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FOOD TECHNOLOGY

The effects of different particle film applications on almond trees

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ABSTRACT: *Particle film applications have become common in agriculture today given the understanding of the effects of limiting high temperatures and solar radiation on plant physiology. This study was conducted to compare the effects of different particle materials on some physiological and fruit quality attributes of almonds. To achieve this, two non-transparent white solid and three transparent aqueous particle film materials were applied by foliar spraying on deficit irrigated almond trees (cv. Ferragnes). Membrane injury (MI), relative water content (RWC), the SPAD chlorophyll index, leaf temperature and some macro- and micro-nutrient contents were examined in addition to fruit sizes, weights, total oils and fatty acid compositions. The applied treatments significantly influenced the evaluated parameters, which indicated reduced stress and improved fruit quality. MI was found to be from 42.8 to 73.9%, RWC varied from 76.8 to 92.9%, and the K/Na ratio ranged between 103.3 and 521.0. As a result of this study, it was concluded that the observed improvements were due to the effects of the evaluated materials and that particle film applications can be beneficial in alleviating heat, light and water stress in almond trees.*
Key words: *almond, foliar, heat stress, particle film, water stress.*

Os efeitos de diferentes aplicações de filmes de partículas em amendoeiras

RESUMO: *As aplicações de filmes de partículas tornaram-se comuns na agricultura hoje, devido ao entendimento dos efeitos da limitação de altas temperaturas e radiação solar na fisiologia das plantas. Este estudo foi conduzido para comparar os efeitos de diferentes materiais particulados em alguns atributos fisiológicos e de qualidade de frutas. Para isso, dois sólidos brancos não transparentes e três materiais de filme de partículas aquosas transparentes foram aplicados por pulverização foliar em amendoeiras com irrigação deficiente (cv. Ferragnes). A lesão da membrana (MI), o conteúdo relativo de água (RWC), o índice de clorofila SPAD, a temperatura da folha e alguns teores de macro e micronutrientes foram examinados, além do tamanho dos frutos, pesos, óleos totais e composições de ácidos graxos. Os tratamentos aplicados influenciaram significativamente os parâmetros avaliados, os quais indicaram redução do estresse e melhora na qualidade dos frutos. O MI foi encontrado entre 42,8 e 73,9%, o RWC variou de 76,8 a 92,9% e a razão K / Na estava entre 103,3 e 521,0. Como resultado deste estudo, concluiu-se que as melhorias observadas foram devidas aos efeitos dos materiais avaliados e que as aplicações de filmes de partículas são benéficas no alívio do calor, luz e estresse hídrico em amendoeiras.*
Palavras-chave: *amêndoa, foliar, estresse térmico, filme de partículas, estresse hídrico.*

INTRODUCTION

Almond (*Prunus dulcis* Miller (D.A. Webb)), part of the *Prunus* genus of the *Rosaceae* family, is a widely grown tree around the world and one of the most commonly grown nut trees, mainly in Mediterranean areas (RHARRABTI & SAKAR, 2016) . Almond production is greater than three million tons worldwide The leading almond producing country is the United States with more than 1.5 million tons, followed by Spain (more than 300 thousand tons); Turkey is in fifth place as a producer with 100 thousand tons (FAO, 2021). Because almonds have a rich nutrient content, they are widely used in various areas including by-products in the food, confectionery and cosmetic sectors, which increases the importance of almonds and the necessity of developing solutions to problems experienced in growing them (NANOS et al., 2002).

The main objective of agriculture is the production of crops with the highest possible yields at an acceptable quality. However, there are numerous obstacles to reach this objective. Abiotic stress factors are a description of the negative impacts of non-living agents on living organisms in a specific environment (GUPTA et al., 2014). Heat, drought, and light intensity, are the most restricting stress factors affecting both the yield and crop quality.

