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Kaolin particle film alleviates adverse effects of light and heat stresses and improves nut and kernel quality in Persian walnut

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ABSTRACT

Spraying with kaolin is becoming a feasible and cheap treatment to alleviate the destructive effects of light and heat stresses. Here, the effects of spraying with kaolin were investigated on leaf temperature, photosynthesis and gas exchange rate, sunburn and quality of nut and kernel, potassium (K) and sodium (Na) concentrations and proline content of the walnut. Three spraying levels of kaolin (0%, 3% and 6%) were used in 5 replicates during two consecutive years. Results indicate that the kaolin spray increases leaf area and chlorophyll content (up to 14.71% and 11.99%, respectively) comparing to the control. The severity of leaf, husk, and kernel sunburn of kaolin treated trees was reduced up to 50% comparing to the control plants. Considering physiological parameters kaolin treatment reduced leaf temperature (4.4 °C and 5.6 °C, respectively in kaolin 3% and 6% compared to the control), but increased photosynthesis rate (A_{max}), gas exchange (g_s), internal CO_2 partial pressure (C_i) and the water use efficiency (up to 29.85%, 30%, 10.97% and 19.88%, respectively) comparing to the control. Kaolin application also improved nut and kernel weight, kernel percentage and kernel oil content (up to 8.2%, 16.1%, 7.7% and 11.29%, respectively) comparing to the control. Kaolin treatments increased potassium level and K:Na ratio, but decreased Na and proline content, both in leaf and kernel, in comparison with the control. However, there was no significant difference between the results of applying kaolin at concentrations of 3% and 6% in almost all of the measured characteristics, but improved results were obtained with higher levels of kaolin, except for nuts and kernel quantities. Considering global warming, using kaolin application can be recommended as a suitable and cheap method for the acclimation of walnut to high temperatures and solar radiation.

1. Introduction

The Persian walnut (*Juglans regia* L.) is one of the most important nut crops which is widely distributed around the world, and is cultivated on a large scale (Vahdati et al., 2018). Because of its geographical location and its specific climatic conditions, Iran hosts intense light radiations among countries producing walnuts, while being more vulnerable to temperature fluctuations and droughts. This issue is much more serious in areas with lower geographic latitudes, in southern Iran such as the Fars province.

Generally, sunburn in the walnut is most common on the southwest side of the tree, and on the lower part of the canopy. Different types of walnuts are completely different with respect to sunburn intensity, darkening of the color and shrinkage of the kernel (Lampinen et al., 2006). Therefore, the use of methods that can protect the tree from extreme solar radiation and high temperatures at the lowest cost are necessary. One solution is to use sprinkler irrigation systems to cool down the trees so as to counteract the effects of high summer temperatures in fruit orchards. This system requires high technology, high costs and adequate water, while also having the side-effect of spreading some diseases (Kotzé et al., 1988). Another method is to use colored netting for making the shadow on the trees, although it is very expensive to install them on the orchard (Widmer, 2001). Considering the height of walnut trees, using the two methods mentioned for walnuts is difficult.

In recent years, use of particle films as a new approach has been put forward and has yielded very promising results. Various studies have been concerned the subject, on different fruit crops which confirm its high efficiency for this purpose and kaolin is now widely used in orchards of warm and dry areas (Glenn and Puterka, 2005). In a study

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in South Africa, Gindaba and Wand (2005) used a variety of methods (cooling by sprinkling, kaolin, and black netting as shading) to control sunburn in 'Royal Gala' apple. In Spain, reports suggest positive effects of kaolin treatment on pomegranate sunburn (Melgarejo et al., 2004). Rosati et al. (2006) used kaolin to reduce the damaging effects of high temperatures and drought stress on the photosynthesis of almonds and walnuts, and reported that use of kaolin cannot compensate for the negative effects of high temperatures and drought stress, but its positive effects on some physiological indices of almond and walnut trees were confirmed under drought stress conditions. Also, Rosati et al. (2007) studied the effects of kaolin on the distribution and absorption of light within the canopy of walnut and almond trees. Lampinen et al. (2006) and De Buse et al. (2010) reported that kaolin treatment reduced the temperature of the canopy of trees, resulting in reduced sunburn in the leaf and fruit of walnut trees. But kaolin spraying cannot be economically efficient if it is only applied to reduce sunburn. However, when other goals such as pest control enters the equation, then perhaps it could become economically feasible.

None of the studies on dealing with kaolin spray on walnut are gone deep on the evaluation of kaolin treatments on the nut and kernel characteristics. Therefore, in this research, the effects of different concentrations of kaolin were investigated on several characteristics such as photosynthesis and other gaseous exchanges by the tree, rate of leaf, husk and kernel sunburn, the quantity and quality of nut and kernel, the absorption of certain nutrients, water use efficiency, and also the amount of proline accumulation as indicators of the presence or absence of stress in walnut trees.

