

# Effect of Shading Net on Absorption of Elements, and Soil Moisture in Quince (*Cydonia oblonga* Mill.) Orchard

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## Summary

The most important abiotic stress in yield production in the central regions of Iran is a shortage of water and climatic changes. Climate change in quince orchards has resulted in problems such as the reduction of water resources. This research was conducted in the quince orchard with 20-year-old trees in 2022 and 2023. The quince cultivar was Isfahan, grafted on hawthorn rootstock. More than a thousand meters of this orchard were equipped with a shade system with green 50% shade nets, and another part was examined as a control plot without a shade structure. The leaf area and fruit in each tree under the shading nets were more than twice outside the shade net. The shade house reduced the pan evaporation by 743 m<sup>3</sup> per hectare during 130 days. Potassium, calcium, and magnesium nutrients and all the micro-elements in the leaves grown under the shade were significantly more abundant than in the leaves of the control plot. The average radiation under the shade treatment decreased by more than 2.5 times compared to outside the shade net, which led to a reduction in water consumption. Considering the reduction in evaporation under shade cover, it is recommended to use this structure in quince orchards in arid and semi-arid areas with high radiation intensity, such as the central regions of Iran.

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## Key words

elements, evaporation, green cover, fruit number, radiation, soil moisture

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## Introduction

Quince (*Cydonia oblonga* Mill.) belongs to the Pomoideae family. This tree is native to Iran and Turkmenistan and has been distributed in the forests of northern Iran (Maniei, 1995). After China, Iran has the largest cultivated area in the world (7.3 thousand hectares) (FAO, 2021). 'Isfahan' is the most cultivated cultivar in Iran. The quality of this cultivar including fruit firmness, aroma and taste is unique. Quince fruit is rich in B vitamins, especially vitamin B6, vitamin A, mineral elements, especially potassium, phenolic content and phytochemical compounds (Legua et al., 2013).

Climate change and drought in recent years can be mentioned as the main concern in agricultural activities. Orchard establishment under shade cover is an effective way to overcome adverse weather conditions. The shading nets can properly distribute light, reduce wind speed, reduce evaporation, and increase water use efficiency (WUE) (Nicolas et al., 2008). Water use efficiency (Wachsmann et al., 2014) is one of the main items affected by shade systems.

Production, post-harvest quality and profitability of fruit trees depend on the availability of sufficient water. With increasing drought periods, the search for effective methods to improve WUE has increased (Rocuzzo et al., 2014). Reducing water loss from the plant and soil surface and increasing the water storage capacity in the soil are effective methods to improve WUE (Medrano et al., 2015). Shading nets have a positive effect on WUE in fruit trees. Reducing evaporation under the shade net increases water availability and reduces water stress during vegetative and reproductive growth (Manja and Aoun, 2019). The results of research on avocado orchards showed that white 20% shade nets had a 29% lower water requirement due to maintaining the soil water matric potential (Blakey et al., 2016).

Creating shade was helpful for mastic seedlings and reduced the effects of drought stress on this species in drought stress conditions (Holmgren, 2000). Temperature has a tremendous effect on physiological, biochemical, and growth processes. Shading nets, in addition to reducing radiation, wind speed and hail damage, also affect soil and canopy temperature (Mditshwa, et al. 2019). In some research, using the shading nets led to a decrease in the canopy temperature (Armand, 2007). Yoo et al. (2022) showed that the apple trees covered with the shading nets reduced the illuminance, solar irradiance, fruit surface temperature and fruit sunburn disorders. However, the shading nets did not affect tree growth and apple fruit quality.

Considering that the most important abiotic stress in quince production in the central regions of Iran is the shortage of water and climatic changes, it seems necessary to investigate the role of shading nets with the effects of reducing water consumption and adjusting climatic factors in these regions.

## Materials and Methods

### Project Location

This research was carried out in the quince orchard with 'Isfahan' cultivar that grafted on the hawthorn rootstocks, located in Fajr Agricultural Company, Isfahan Province, Iran, and were about 20 years old. The distance between the trees was 3×5 meters.

## Shading Nets Establishment

At the beginning of 2022, a plot with an area of 1000 m<sup>2</sup> was equipped with a shade system that had a appropriate pattern to the size of the tree canopy. 60 trees were covered by the shading nets. According to the results of the previous research (Tatari, 2024), 50% green shade nets were used. A plot without shading nets was also examined as a control.