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Plant physiology including stomatal activity and photosynthesis are adversely affected by the abiotic stress factor, which results in production losses. For those reasons, alleviating abiotic stress factors is of significant importance. Considering that most of the almond production in the world occured in hot regions having water restrictions and high solar radiation, the subject is even more crucial.

Particle film applications are known to reduce the negative effects of temperature and water stress on plant physiology and productivity (ROSATI et al., 2006). Their application is based on spraying related materials onto the leaf or fruit surface to form a protective film layer that reflects sunlight and reduces the leaf temperature and enhance high-quality fruit production . Such applications have also been reported to increase stomatal conductance, help the plant to use water efficiently, and promote photosynthesis (CHAMCHAIYAPORN et al., 2013). Thanks to such contributions, foliar particle film applications are used in practice to mitigate the impacts of related stresses.

In previous studies, the effects of various particle film materials applied for a variety of different purposes have been examined (OURIQUE et al., 2019). ROSATI et al. (2006) monitored the physiological effects of kaolin applications on almond trees, and they reported no negative effects on the stomatal conductance and reducing the leaf temperature. SOTIROPOULOS et al. (2016) applied 'Sun Protect' to the apple trees and found no difference between the treatments in terms of photosynthetic leaf rate and gas exchange. In turn, water use efficiency, photosynthetic activity and stomatal conductivity were increased in treated trees compared to the control. CHAMCHAIYAPORN et al. (2013) examined the effects of kaolin application on mango trees, and reported that tree yield and fruit quality parameters were improved by the kaolin applications.

Previous studies have also shown the positive effects of different reflective particle film materials indicating the benefits of utilizing the appropriate materials. On the other hand, selection of the plant-specific appropriate material suitable for the purpose constitutes a significant importance. However, despite some studies (DENAXA et al., 2012) there are few previous studies comparing the effects of these different particle film materials.

In summary, the hypothesis behind this study is the physiological parameters and accordingly fruit characteristics can be improved via particle film applications, especially in the areas where the temperature often reaches over the optimum level, having water restrictions and high solar radiation. Particle films constitute a surface cover on the leaves that reflect and/or block sunlight reach on the leaf surface in a particular amount that changes according to the specific characteristics of the applied materials. Based on their characteristics, the particle films are mainly divided into two groups; non-transparent white covers and transparent colorless covers. Both of the groups have different advantages and disadvantages when compared to each other. The non-transparent film materials are rather thought to be more successful in decreasing leaf temperature and thus reducing the negative impacts of high temperature. Transparent films only reflect specific wavelengths, especially UV, so allowing a higher light incidence on leaf surface which is important for photosynthesis. On the other hand, the period of efficiency is another important factor in deciding which particle film materials to be used in growing.

For all those reasons, this study was conducted to compare the effects of different foliar particle film applications on some physiological and pomological parameters in almond trees, together with the efficiency period of tested materials which was commented based on the leaf temperature measurements performed in different dates.

MATERIALS AND METHODS

The study was carried out in a commercial orchard (N 37°47′46.03″, E38°48′02.16″) located in the Kahta district of Adıyaman province in Turkey during the growing season of 2019 and replicated in 2020. The climate of the study area is characterized by mild temperatures in autumn and winter, and hot and dry summers. In the study area, the temperature reaches above 35 °C in more than 70 days and above 40 °C in more than 15 days totally during the almond vegetation period which causes a significant heat stress on the almond trees cultivated in the area (MGM, 2021).

The plant material was the almond trees (cv. Ferragnes) grafted on seedling rootstocks of *Prunus dulcis* var. amara planted in a 5 × 5 m grid (400 trees/ha) in 2012. The trees were applied to regulated deficit irrigation at 75% of evapotranspiration (ET). Pest management and control of weeds were performed and shallow soil cultivation was performed twice to contribute to weed control and soil aeration. Basal fertilizer applications (250 gr P and 250 gr K) were carried out at the dormant stage in solid form, and the rest of the fertilizers were applied via fertigation

(600 gr N, 200 gr P, 200 gr K, 35 gr Ca, and 20 gr Mg). There was no significant nutrient deficiency and pests/diseases that would affect the results observed during the study. The trees were trained for a modified leader system and pruned one month before blooming (February) in the study years.

