

EFFECTS OF DIFFERENT PARTICLE FILM COATINGS APPLIED FOLIARLY TO APPLE TREES

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Abstract

Particle film coatings form a thin reflective layer on plant surfaces, reducing leaf and fruit surface temperatures and helping plants tolerate abiotic stresses such as high temperature, intense light, and water deficit. This paper evaluates literature findings on the effects of particle film applications on sunburn, physiological traits, yield, and fruit quality in apple cultivation. Studies show that kaolin-based coatings reduce fruit and leaf temperatures, decrease sunburn incidence, and support physiological processes such as photosynthesis and gas exchange. Under limited irrigation and high-temperature conditions, they can improve chlorophyll content, membrane stability, and plant water relations. Fruit quality traits, including fruit weight, firmness, soluble solids, and color development, are generally not negatively affected and may improve in some cases. Particle films may also reduce post-harvest weight loss and help maintain storage quality. Overall, they represent a practical strategy for sustainable apple production under climate change-related heat and drought stress.

Keywords: apple, particle film coating, sunburn, environmental stress

1. INTRODUCTION

Türkiye is an important production center where a wide variety of fruit species can be cultivated thanks to its diverse climatic and soil characteristics. A significant proportion of cultivated fruit species and cultivars can be commercially grown in the country. Among these fruits, apple (*Malus × domestica* Borkh.) occupies a leading position in terms of both production quantity and economic value. In recent years, extensive research on apple has further increased its economic importance.

In recent years, with global climate change, stress factors such as rising temperatures, drought, and high light intensity have become more frequent in agricultural production. These conditions reduce photosynthetic rates, limit stomatal activity, and consequently lead to yield and quality losses. In particular, the depletion of water resources has made it necessary to carry out production under limited irrigation conditions; consequently, this situation has made the development of alternative practices to enhance plant tolerance against stress conditions increasingly important (Baydar et al., 2022).

Reports of the Intergovernmental Panel on Climate Change confirm increases in atmospheric and ocean temperatures as well as greenhouse gas concentrations. Between 1880 and 2012, average land and ocean temperatures increased by approximately 0.85 °C, while greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) reached levels around 300 ppm in recent

years (Lamaoui et al., 2018). These changes necessitate planning strategies that ensure efficient use of existing resources and minimize potential risks. Due to its variable geographical and ecological structure, Türkiye is considered among the countries most vulnerable to global warming, making studies aimed at reducing the negative effects of climate change highly important (Byers et al., 2018).

The primary objective of agricultural production is to achieve maximum yield with acceptable quality (Gupta et al., 2014). However, environmental stresses such as increasing temperature, drought, intense light, salinity, heavy metals, and frost negatively affect stomatal activity and photosynthesis, resulting in yield and quality losses. Heat stress can be defined as the condition in which soil and air temperatures exceed threshold levels that adversely affect plant growth. Under such conditions, transpiration decreases, leaf area is reduced, and leaf curling occurs. In plants continuously exposed to heat stress, leaf thickness and pubescence increase while stomatal density decreases; chlorophyll pigments decline and nutrient transport becomes restricted (Lamaoui et al., 2018).

Within this context, one method used to protect plants from environmental stresses is the application of particle film coatings. Most particle film coatings are kaolin-based materials consisting of chemically dispersed, porous, thin-layered aluminosilicate minerals that are easily soluble in water. These materials form a thin film layer on the leaf surface, reflecting potentially harmful ultraviolet and infrared radiation, reducing leaf temperature, and decreasing transpiration. Through these positive mechanisms, they contribute to increased photosynthetic efficiency under drought stress conditions (Glenn and Puterka, 2010). In addition, these materials are effective in preventing problems such as pests, diseases, and sunburn. In recent years, research on the use of particle film applications in fruit cultivation has intensified.

2. EVALUATION OF FINDINGS OBTAINED FROM PARTICLE FILM COATING APPLICATIONS IN APPLE

Particle film coatings are defined as materials that form a thin layer on the plant surface and reflect part of incoming solar radiation, thereby reducing leaf and fruit surface temperatures. Due to these characteristics, they are used particularly in hot and arid climatic conditions to increase plant tolerance against abiotic stress factors. Literature reports indicate that particle film technology can be used to repel insect pests, reduce diseases, prevent sunburn, and improve fruit quality characteristics (Sharma et al., 2015; Glenn, 2016). It has been stated that processed calcined kaolin particle film (PKPF) applications can repel certain insects, reduce environmental stresses, and consequently improve yield and quality (Glenn, 2016).

Although the mechanism of sunburn formation has not been fully explained, it is generally accepted that it occurs as a result of the combined effects of high temperature and intense light (Glenn and Erez, 2002; Schrader et al., 2003). Light-reflecting materials applied to the plant surface reflect part of incoming radiation, reducing leaf and fruit surface temperatures and thereby lowering the risk of sunburn (Lotze and Hoffman, 2014). Kaolin-based particle film coatings have been reported to reduce surface temperature by reflecting part of ultraviolet and visible light, thus decreasing sunburn damage (Warner, 2000; Glenn and Erez, 2002). In a study conducted under South African conditions, kaolin application significantly reduced sunburn damage in ‘Royal Gala’, ‘Fuji’, and ‘Granny Smith’ apple cultivars, with damage rates reduced by up to 50% in some years (Le Grange et al., 2002).

