mechanisms, which makes grape berry coloration a complex process. Regulatory genes and structural genes control the biosynthesis of anthocyanins in grape berries. Anthocyanin biosynthesis pathways encoding most structural genes have been identified in grapevines. There are several regulatory genes that control the expression of these genes (Zhang *et al.,* 2021). Being brightly coloured, anthocyanins are water-soluble and highly safe. In addition to their antioxidant and antitumor properties, these phytochemicals also protect against coronary heart disease, cancer, and ultra violet damage (Reis *et al.,* 2016). Anthocyanins and proanthocyanins (PAs) are found in grape berries. Anthocyanins accumulate in berry skins during ripening, while PAs are mainly biosynthesised during the green stage. A red wine's colour is; therefore, heavily influenced by the anthocyanin content and relative abundance of its different compounds (Olivares *et al.,* 2017). In addition to influencing grape colour, anthocyanin contributes to wine quality and pericarp structure. The temperature, light, water, soil, climate, and light all have a direct impact on anthocyanin biosynthesis, according to previous research. Increasing temperatures inhibits the accumulation of anthocyanin, whereas sufficient water, food, and light promote the coloration of the pericarps (Sun *et al.,* 2020).

7. Overcoming problems in crimson seedless grapes

The appearance and quality of red-coloured table grapes can be improved by applying exogenous hormones. Abscisic acid, methyl jasmonate, brassinosteroids, and 2, 4-epibrassinolides are among these hormones. A variety of fertilizers, including boron, kaolin, and cyanocobalamin, can be used to improve grape berry colours (Baghdady *et al.,* 2020). Veraison is the phenological stage during which red grapes accumulate anthocyanin, a complex process that is also influenced by the plant hormone abscisic acid (S-ABA). S-ABA and 2-chloroethyl phosphonic acid (ethephon), which are plant growth regulators, are permitted in some countries to ensure homogeneous colour in bunches, such as the USA, Chile and Australia. There has been an improvement in Crimson Seedless grape colour in the USA and Israel as a result of exogenous S-ABA application (Ferrero *et al.,* 2018). ABA seems to enhance grape colour by increasing anthocyanin content in the grape skin. Paclobutrazol improved anthocyanin levels in Crimson Seedless berries by inhibiting gibberellic acid. In addition to jasmonic acid, salicylic acid, 1-naphthaleneacetic acid (1-NAA) and 2, 4-dichlorophenoxy acetic acid (2, 4-D), other phytohormones have also been successfully used for this purpose (Samaan *et al.,* 2020). When applied during post-veraison, DI (deficit irrigation) can result in an increase in red berry colour (intensity and uniformity), which represents the most important disadvantage of this cultivar from a marketability perspective. DI can; therefore, improve berry quality in 'Crimson Seedless' table grapes (Temnani *et al.,* 2021). To improve the quality and colouring of red grape varieties, farmers use agricultural practices and plant hormones. During the veraison stage, farmers typically gird the grapes to boost the soluble solids content (SSC) and total phenolic content (TP) of red grape varieties to enhance sugar accumulation and colour. The application of girdling alone or in combination with jasmonic acid significantly increased the percentage of red and pink berries. Further, Pereira *et al.* (2020) observed an increase in anthocyanins in the berry skin following girdling. There are many benefits of girdling in viticulture, such as increased berry size, more vibrant colour, and faster ripening. Cultivars and girdling times determine the quality of the results, however. The girdling of Crimson Seedless, when it is beginning to ripen, enhances its bright red fruit colour (Lavado *et al.,* 2019). It is influenced by many factors such as light, temperature, sugars, minerals, nutrition, and hormones of plants that anthocyanins and carotenoid pigments accumulate within leaves. Fruit colour pigmentation can also be strongly impacted by orchard management practices such as bagging, pruning, and fertilization (Muengkaew *et al.,* 2016).

Table 1: Effect of various chemicals used for enhancing colour development in Crimson Seedless

S.No.	Chemical used	Response	Reference
1	ABA + Sucrose	It results in an increase in anthocyanin levels, contributing to the development of colour. Firmness, soluble solids, and acidity of grapes were not affected by the increase in colour.	Olivares *et al.*, 2017
2	S-ABA	By applying S-ABA, grape colour was improved, becoming a more intense red-violet, which increased the quality of and the marketability of bunches. A significant increase in anthocyanin production was detected after S-ABA treatment.	Ferreira *et al.*, 2017