In addition to the 'Control' treatment, five different particle film materials – two non-transparent white solids ('Kaolin' and 'Güneş-Stop') and three transparent liquids ('Sun-Protect', 'Solarex' and 'Vital') – were examined as part of the study. Ingredients and other specifications of the applied materials are described in table 1. Two applications were performed for all treatments, which were on June 29th and July 21st. The application doses of the materials were determined according to the commercial recommendations, except for 'Kaolin'. The applied amounts of 'Sun-Protect', 'Güneş-Stop','Solarex', and 'Vital' were 250 ml, 2 liters, 200 ml and 350 ml in 100-liter of water, respectively. Since ROSATI et al. (2006) recorded some disadvantages with 6% 'Kaolin' treatment, a 5% dose of 'Kaolin' was preferred in this current study. In all 100-liter treatment solutions, 25 ml of a spreader–binder solution ('Armando' of Agri Sciences, Torbalı, İzmir/Turkey) were added to improve the efficiency.

In order to observe the effects of the treatments, some physiological and fruit quality parameters were measured. In terms of physiological parameters, membrane injury (MI), relative water content (RWC), the SPAD chlorophyll value, leaf temperature (LT) and some macro- and micro-nutrient contents (P, K, Ca, Mg, Fe, Zn, and Na) were examined in leaf samples. As part of fruit quality evaluations, pomological traits including nut height (NHE), nut width (NWI), nut thickness (NTH), nut weight (NWE), kernel height (KHE), kernel width (KWI), kernel thickness (KTH), kernel weight (KWE), kernel/nut ratio (K/N)– indicating shelling percentage, and the chemical traits of kernels including total oil and fatty acid compositions were measured.

The MI, RWC and SPAD parameters were measured for the leaf samples collected in triplicate from sun-exposed shoots (the south-facing part of the trees) on July 31st, 10 days after the second particle film application and also two days after irrigation. In accordance with the commercial product recommendations, LT was measured for two times with 10 days intervals (July 24th and August 4th) to determine how long the effect of the application lasted which gave the opportunity to make comments of the efficiency periods of the tested materials. To measure MI, 1 cm^2 leaf sections from each replication were kept in 15 ml of distilled water for four hours at room temperature and then autoclaved at 100°C for 10 minutes. The electrical conductivity (EC) values of the solution were measured before autoclaving after four hours kept in distilled water at room temperature (EC_{first}) and after autoclaving when the solution temperature reached room temperature (EC_{last}). MI values were calculated according to the formula (1) below (DEVECI et al., 2018). RWC was calculated according to the second formula (2) below with fresh, turgid, and dry leaf weights (FLW, TLW, and DLW) of 15 leaves sampled for each replication of the applications (SADE et al., 2015). Turgid weight was measured after keeping the leaf samples in distilled water for four hours. The foliar chlorophyll content was assessed according to the SPAD value, which was detected via a chlorophyll meter (Konica Minolta SPAD-502). LT was measured by using an infrared thermometer.

(1) $$MI\ (\%) = \frac{EC_{last} - EC_{first}}{EC_{last}} \times 100$$

(2) $$RWC\ (\%) = \frac{FLW - DLW}{TLW - DLW} \times 100$$

Macro- and micro-element contents were detected in leaf samples collected from two replications at commercial harvest time (September 1st). 250 mg part of the collected leaf samples were taken from each replication and subjected to elemental analyses. The P, K, Ca, Mg, Fe, Zn and Na contents were determined according to a standard stock solution (1000 mg/l) of each element using an inductively coupled plasma mass spectrometer (ICP-MS) (Perkin Elmer NexION 350X) after a digestion procedure using 4 ml of HNO_3 (65%) and Speedwave microwave digestion equipment (Berghof MSW-4) (DINIZ et al., 2019). The K/Na ratio, an important sign of plant stress status, was calculated by dividing the K content by the Na content (GHARAGHANI et al., 2018). Macro-elements were expressed in g/kg, whereas micro-elements were expressed in ppm.