One of the methods used to prevent sunburn is the use of shade nets; however, this method is considered impractical in all production systems due to its high cost (Smit, 2007). Therefore, particle film coating applications have emerged as a more economical and practical alternative. Research conducted in apple cultivation demonstrated that kaolin applications significantly reduced sunburn and influenced water use efficiency and photosynthetic activities (Sotiropoulos et al., 2016). Glenn (2009) reported that kaolin-based particle film applications reduced leaf, fruit, and canopy temperatures, thereby increasing plant productivity and helping maintain photosynthetic rates especially under high temperature and high vapor pressure deficit conditions. The same study also indicated that the combined use of particle film and adequate irrigation reduced midday declines in photosynthesis and increased daily carbon gain.

Studies on the 'Royal Gala' apple cultivar revealed that kaolin and calcium carbonate applications reduced fruit surface temperature and increased light reflectance. Compared with the control treatment, fruit surface temperatures were reported to be 1.1–2.1 °C lower with calcium carbonate and 1.1–2.5 °C lower with kaolin applications (Alvarez et al., 2015). Similarly, studies conducted on 'Red Delicious', 'Fuji', 'Royal Gala', and 'Cripps Pink' cultivars indicated that kaolin application reduced sunburn without negatively affecting quality traits such as fruit diameter, fruit weight, firmness, and total soluble solids content (Schupp et al., 2002; Glenn et al., 2002; Wand et al., 2005; Sarooghina et al., 2020). In a recent study conducted in high-density apple orchards, 7% kaolin application reduced leaf temperature, transpiration, and fruit surface temperature, while increasing chlorophyll content, photosynthetic rate, fruit weight, yield, firmness, and total soluble solids content (Khursheed, 2024).

It has also been reported that particle film coatings not only reduce sunburn but also influence physiological and biochemical activities in plants. Gharaghani et al. (2014) observed increased photosynthetic rates in kaolin-treated plants, whereas lower values were recorded in control plants. Glenn (2016) reported that particle film application reduced leaf temperature, increased stomatal conductance and gas exchange, and consequently improved total yield and quality. However, under some conditions, water use efficiency decreased, although overall performance was positively affected due to increased gas exchange and yield.

Research conducted under water deficit conditions also demonstrates the stress-mitigating effects of particle film applications. In Iran, a study on 'Golab' and 'Shafi-Abadi' apple cultivars grafted onto seedling rootstocks showed that deficit irrigation reduced shoot growth and chlorophyll index, whereas kaolin application partially alleviated these negative effects. Furthermore, increasing kaolin doses reduced malondialdehyde (MDA), an indicator of lipid peroxidation, and increased cell membrane stability (Faghih et al., 2019). Similarly, another study conducted under different irrigation levels reported that 1.5% and 3% kaolin applications increased fruit firmness and total soluble solids content (Faghih et al., 2021).

The effects of particle film coatings on plant health and quality may continue not only during the growing season but also in the postharvest period. In a study conducted on the 'Galaxy' apple cultivar, kaolin application reduced weight loss during storage and slowed decreases in total soluble solids content and titratable acidity (Ergun, 2012). Kaolin applications have also been reported to reduce the severity of powdery mildew, increase fruit calcium content, and decrease storage disorders such as bitter pit. Additionally, kaolin-treated apples showed increased anthocyanin and phenolic compound contents as well as improved fruit color development (Sharma et al., 2020). Similarly, particle film applications have been reported to increase fruit number and fruit volume, while reductions in abiotic stress may contribute to increased fruit weight (Gullo et al., 2020).

When all studies are evaluated together, it is evident that particle film coating applications reduce fruit and leaf surface temperatures under high temperature and intense light conditions, decrease sunburn, positively influence photosynthesis and gas exchange processes, reduce cellular damage under water stress conditions, and in most cases improve yield and fruit quality characteristics. These findings indicate that particle film coatings are an important cultural practice for sustainable apple cultivation, especially under arid and semi-arid climatic conditions.

3. RESULTS AND DISCUSSIONS

With the impacts of global climate change, temperature and drought stress have become major problems in agricultural production. These stress factors negatively affect plant physiological processes, leading to yield and quality losses. Therefore, the development of sustainable production techniques capable of reducing the effects of environmental stress factors has become highly important.

When the literature findings are evaluated collectively, particle film coating applications appear to be an effective method for reducing the negative impacts of abiotic stress conditions such as high temperature, intense light, and water stress in apple cultivation. It has been reported that kaolin-based particle film applications reduce surface temperature by forming a reflective layer on leaf and fruit surfaces, significantly decrease sunburn occurrence, and contribute to the maintenance of gas exchange and photosynthetic activity in plants. In addition, these applications may positively influence physiological and biochemical parameters such as stomatal conductance, chlorophyll content, water relations, and cell membrane stability, particularly under deficit irrigation and high vapor pressure deficit conditions, thereby enhancing plant stress tolerance.

Particle film coatings not only exhibit stress-reducing effects but also positively affect quality characteristics such as fruit weight, fruit diameter, firmness, total soluble solids content, phenolic compounds, and color formation in most cases. Some studies have also reported yield increases and reductions in quality losses during postharvest storage. Furthermore, compared with shading systems, particle film coatings are less expensive and easier to apply, increasing their practicality under commercial production conditions.

In conclusion, particle film coatings are considered an effective and sustainable cultural practice for preserving yield and quality in apple-growing regions where high temperature and light stress are prevalent, especially under arid and semi-arid climatic conditions. When used with appropriate doses, application timing, and irrigation management, these materials can significantly improve plant performance.

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