## Measured Traits

During 2022 and 2023, traits, including leaf area index, fruit weight, fruit number per tree, soil moisture percent, evaporation rate from pan A, and leaf nutrient analysis in two treatments under and outside the shading nets, were evaluated. Leaf area was measured using a leaf area measuring device (LI-COR 3100 model). Leaf area evaluation was done on 20 trees and three leaves from each tree in both treatments. To measure fruit weight, 10 fruits on 20 trees from each treatment were weighed using a scale. The number of fruits on these 20 trees was recorded as the number of fruits per tree.

For the measurement of soil surface evaporation, two class A evaporation pans were used. One of the pans was placed under the shading nets, and the other outside the shade on a wooden platform and on the ground. The pans were installed in the ground from the beginning of July until the time of harvest, and the amount of evaporation from the surface of the pans was recorded. The surface pan evaporation was calculated according to the following formula:

$$E = K (E_{pan})$$

where

$E$  – Evaporation,

$K$  – Evaporation coefficient,

$E_{pan}$  – Pan evaporation.

For determination of the soil moisture, soil samples were taken from the depths of 0-20 and 20-40 cm from the soil surface. These samples were taken 24 hours before each irrigation from the soil located in the last third of the tree canopy. Five samples were prepared inside the shading system and five from outside the shade. The samples were transferred to the laboratory, and the soil moisture percent was calculated using the following formula:

$$GWC = (M_{wet} - M_{dry}) / M_{dry}$$

where

$GWC$  is Gravimetric water content,

$M_{wet}$  is Mass wet,

$M_{dry}$  is Mass dry.

In order to analyze the nutritional elements of the leaves, 20 leaves from different geographical directions of the trees were separated from under and outside shade treatments in July, and then were transported to the laboratory. Some macro-nutrients, including nitrogen, phosphorus, potassium, calcium and magnesium, as well as micro-nutrients, including sodium, chlorine, iron, zinc, manganese, copper and boron, were measured in these leaves. The Kjeldahl method was used to determine the nitrogen content in leaf samples (Jones, 2001). Briefly, 0.3g of fine dry powder was digested in concentrated H<sub>2</sub>SO<sub>4</sub> and distilled

with NaOH (40%), and ammonium nitrogen was fixed in  $H_3BO_3$  (2%) and titrated with 0.1N  $H_2SO_4$ . The P content of samples was determined by the vanadate-molybdate colorimetric method (Chapman and Pratt, 1982). The absorbance of samples was measured at 470 nm in a UV/visible spectrophotometer (model PG Instrument+80, Leicester, UK). Potassium (K) and sodium (Na) contents were determined by the flame photometric method as described by Jones (2001). The digested extract was diluted by calcium chloride ( $CaCl_2$ ) at 1:9 ratios (v/v) and the absorbance was measured at 766.5 nm (Jones, 2001). Calcium (Ca) and magnesium (Mg) were measured using atomic absorption spectroscopy. Briefly, digested extracts were diluted with distilled water (1:9 v/v), then 4.75 mL of lanthanum nitrate [ $La(NO_3)_3$ ] was added to 250 mL of the diluted extract. Finally, the absorbance was measured at 422.7 nm for Ca and 285.2 nm for Mg by atomic absorption. Chloride ion content was determined by titration (Jones, 2001). The concentrations of iron, zinc, manganese and copper were evaluated using an atomic absorption (Emami, 1996). Boron contents in the roots and leaves were determined by azomethine-H method (Wolf, 1971).

At the beginning of the experiment, two portable meteorological monitoring systems (data logger) were installed under and outside the shading nets. The radiation and temperature in the shade net plot and the control plot were recorded using this device.

### Statistical Design

The experimental design was considered as a t-test to compare two treatments under shading nets and outside the shade. Statistical analysis was carried out in SAS software version, 9.1 and a comparison of means was calculated using the LSD method.