The effects of the applications on nut and kernel quality were evaluated on fruit samples collected in three replications at commercial harvest time. Nut and kernel size parameters were measured in millimeters using a digital caliper. Weights were measured with precision scales and expressed in grams. K/N was determined according to the percentage ratio of KWE to NWE. Compositional values (total oil content and fatty acid composition) were evaluated on mixed fruit samples from three

Table 1 - Description of different particle film film applications.

Treatments	Details of Applied Materials
Control	Only water sprays in same amount of the other applications
Kaolin	Kaolin white clay (Sunguard WP, Turcan Tarım, Ankara/Turkey)
Sun-Protect	A mixture of α-tocopherol, phenolic acids and boron (Compo-Expert, Münster/Germany)
Güneş-Stop	Calcium based microcrystalline prismatic reflector (Doğal Kimyevi Maddeler, İstanbul/Turkey)
Solarex	25% Titanium Dioxide (TiO_2) (Solarex UV-Blocker, Doğatech, Kayseri/Turkey)
Vital	0.5% Fe + 1.5% Zn + Oligosaccharide + Triglyceride (Power Filter, Hekagro, Mersin/Turkey)

replications. The total oil content was determined by extraction of oil with n-hexane (60 °C) for 6 hours using a Soxhlet extractor, and extracted oil samples were subjected to fatty acid composition analyses according to (GECGEL et al., 2011). Fatty acid methyl esters were detected using a gas chromatography-mass spectrometry (GC-MS) device (Shimatzu QP2010 ULTRA) with an Rtx-5 MS capillary column and a flame ionization detector. Since palmitic acid (C16:0), palmitoleic acid (C16:1), stearic acid (C18:0), oleic acid (C18:1) and linoleic acid (C18:2) were the most significant fatty acids detected, the fatty composition of the samples were expressed as percentages of those fatty acids.

The study was set up according to the randomized block design. All data were subjected to statistical evaluations by one-way ANOVA using Duncan's Multiple Range Test, which was performed with SPSS 23.0 statistical software for Windows. Variations and differences among the treatments were analyzed at the $P \leq 0.05$ significance level. Data obtained from fatty acid composition analyses represents the average of multiple parallel measurements.

RESULTS

The results obtained from physiological evaluations are given in table 2 which indicated significant differences among the treatments in all assessed traits without any effect of the study year. The highest MI value was detected in the 'Control' treatment (73.9%), whereas the lowest were found for 'Solarex' and 'Güneş-Stop' treatments (42.8 and 43.8%, respectively). In terms of RWC, 'Kaolin', 'Sun-Protect' and 'Vital' gave the highest values (92.9, 91.9 and 90.4% respectively), followed by the 'Control' (89.5%). 'Güneş-Stop' gave the lowest RWC value (76.8%). The highest SPAD values were obtained from 'Güneş-Stop' and 'Kaolin' treatments, which were 48.9 and 47.9, respectively.

Leaf temperature results are presented in figure 1. The highest leaf temperature (37.4 °C) was measured in the 'Control' treatment for the

Table 2 - Results of the assessed physiological parameters obtained from different applications.