3	OR-151	The level of anthocyanins is significantly higher. There was also a significant increase in peonidin levels. As far as the physiology of the fruit and the composition of fruit juice is concerned, OR-151 had no effect on any of these parameters, including berry dimensions, berry firmness, pH, TA, and total soluble solids.	Le, 2018
4	Ethanol	The fruit quality, yield, and berry colour increase significantly under Egyptian desert conditions.	Baghdady *et al.*, 2020
5	Potassium	This increases the quality and yield of Crimson Seedless vines, as well as the biochemical changes they undergo and the shelf-life of their fruit.	Ramteke *et al.*, 2021
6	Chitosan	Physiochemical characteristics and yield of berries are influenced significantly by it.	Bedrech *et al.*, 2022
7	Chitosan + Nano Silica + Sodium alginate	By treating the film with the composite material, the reddening in the fruits were inhibited, chlorophyll content was increased, PPO and PAL activity was inhibited, and the increase of total soluble solids and ascorbic acid decreased, as well as the weight loss.	Kou *et al.*, 2019
8	Forchlorfenuron + Gibberellic Acid + Abscisic acid	CPPU + GA_3 + abscisic acid are beneficial to fruit quality and yield at the early stages of fruit enlargement. As well as extending shelf-life, they also improve quality.	Khalil, 2020
9	Ethephon + Methyl Jasmonate	In most cases, the combination of Ethephon + Methyl Jasmonate is most effective. The product enhances the colour of the berries at harvest and increases the amount of fruit that can be packed. In addition to increases in anthocyanin content and TSS/acid ratio, the same treatment resulted in increases in total soluble solids percentage.	Samy, 2021
10	Abscisic acid + boric acid + rosemary oil	The Crimson Seedless grapes' berries are significantly improved through its use, resulting in clusters that are more appealing to consumers. Fruits or clusters remain unchanged in their physicochemical properties.	Magda *et al.*, 2022

8. Pharmaceutical properties of crimson seedless grape

8.1 Antioxidant effects

Flavonoids, anthocyanins, and resveratrol are abundant in Crimson Seedless grapes. The antioxidants in these foods protect the body from harmful effects of oxidative stress. They possess flavonoids, such as quercetin, kaempferol, and catechins that promote overall health and prevent disease (Izcara *et al.,* 2021). Free radicals in the body can be scavenged and neutralized by flavonoids. Additionally, they may boost the body's ability to cope with oxidative stress by increasing enzyme antioxidant activity. Chronic diseases may be reduced by flavonoids by reducing oxidative damage. Anthocyanins are flavonoids that contribute to the deep red color of Crimson Seedless grapes. Several health benefits have been associated with anthocyanins, such as strong antioxidant properties (Conesa *et al.,* 2016). Several diseases, such as heart disease, diabetes, and certain cancers, can be prevented by protecting cells from oxidative damage and inflammation. Cognitive function and healthy ageing may also be supported by anthocyanins. There is a polyphenol known as resveratrol in Crimson Seedless grapes that has antioxidant properties. Health benefits associated with resveratrol have received significant attention. Antioxidants, anticancer, anti-inflammatory, and cardioprotective activities are all provided by this compound (Gunde and Amnerkar, 2016). There is some evidence that resveratrol could improve cardiovascular health, reduce cancer risk, and promote longevity (Lutz *et al.,* 2011). In addition to neutralizing harmful free radicals, reducing oxidative stress, and protecting cells from damage, Crimson Seedless grapes contain antioxidants that can provide individuals with several health benefits. Health and well-being can be improved, as well as the risk of various diseases decreased (Choudhary *et al.*, 2022**).** As important as Crimson Seedless grapes are for their antioxidant abilities, it is also necessary to eat a variety of antioxidant-rich foods, including fruits, vegetables, and other whole foods. As a result, antioxidants, vitamins, and minerals are consumed in a diverse manner (Zhang *et al.,* 2021).

8.2 Cardiovascular health

The phytochemicals found in Crimson Seedless grapes have been shown to support cardiovascular health. Crimson Seedless grapes contain flavonoids, which stimulate blood flow and dilate blood vessels. These molecules have vasodilator effects that relax blood vessels and widen them, reducing blood pressure and improving circulation. Heart health is improved by improved blood flow (Jeszka *et al.,* 2020). Cardiovascular diseases develop and progress as a result of chronic inflammation. Having anti-inflammatory properties, black seedless grapes are rich in flavonoids and resveratrol. They help calm blood vessel inflammation and reduce heart attack risk. Atherosclerosis, which is plaque buildup in the arteries, can potentially be reduced through the reduction of inflammation by these phytochemicals (Ulaszewska *et al.,* 2020).

Low high blood pressure (hypertension) is a significant risk factor for heart disease. Their vasodilatory properties reduce blood pressure and increase blood flow by relaxing blood vessels. It may be possible to reduce the risk of heart disease and other cardiovascular conditions by maintaining healthy blood pressure (Rad *et al.,* 2019). Heart disease risks are increased by elevated low-density

lipoprotein (LDL) cholesterol levels. It has been shown that flavonoids and resveratrol affect cholesterol metabolism in a positive way. By reducing LDL cholesterol oxidation, inhibiting its formation, and increasing high-density lipoprotein (HDL) cholesterol, known as "healthy cholesterol", they may help lower blood cholesterol levels (Bocsan *et al.,* 2022). It is essential for heart health that LDL cholesterol and HDL cholesterol are maintained in a healthy balance. It is possible to gain cardiovascular health benefits from Crimson Seedless grapes by incorporating them into a balanced diet. While grapes are good for the cardiovascular system, the fruits by themselves cannot ensure it. The health of your heart depends on a variety of lifestyle factors, including a healthy diet, regular physical activity, and a healthy lifestyle outlook. The best way to maintain a healthy circulatory system is to seek medical advice from a healthcare professional (Ali *et al.,* 2023).