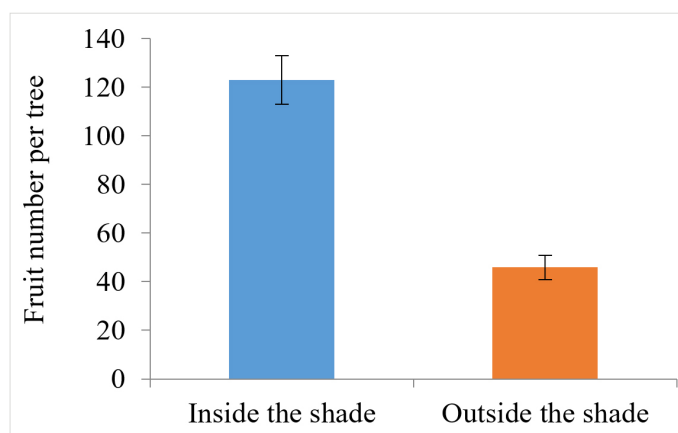
## Results

### T-Test Statistics, Leaf Area, Fruit Weight and Fruit Number

According to Table 1, the shading nets had a significant effect on all measured traits at the 1% level except fruit weight. The number of fruits per tree under shading treatment was 2.68 times that in the outside shading net (Fig. 1).

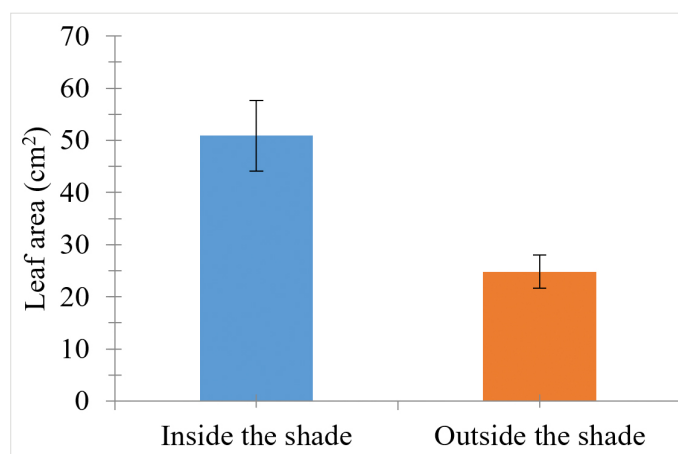
**Table 1.** The effect of the shading system on the evaluated traits according to the T-test statistics

Trait	probability level ( $Pr >  t $ )	T-test statistics (t value)
Leaf area	0.0001	-8.65
Fruit number	0.0001	-22.72
Fruit weight	0.1280	1.59
Yield per tree	0.0001	-13.87
Soil moisture percentage	0.0002	-9.24
Pan evaporation	0.0001	-11.68



**Figure 1.** The effect of the shading nets on the fruit number per tree

The leaf area outside the shade was less than half its rate under the green shade system (Fig. 2).



**Figure 2.** The effect of the shading nets on the leaf area of quince trees

### Class 'A' Evaporation Pan

The average pan evaporation, the monthly radiation, and the temperature in the two parts under and outside the shading nets during the 130-day study period are shown in Table 2. During the period of 130 days, the total Class A pan evaporation was 347.2 mm in the outside part of the shade and 272.9 mm in the part under the shade.

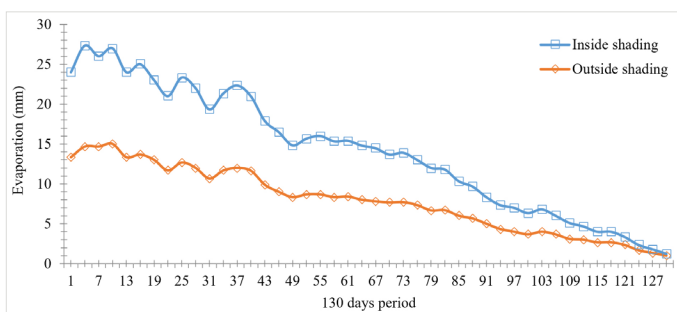
According to Fig. 3, the difference between the amount of evaporation under and outside the shade was more remarkable in summer and in July, August, and September. This difference decreased as autumn approached. The most significant difference in evaporation between under and outside the shade system was observed on the seventh of July.

**Table 2.** The average pan evaporation, the monthly radiation, and the temperature both under and outside the shading nets in 130 days

The period	Under the shading nets			
	Temperature (°C)	Relative humidity (%)	Radiation (Lux)	Pan evaporation (mm)
July	27.02	21.23	12582.40	10.70
August	29.67	14.18	12931.23	8.10
September	25.39	18.91	10736.62	5.50
October	18.16	63.62	10342.18	2.20
December (first decade)	15.32	55.11	9921.45	0.60
Total	-	-	-	272.90
Average period	23.11	21.29	11302.77	-