Treatments	MI (%)	RWC (%)	SPAD
Control	73.9 a	89.5 ab	43.1 b
Kaolin	60.6 b	92.9 a	47.9 a
Sun-Protect	66.8 b	91.9 a	41.3 b
Güneş-Stop	43.8 c	76.8 c	48.9 a
Solarex	42.8 c	84.2 b	41.7 b
Vital	59.0 b	90.4 a	41.9 b

Differences between values signed with different letters within the rows are significant at $P \leq 0.05$
MI: Membrane Injury; RWC: Relative Water Content

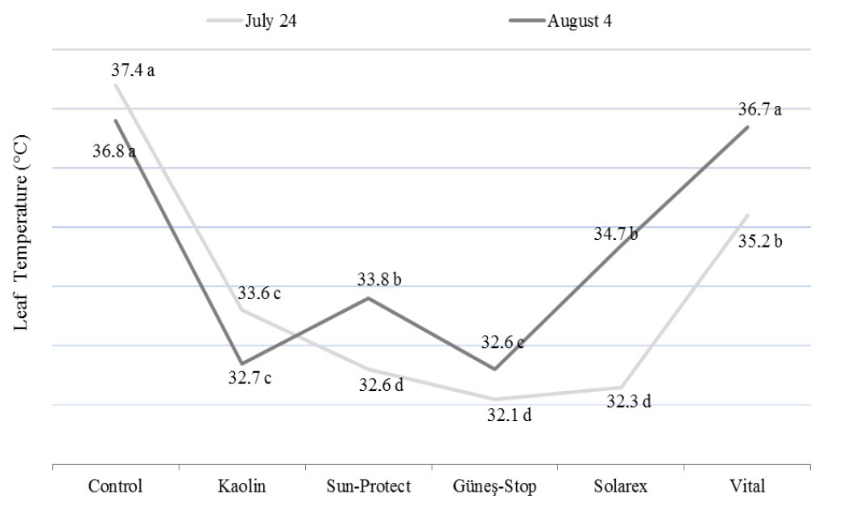

Figure 1 - Leaf temperature results obtained from different applications.

first measurement on July 24th, while 'Güneş-Stop', 'Solarex' and 'Sun-Protect' gave the lowest values of 32.1, 32.3, and 32.6 °C, respectively. In the second measurement, which was on August 4th, the highest leaf temperature values were obtained from the 'Control' and 'Vital' treatments (36.8 and 36.7 °C, respectively), and 'Güneş-Stop' and 'Kaolin' showed the lowest leaf temperatures at 32.6 and 32.7 °C, respectively.

Significant differences were also obtained for the macro- and micro-element contents among the treatments, except for Mg and Zn (Table 3). 'Sun-Protect' resulted in the highest P content (1.37 g/kg), while the 'Control' treatment resulted in the lowest (1.05 g/kg). In terms of K content, 'Sun-Protect' and 'Solarex' were the leading applications with amounts of 19.0 and 18.6 g/kg, respectively, while the 'Kaolin' gave the lowest K content of 14.1 g/kg, respectively. 'Güneş-Stop' resulted in the highest Ca content (14.6 g/kg) compared to the other treatments. The highest Fe contents were found in 'Güneş-Stop' (104.9 ppm) and 'Kaolin' (104.2 ppm), while 'Solarex' (80.0ppm) and 'Vital' (82.0 ppm) were the lowest. In terms of Na contents, 'Güneş-Stop' presented the highest amount (170.3 ppm), and 'Sun-Protect' the lowest (36.4 ppm). In contrast, the highest K/Na ratio was found with 'Sun-Protect' (521.0) and the lowest (103.3) with 'Güneş-Stop'.

Table 4 presents the results of the pomological examinations. Except for NHE, KHE and KTH, significant differences were found among the treatments for all pomological characteristics. In terms of nut sizes and weight parameters, the lowest values were obtained with the 'Control' treatment, which were 23.4 mm for NWI, 15.9 mm for NTH, 4.32 g for NWE and 1.41 g for KWE. 'Vital' gave the highest NWI (24.6 mm) and NWE (4.86 g) values. NTH, KWI and KWE were highest in 'Solarex' (16.9 mm, 15.5 mm and 1.6 g, respectively) and 'Güneş-Stop' (16.7 mm, 15.4 mm and 1.6 g, respectively). The K/N ratio was highest in 'Sun-Protect' (35.9%), and the lowest in 'Vital' (31.4 %).