8.3 Anti-inflammatory properties

Crimson Seedless grapes contain phytochemicals that are anti-inflammatory, such as quercetin and resveratrol, which can reduce inflammation in the body (Izcara *et al.,* 2021). Crimson Seedless grapes contain a flavonoid called quercetin, which is known for its potent antioxidant activity. Quercetin reduces inflammation and may reduce chronic disease risk. It inhibits the production and release of inflammatory molecules, such as cytokines and prostaglandins. Various diseases are fueled by chronic inflammation, which is controlled by quercetin by reducing the levels of these inflammatory mediators (Pannu *et al*., 2019). Crimson Seedless grapes are also rich in resveratrol, another phytochemical with anti-inflammatory properties. Through its modulatory effects, it reduces inflammation within the body by inhibiting inflammation-promoting enzyme activity and signaling pathways. Resveratrol suppresses the production of inflammatory molecules, such as tumor necrosis factor-alpha (TNF-α) and interleukins (Hasan and Bae, 2017).

Numerous diseases occur as a result of chronic inflammation, including cardiovascular diseases, diabetes, and certain types of cancer. Inflammation may be reduced and the risk of these long-term conditions may be lowered through the consumption of foods rich in anti-inflammatory compounds like Crimson Seedless grapes (Jeszka *et al.,* 2020). An inflammatory condition such as chronic inflammation can lead to cardiovascular disease, such as atherosclerosis. Ultimately, this can result in heart attacks and strokes. Crupi *et al*. (2015) found that inflammation plays a role in insulin resistance and type 2 diabetes. Crimson Seedless grapes may reduce inflammation, reducing the risk of cardiovascular diseases. It is possible that Crimson Seedless grapes provide benefits in managing diabetes by fighting inflammation. The anticancer properties of Crimson Seedless grapes are likely due to their ability to reduce inflammation. Further research is necessary to figure out how these compounds affect different types of cancer (Izcara *et al.,* 2021).

8.4 Cancer prevention

There have been studies demonstrating cancer prevention with phytochemicals in Crimson Seedless grapes, such as resveratrol and quercetin. Here is an explanation of how these compounds might have anticancer properties: Resveratrol: Resveratrol is a polyphenol found in grapes, including Crimson Seedless grapes. The anticancer properties of this molecule have been studied (Baroi *et al.,* 2022). Various mechanisms may be responsible for resveratrol's ability to inhibit cancer cell proliferation and growth. Anti-proliferative effects of resveratrol inhibit cancer cell proliferation (Hosseini and Ghor bani, 2015). Resveratrol may act as an antiangiogenic agent by preventing the growth of angiogenesis (growth-promoting blood vessels) that supply nutrients and oxygen to tumors. The anticancer activity of resveratrol is based on its ability to inhibit angiogenesis. It is the process of causing damaged or abnormal cells to die. Apoptosis is also called programmed cell death. Several studies have shown that resveratrol can cause cancer cells to undergo apoptosis, triggering auto-destruction (Conesa *et al.,* 2016). Cancer development may be inhibited by anti-inflammatory effects. Cancer prevention and management can be enhanced by the anti-inflammatory properties of resveratrol (Arif *et al.,* 2022). The flavonoid quercetin is found in Crimson Seedless grapes and may have cancer-fighting properties. The antioxidant and anti-inflammatory effects of quercetin in cancer prevention and treatment have been shown to be promising, though more research is required (Chellammal *et al*., 2022). In addition to its antioxidant properties, quercetin exhibits strong anti-inflammatory properties, which can help protect against oxidative stress and chronic inflammation, both of which contribute to the development of cancer (Rodriguez *et al.,* 2022). Cancer cells undergo apoptosis induced by quercetin, which prevents their growth and promotes self-destruction. Activates antioxidant enzymes that prevent cancer cells from growing and metastasizing. Signaling pathways critical to tumor proliferation and metastasis may be disrupted by this. Quercetin inhibits angiogenic activity, similar to resveratrol, preventing tumors from growing by inhibiting the formation of blood vessels that supply nutrients to them (Raja *et al.,* 2020).

9. Conclusion

It is concluded that S-ABA treatment of 'Crimson Seedless' grapes substantially promoted colour development both in a vineyard and on detached berries. A spray of ABA after veraison would be beneficial for 'Crimson Seedless' grapevines in warm climates where colour development is poor. A double packable yield is achieved with the use of ABA or Ethephon. To improve the colour of Crimson Seedless grapes, ABA treatment is an effective alternative to treating them with ethephon. It also reduces rachis browning during post-harvest storage, which has the additional benefit of improving grape appearance. A significant increase in leaf enzyme activity, as well as reductions in overall and reduced sugars in berries, were also seen in Crimson Seedless grapevines treated with ZnO nanoparticles. Ripening may be more important than fertilizer treatments for controlling berries' colour.

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Conflicts of interest

The authors declare no conflicts of interest relevant to this article

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