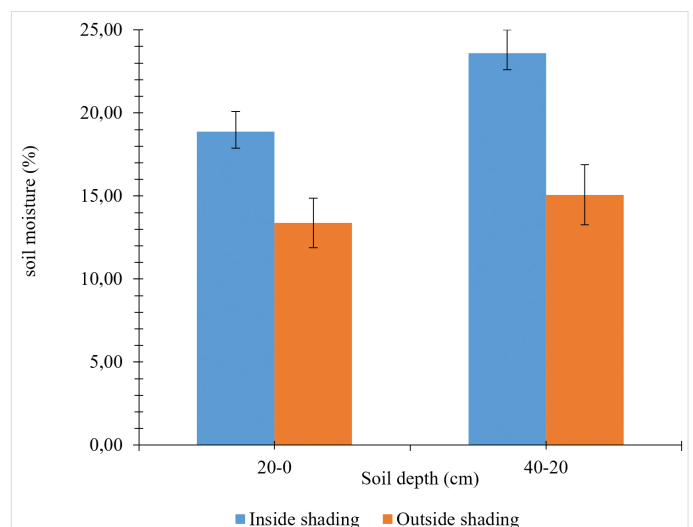
The period	Outside the shading nets			
	Temperature (°C)	Relative humidity (%)	Radiation (Lux)	Pan evaporation (mm)
July	27.69	20.07	31030.56	13.50
August	30.00	13.55	31832.60	9.70
September	26.93	18.77	28569.01	7.00
October	18.80	37.88	28560.09	3.50
December (first decade)	15.92	52.11	24413.26	1.60
Total	-	-	-	347.30
Average period	23.86	28.47	28881.10	-
The difference between under and outside the shading nets	0.75	0.74	17578.33	74.40



**Figure 3.** Comparison of evaporation outside and inside shading in 130 days

### Soil Moisture Percentage

The average weight moisture percent under the shade screen at two depths of 0-20 and 20-40 was equal to 18.88 and 23.60%, respectively, while the moisture values measured in the same two depths outside the shade net were 13.38 and 15.11, respectively (Fig. 4).



**Figure 4.** Comparison of soil moisture percentage under and outside the shade screen at two different depths

### Analysis of Leaf Nutrients

The results of the analysis of nutrients in quince leaves under and outside the shade netting are presented in Table 3. Among the macro-nutrients, potassium, calcium, and magnesium in the leaves grown under the shade net were higher than in the leaves of the control plot, but nitrogen and phosphorus in the leaves of the control plot were in slightly higher amount than in the leaves of the shading plot. The amount of chlorine did not show any difference between the two treatments. All micro-elements in the leaves grown under the shade screen were greener than the leaf samples in the control plot, so in the leaves under the shade iron, zinc, manganese and boron were more present than in the leaves exposed to sunlight (70, 54.1, 17.6 and 28.8 mg·kg<sup>-1</sup>, respectively). In general, the tree leaves under the shade system were greener and fresher than the control plot.

### Temperature by Day and Night

The curve of temperature changes during one day and night in spring (Fig. 5) on 23 April, 2021 showed that with sunlight during the day, the temperature under the shade net was lower. At noon, the temperature difference between under and outside the shade reached its maximum value. As the sun set, the temperature inside and outside the screen became almost the same, and this temperature difference was minimized. Finally, at night, the inside and outside of the shade were at the same temperature. The most significant temperature difference between the two environments during this day and night was 1.1 °C and was related to 4.55 o'clock in the afternoon. The average temperature of the entire period outside the shade was 0.75 °C higher than under the shade net (Table 2).

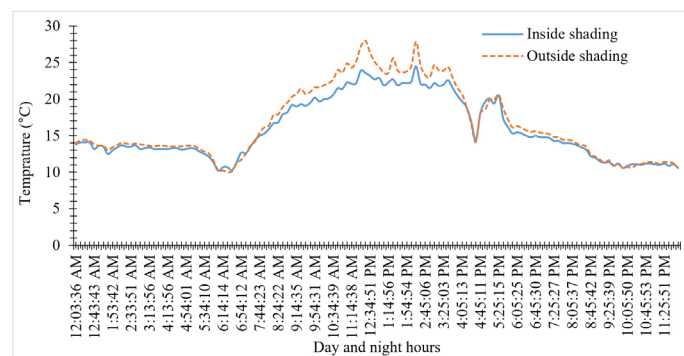


Figure 5. Temperature changes during one day and night in spring

Table 3. Analysis of nutrients in quince leaves under and outside the shade screen