Total oil and fatty acid compositional evaluations are presented in figure 2. The total oil content substantially changed among the treatmentsfrom 35.5% ('Kaolin') to 41.8% ('Vital'). In terms of fatty acid compositions, the main differences were observed in the oleic and linoleic acid contents. Oleic acid contents varied from 74.4% ('Vital') to 77.7% ('Güneş-Stop'). In contrast, the highest linoleic acid content was found in 'Vital' (16.2%), whereas 'Güneş-Stop' presented the lowest value (13.4%).

DISCUSSION

Even though almond is accepted as a high temperature and drought-tolerant plant, almond trees are more productive in moderate summer temperatures and well-irrigated conditions that favor growth and

Table 3 - Macro andmicro element contents of leaf samples collected from different applications.

Treatments	P (g/kg)	K (g/kg)	Ca (g/kg)	Mg (g/kg)	Fe (ppm)	Zn (ppm)	Na (ppm)	K/Na
Control	1.05 c	16.0 b	13.8 b	5.2	098.6 b	9.9	098.4 b	163.0 c
Kaolin	1.22 b	14.1 c	12.9 b	5.9	104.2 a	9.0	104.3 b	141.1 c
Sun-Protect	1.37 a	19.0 a	12.1 b	5.8	092.6 b	9.3	036.4 c	521.0 a
Güneş-Stop	1.22 b	16.3 b	14.6 a	5.5	104.9 a	9.2	170.3 a	103.3 d
Solarex	1.22 b	18.6 a	12.5 b	4.7	080.0 c	7.5	085.8 b	252.0 b
Vital	1.24 b	17.9 ab	11.9 b	4.7	082.0 c	10.8	095.6 b	207.0 b

Differences between values signed with different letters within the rows are significant at P ≤ 0.05.

development. Thus, the optimum leaf temperatures for photosynthesis functions are from 18 to 32 °C, and the positive influence of irrigation on yield and fruit quality has been implied in previous reports (MICKE, 1996; NANOS et al., 2002). However, almonds are cultivated in rather warm climates and usually under water-deficits worldwide. Particle film applications have been used in agriculture for various purposes mainly for sunburn protection, but also for reducing drought stress, and disease damages in fruit trees (CHAMCHAIYAPORN et al., 2013).

The results of this current study are in accordance with the previous findings in a general point of view that shows the contribution of particle film applications to alleviate negative impacts of heat and drought stresses. Leaf temperature decreased as a result of applied treatments which confirm the previous findings. ROSATI et al. (2006) reported that the application of 6% kaolin reduced almond leaf temperature by 1 to 3°C. Similar results were also reported for olives by DENAXA et al. (2012). Another important sign of heat stress is that cell membrane integrity is under threat from high temperature and solar radiation, which can negatively affect it by allowing electrolytes to leak freely (DEVECI et al., 2018). For that reason, the decrease of membrane injury is a sign of the alleviation of high temperature and radiation. The results of this study indicate the contribution of particle film applications in decreasing membrane injury that would probably be caused by the decrease in leaf temperature and light stress as a result of shading and reflecting solar radiation. COLAVITA et al. (2010) found similar results in decreasing membrane injury by 10% for

Table 4 - Results of the assessed pomological parameters obtained from different applications.