2. Materials and methods

2.1. Experimental site

This study was done in a commercial orchard located in Khan-Zenyan region, a district of Shiraz, in Fars province with 1486 m altitude where the climate exhibits dry and hot summers, but cold and semi-humid winters. Average of rainfall is 273 mm a year, and most of this rainfall occurs in late fall and winter. The experiment was conducted on 15-year-old walnut trees with planting distances of 7 × 6 m, which were irrigated by the flood irrigation system. In the selected region for the test, adverse effects of hot summers were confirmed in walnut orchards in the previous years. Regarding this point that walnut trees in the experimented orchard were seedlings and non-uniform, uniform trees with relatively similar vigour, and also nut features (the study of nut features was done in the previous year from the beginning of the experiment) were selected for this purpose in order to increase the accuracy. The trees under the experiment received all the usual cares of a commercial orchard such as fertilization, irrigation, and protection against pests and weeds.

2.2. The experimental design and kaolin spraying treatments

The experiment was performed through a complete randomized block design with three treatments [three levels of kaolin spraying 0% (control) 3% and 6%], with five replications (each replication including one tree) in two subsequent growing seasons (2013 and 2014). The kaolin (Sepidan® WP, Kimia Rahavard Ltd., Tehran, Iran) spraying treatments were applied twice on the same trees each year. In each growing season, the first instance of kaolin spraying was done on all the foliage of the trees in the middle of June (when the fruits were the size of a hazelnut), with appropriate concentrations by a sprayer behind the tractor with a high diffusion mode. The second application of kaolin spraying which had a supplemental mode was carried on one month after the first spray; with half amount of the first dosage (respectively with the densities 0%, 1.5% and 3%) and according to the method of the first application on trees, especially on newly grown branches. All these treatments were also repeated on these trees in a similar way in the second year.

2.3. Measurements

For this purpose, five branches were tagged in different directions on each tree, and other subsequent measurements were done on the leaves and fruits of these branches.

2.3.1. Leaf surface

Ten leaves were taken randomly from each tree in different directions of the tree and from the middle of branches at the end of August. Then, they were moved to the laboratory and the surface area of each leaf was measured by the leaf surface measurement device (Li-Cor, Model Li-1300, USA), thereby recording the average of leaf surface area.

The chlorophyll rate was measured by the SPAD-502 system (made in Japan) at the beginning of August. The obtained number is the average of 8 measurements from different directions of the trees.

2.3.2. The leaf sunburn rate

For this purpose, 20 leaves were removed randomly in different directions of the tree in the middle of branches at the end of August. The sunburn rate of each leaf was investigated by using a coding system as follows; Lack of sunburn (0), mild sunburn (1), medium sunburn (2) severe sunburn (3), very severe sunburn (4), and the averages were recorded.

2.3.3. Photosynthesis rate, leaf temperature, gas exchanges, and water use efficiency

A portable device (ADC BioScientific LCA4 Ltd., UK) was used in order to measure photosynthesis and other gas exchanges. Reading of the parameters was done at the beginning of August, on a sunny day, and measurements were made on 5 leaves located in different directions of each tree between hours 10–12 in the morning. Accordingly, the gas exchange rate of the stomata, the leaf surface temperature, photosynthesis amount, and carbon dioxide rate of intake under the stomata module were measured, while water use efficiency was obtained.

2.3.4. Quantitative and qualitative indicators of nuts

The weight of green husk, nut, kernel, and the ratio between them were measured; for this purpose, all the fruits of tagged branches were harvested in a common time of commercial harvesting. Among the harvested product, 100 fruits per tree were selected randomly and the weight of their green husk was recorded after peeling the fruits. The nuts were dried in a sunshine-shadow place for two weeks, and then they were weighted. Their kernels were brought out and their weight was measured. Finally, the weight ratio of the kernel of the nut was calculated.

2.3.5. Rate of sunburn in green husk and kernel

For measuring the sunburn rate of the green husk, numeric codes of zero (without sunburn) to four (severe sunburn) were used (Fig. 1). For this purpose, 20 fruits were selected randomly from each tree and coded on this scale. Finally, the averages were recorded for each tree.

2.3.6. Percentage of kernel oil

The Soxhlet system was used for measuring the total oil. Accordingly, 20 kernels were selected firstly from each experimental unit at random, and they were placed in the oven (70 °C for 72 h) in order to be dried completely. They were then ground, and 2.5 g of kernel powder was put in the Soxhlet device. The separated oil content in the flask was placed in the oven for three hours at 70 °C after 2 h and 30 min of washing with *N*-hexane solvent. Finally, it was measured and the total oil content was obtained by subtracting the amount from the first weight of the flask (Parvaneh, 1995).