Unit of measurement	N	P	K	Ca	Mg	Cl	Na	Fe	Zn	Mn	Cu	B
	%						Mg/Kg					
Outside the shade	1.60	0.49	2.30	0.70	0.33	0.07	3090.00	230.00	47.90	23.00	11.50	54.60
Under the shade	1.56	0.38	3.20	1.40	1.20	0.07	5308.00	300.00	102.00	40.60	50.00	83.40

### Radiation Intensity by Day and Night

A study on the curve of changes in radiation during one day and night on 23 April, 2021 showed that the use of shade cover reduced the intensity of radiation entering the orchard. The peak of this decrease in light was from 12:00 to 2:00 p.m. when the solar radiation was more intense. At this time, the solar radiation outside the shade was several times that of the rates inside the shading cover (Fig. 6). In the experimental period, the average radiation inside the shade was 17578.33 Lux, more than the outside cover (Table 2).

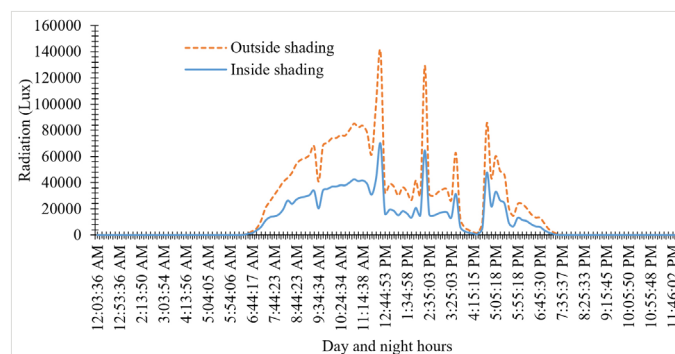


Figure 6. Changes in radiation intensity during one day and night in spring

## Discussion

### Leaf Area and Fruit Number

Shade cover impressed leaf area trait so that the leaf area inside a shade system was more than twice the leaf area outside the shade (Fig. 2). According to the report by Ozturk and Serdar (2011), the leaf area in the seedlings grown under the shade was more than the control treatment. More relative humidity under the shade screen can lead to more leaf development (Blakey et al., 2016). Similarly, greater leaf area was reported in avocado trees grown under a white shade with a shading intensity of 20% compared to unshaded trees over two growing seasons (Blakey et al., 2016). Yang et al. (2019) reported that shading imposed significant impacts on the growth and leaf photosynthetic characteristics, while there were differences among species.

The fruit number in the trees under the shading nets was significantly higher than the fruit number in the control plot (Fig. 1).

Stone et al. (2017) reported that mango trees under the white shade net with 20% shading had more yield compared to the trees outside. According to their research, under the shading nets, the fruits were bigger and resulted in more economic profit, but in our research, there was no significant difference in fruit weight between the two treatments. Similarly, Edgo and Gertrudes (2018) reported an increase in the marketable product under the shading nets. In contrast to these results, Germana et al. (2003) observed less production of tangerine under the dark cover, such as 50% gray and 67% black shade nets. Lower yield under these conditions could be due to less light exposure and thus less photosynthesis.

### Class 'A' Evaporation Pan

Economic production and sufficient fruit growth during a long growing season will require sufficient water. By installing the shade net during the 130-day period from June 20 to October 27, 74.3 mm, which is equivalent to 743 m<sup>3</sup>/ha, was saved in water consumption (Fig. 3). This amount of water can remain in the root environment and be used by the plant. In other words, this amount of moisture has not been wasted from the root environment of the plant. Reducing evaporation under the shading nets increases water availability and reduces water stress during vegetative and reproductive growth (Manja and Aoun, 2019). Due to the temperature and radiation reduction, the water deficit in trees growing under the canopy is negligible (Medina et al., 2002). Despite the color and intensity of shading nets, WEU increases significantly in shading conditions. It has been reported that the increase of WEU in trees under shade is directly related to the root efficiency in absorbing water and elements (Manja and Aoun, 2019). Manja and Aoun (2019) showed that the trees under the shade nets had a deeper root system. Therefore, due to the strong interaction between the stem and the root, an increase in WEU was observed under these shades.

### Soil Moisture Percentage

The comparison of soil moisture percent values showed that installing a shade net reduced the soil surface evaporation and prevented water wastage. At the soil depth of 0-20 cm, the surface under the shade system retained 5.5% more moisture than the surface without shade. Likewise, at a depth of 20-40 cm, 8.52% more soil moisture was maintained under the shade screen (Fig. 4). In these conditions, tree roots spend less energy to absorb water and nutrients.