Treatments	NHE	NWI	NTH	NWE	KHE	KWI	KTH	KWE	K/N	K/oz
Control	36.6	23.4 b	15.9 b	4.32 b	28.2	14.6 ab	7.21	1.41 b	32.2 bc	20.2 a
Kaolin	37.2	23.8 ab	16.5 ab	4.63 ab	28.5	14.2 b	7.74	1.50 ab	32.3 bc	19.1 ab
Sun-Protect	36.5	23.3 b	16.3 ab	4.35 ab	29.1	14.8 ab	7.75	1.56 ab	35.9 a	18.3 b
Güneş-Stop	37.6	24.3 ab	16.7 a	4.60 ab	29.7	15.4 a	7.54	1.60 a	34.9 ab	17.8 b
Solarex	37.4	24.3 ab	16.9 a	4.71 ab	29.0	15.5 a	7.59	1.60 a	34.0 ab	17.8 b
Vital	37.3	24.6 a	16.5 ab	4.86 a	28.2	15.3 ab	7.43	1.52 ab	31.4 c	18.8 ab

Differences between values signed with different letters within the rows are significant at P ≤ 0.05.
NHE: Nut Height, NWI: Nut Width, NTH: Nut Thickness, NWE: Nut Weight, KHE: Kernel Height, KWI: Kernel Width, KTH: Kernel Thickness, KWE: Kernel Weight, K/N: Kernel/Nut Ratio, K/oz: Number of Kernels in 1 Ounce.

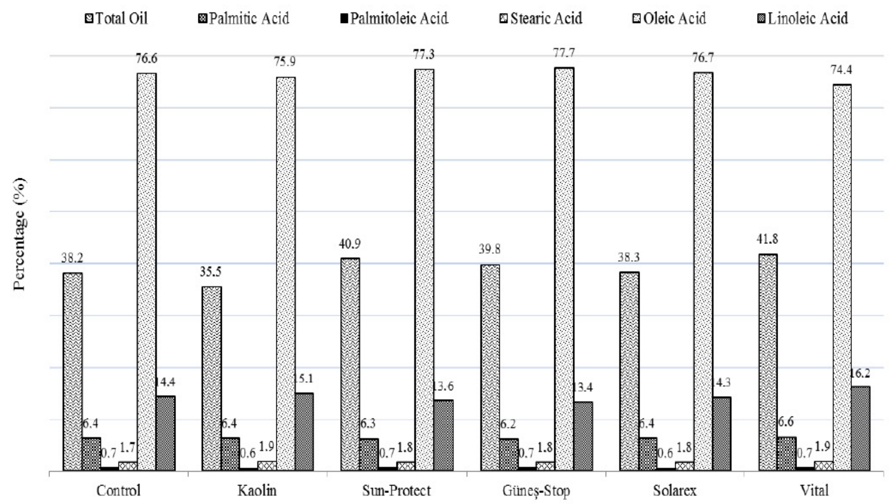

Figure 2 - Total oil and fatty acid compositions (percent) of almonds from different applications.

kaolin applications in pear trees. Considering leaf temperature and cell membrane integrity, 'Solarex' and 'Güneş-Stop' showed favorable results. Regarding the efficiency period of the applied materials, solid materials ('Kaolin' and 'Güneş-Stop' were found to have a longer period of action as expected, but followed by 'Sun-Protect' with a slightly shorter period.

RWC is accepted as an important indicator of plant water stress and is also noted to be positively correlated to photosynthetic capacity. The results reported in the previous studies on RWC imply that particle film applications alleviate the effect of water stress. SEGURA-MONROY et al. (2015) reported a reduction in the RWC for kaolin applications in gooseberry plants. In support of this, ROSATI et al. (2006) reported the application of kaolin had no negative effect on stomatal conductance in almonds. On the other hand, DENAXA et al. (2012) found no effects for different foliar applications, including kaolin, on the RWC of well-irrigated olive leaves. In contrast, the authors reported improving effects for kaolin and glycine betaine in water-stressed plants but no effect of Ambiol. The current study resulted in similar results to DENAXA et al. (2012) a slightly increasing effect of 'Kaolin','Sun-Protect' and 'Vital' on the RWC compared to control plants. The differences among the results of the studies would be caused by different plant species and the applied dose of kaolin.

SPAD value results were higher in the solid particle film treatments ('Kaolin' and 'Güneş-Stop') when compared to the 'Control'. This result is in accordance with the previous findings (SEGURA-MONROY et al., 2015). This effect would probably be caused by the shading of those applications, as reported by WÜNSCHE et al. (2002) who noted that the applied kaolin blocked 20% of the light to be absorbed by apple leaves. In support, ROSATI et al. (2006) stated the reducing effect of a 6% kaolin application on photosynthetically active radiation. Heat and water stresses are also of the factors for the decreased chlorophyll content by causing lipid peroxidation due to the production of reactive oxygen species. In this context, the superior SPAD reading of 'Kaolin and 'Güneş-Stop' indicated an important advantage for those applications that would promote crop yield productivity.

The results for leaf mineral composition confirmed the improved physiological parameters evaluated. The P content was increased with all applied particles but in K contents the increasing effect was only observed in aqueous materials, especially in 'Sun-Protect'. On the other hand, Fe content was higher in solid materials that would be related with the reduced light intensity on the leaf surface by the solid material applications (SHI et al., 2006). Na content was significantly higher in 'Güneş-Stop' and lower in 'Sun-Protect', but no significant impact obtained in the rest of the applications compared to 'Control'.

GHARAGHANI et al. (2018) reported an increasing K and decreasing Na content in walnut leaf samples. The results obtained by MARTINS et al. (2014) indicated that higher temperatures increased the K content of coffee leaves, whereas they had no effect on P and Mg. The reason for the improved P and K content of leaf samples treated with particle films in this study would be a combination of alleviated stress factors. The results of Fe contents were found in accordance with the SPAD reading results.

Another sign of water stress, the K/Na ratio that indicates water use efficiency, was significantly improved by particle film applications in this study. On the other hand, in contrast with GHARAGHANI et al. (2018) reported kaolin to increase the K/Na ratio in Persian walnut, no significant difference was found between the 'Control' and the 'Kaolin' in this current study. When the RWC and K/Na are considered together, 'Sun-Protect' is distinguished by its leading scores.

As the physiological properties, fruit quality evaluations also revealed the significant effects of particle film applications. Almost all evaluated fruit quality aspects were improved by the applications in accordance with the other obtained results as part of the study. For example, the highest shelling percentage (one of the most important quality traits for hard shell textured almonds) was obtained by 'Sun-Protect', which also produced the highest K content. Similarly, KILIÇ & TÜREMIŞ (2017) reported enhanced fruit sizes, fruit weight and shelling percentage with kaolin application in their study on walnuts. GHARAGHANI et al. (2018) found higher total oil content of up to 11.3% in kaolin applied to walnut trees similar to the 'Vital' and 'Sun-Protect' applications in this study. The variation in the total oil content among treatments would be similar to the other physical and chemical fruit quality traits. However, previous studies have reported various results regarding the influence of plant water status on the total oil content of almond kernels (DENAXA et al., 2012; KARAAT, 2020). KILIÇ & TÜREMIŞ (2017) analyzed the fatty acid composition of walnut cultivars treated with kaolin and found that kaolin application had no significant effect on the fatty acid composition, whereas previous studies revealed that the fatty acid composition of almonds can be altered significantly by the growing conditions including ecological and cultivation factors (KARAAT, 2019).

CONCLUSION

This study was conducted to compare the effects of different particle film materials on some physiological and pomological attributes of almond trees. The evaluated parameters were significantly influenced by the treatments and confirmed the benefits of using the appropriate material for agricultural purposes, especially under heat- and water-stressed conditions. Based on the obtained results, transparent liquid materials, especially 'Solarex' and 'Sun-Protect' were found rather advantageous. In terms of how long the effect lasted, the solid materials were found to have a longer acting period when compared to the transparent liquids. It would be accepted as an advantage for using solid materials to reduce costs. When the overall effects of all applications are considered together, 'Solarex', 'Güneş-Stop' and 'Sun-Protect' were considered the most useful materials in alleviating the negative effects of solar radiation, heat and water stresses.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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