### Analysis of Leaf Nutrients

It has been reported that the absorption of nutrients such as nitrogen, phosphorus and potassium in trees grown inside the screen nets is greater than in trees without shade (Al-Helal and Abdol-Ghany, 2010). In this study, potassium, calcium, and magnesium nutrients in the leaves grown under the shade screen were more present than in the leaves of the control plot, but nitrogen and phosphorus in the leaves of the control plot were slightly more present than in the leaves of the covered plot (Table 3). Increased potassium absorption under the white net has also been reported (Al-Helal and Abdol-Ghany, 2010).

About micro-elements, iron 30.43%, zinc 112.94%, manganese 76.52% and boron 52.75% in the leaves under the cover were in greater quantities than in the grown leaves exposed to sunlight,

which led to greener and fresher leaves of the tree under the shading nets compared to the control plot. Thin roots have a significant effect on water absorption, and the effect of a shade system on the growth of these roots has been reported (King et al., 2002). It is argued that the shade net can create a favorable environment in the soil and air around the root system, thus enhancing the absorption of nutrients by the roots (Abul-Soud et al., 2014).

### Temperature by Day and Night

The average temperature during the experimental period inside the shade net was 0.75 °C lower than in no shade condition (Table 2). Also, the temperature difference in these two environments was the largest around noon. As the night approached, the same temperature occurred (Fig. 5). In some reports, the temperature drop inside the shade system was greater than the reported value in the present study. For instance, an approximate temperature difference of 4 °C under and outside the shading nets in the grapefruit cultivar Ruby Red was reported by Jifon and Syvertsen (2003). In confirmation of the present results, Zhou et al. (2018) could not observe a noticeable temperature difference between the inside and outside of the shade in the 'Valencia' orange. Momeni (2022) also reported the temperature inside the shading net was lower than outside, but no significant differences were observed between the months. However, the results of most studies indicate a decrease in temperature under the shading nets. A decrease in radiation inside the shade system resulting in a decrease in temperature was reported by Mahmood et al. (2018). In the current study, the average temperature reduction under the shade was slightly more than 0.5 °C, and there was no significant temperature difference between under and outside the shade system. The color of the nets, the shading nets percentage, and the experimental site are effective in the temperature difference under and outside the shade. The results of the research by (Armand, 2007) showed that the temperature difference in the leaves of apple cultivars under and outside the nets was 2.8 °C on a mild day and 5.25 °C on a hot day.

### Radiation Intensity by Day and Night

According to the results, the shade system reduced the average solar radiation by more than 2.5 times. The peak of the radiation difference between under and outside the shade was at noon and early afternoon. Similarly, Basile et al. (2008) reported that the photosynthetic active radiation was reduced under the screen. The shade net acted like a light filter, so the more the light intensity outside the shading nets, the fewer changes inside the shade (Fig. 6). A decrease in light intensity leads to a decrease in leaf surface temperature, heat stress and water dehydration, evaporation and transpiration, as well as an increase in respiration, yield and harvest period (Treder et al., 2016). The amount of radiation in the orange orchard established under yellow and red shade nets in the semi-arid region was 15.7-62% lower than in the condition without shade (Zhou et al., 2018). The red nets, with 20% shading, receive 82% of the active photosynthetic radiation. These values were equal to 90% for transparent nets with 13% shading (Incesu et al., 2016). The black shade, with 75% shading, received 54% of the photosynthetically active radiation compared to no shade net treatment (Basile et al., 2008).

## Conclusion

Evaluated traits such as leaf area, fruit number and amounts of nutrients in the leaves of trees inside the shading system were more significant than those outside the shade. Among the evaluated climatic factors, the radiation intensity was affected by the shade nets more than temperature. In addition, the shading net has a positive effect on increasing the absorption of nutrients, especially iron, zinc and boron, maintaining soil moisture and reducing evaporation, which is especially important in arid and semi-arid areas.

## CRedit Authorship Contribution Statement

**Maryam Tatari:** Conceived the project and supervised the work. Conceptualization, investigation, performed most of the experiments, analyzed the data and drafted the manuscript. **Mohsen Dehghani:** Performed some of the experiments. **Raziyeh Mahmoudi:** Contributed to the editing of the manuscript. **Daryoush Atashkar:** Contributed to the editing of the manuscript.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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