AgroLife Scientific Journal - Volume 6, Number 2, 2017
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

IMPACT OF KAOLIN PARTICLE FILM ON LIGHT EXTINCTION COEFFICIENT AND RADIATION USE EFFICIENCY OF PISTACHIO (*Pistachia vera*)

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Abstract

Kaolin application became a common treatment in orchards against different pests like psyllid. After kaolin application a thick powdery layer covers both sides of each leaf. It is a major concern that how much this layer affect light absorbance of leaves and net plant production, although light interception can be altered by changing spacing, tree height, tree shape and/or row orientation. In order to investigate the effect of kaolin spray on light extinction coefficient and radiation use efficiency of pistachio, an experiment conducted on a commercial orchard in khorasan razavi province. Three concentrations (0%, 3% and 6%) of processed Kaolin particle film sprayed on four varieties (Ohadi, Sepid, Kalehghoochi and Akbari) of pistachio as a liquid suspension, which evaporates, leaving white colour powdery film on the surfaces of leaves, stems and fruits. Treatments arranged in a randomized block design with 3 replications. Imaging softwares used to extract canopy structure and light transmission factor. In this case that we could not measure total plant production, only dried fruit production of each tree was used to estimate RUE (Radiation Use Efficiency). The results showed that kaolin film decreased single-leaf light absorbance and increased total light absorbance of pistachio tree. K, the Light extinction coefficient was not significantly different in different concentration of kaolin treatments.

Key words: *Dry matter accumulation, Light intercept, Net production, RUE.*

INTRODUCTION

Mineral-based particle films have long been considered as useful crop protectants. From the 1920s through the 1960s many growers and researchers attempted to apply mineral-based particle films to a variety of agricultural production problems (Glenn et al., 1999). Kaolin (kaolinite) a white aluminosilicate clay, with fine and porous, non-abrasive particles disperses easily in water. This inert mineral is used in the paper, paint and plastic industries, depending on the processing and characteristics of the particles (size, dimensions and brightness). It is also a component of drugs, toothpaste, cosmetics and alimentary products (Glenn and Puterka, 2005). Particle film technology (i.e. spraying canopies with a suspension of particles of various kinds of clay, leaving a film on the leaves) has long been used to limit the impact of water and heat stress on crops (Rosati et al., 2006).
Different studies on crops showed that using mineral particle films may have beneficial effects on tomato (Srinivasa Rao, 1985), peanut (Soundara Rajan et al., 1981), apple (Glenn et al., 2001) almond and walnuts (Rosati et al., 2007).
Studied focused on kaolin particle films application, report that it may decrease single leaf photosynthesis which is related to the reduction in light reaching the photosynthetic apparatus, due to a 20-40% increase in reflection and decreased absorption (Grange et al., 2004; Wünsche et al., 2004; Rosati et al., 2006; Rosati et al., 2007). In contrast to these findings, Glenn et al. (2003) reported that total canopy photosynthesis increased.
Wunsche et al. (2004) suggested that this is due to improved light distribution within the canopy. Rosati et al. (2007) tested the relationship between individual-leaf and canopy photosynthesis in almond and walnut by means of modeling and they report an increase in total photosynthesis.
In this study we object to measure effect of kaolin application on photosynthesis active

radiation (PAR) absorption by the canopy and its possible effects on radiation use efficiency.

Radiation attenuates exponentially within a canopy and is given by

(1)

$$I/I_0 = e^{-k\,\mathrm{LAI}}$$

Where I and I_0, are the total PPFDs (Photosynthetic Photon Flux Density) at points below and above the canopy, respectively (Monsi and Saeki, 1953), k is the direct beam extinction coefficient and LAI is the cumulative leaf area index from the top of the canopy.

(2)

$$\mathrm{LAI} = \frac{\text{Leaf area } (m^2 \text{ or } cm^2)}{\text{Land area it was measured above } (m^2 \text{ or } cm^2)}$$

If k = 1 and LAI = 1, all leaves distributed randomly in the horizontal plane will intercept 63% of the incident PPFD. Taking the natural log of both sides in the above equation,

(3) $\mathrm{Ln}\,(I/I_0) = K.\mathrm{LAI}$

When Ln (I/I_0) was plotted against LAI, the slope of the straight line, k, is a function of the orientation of leaves forming the canopy (Acock, 1991). Plants such as grasses, which have narrow erect leaves, have a smaller k value than plants such as eggplant which have broad horizontal leaves, suggesting that PPFD penetrates further into a grass canopy than into a eggplant canopy. A k value of 0.68 for the upper leaf layer and stem in eggplant canopy was reported; it decreased to 0.63 with depth in the canopy. Suggesting the leaf area was less efficient at intercepting PPFD towards the base of the canopy. The lowest third leaf layer absorbed less than 10% PPFD incident downward on a horizontal plane above the canopy.

Daily accumulated light interception and the daily dry matter production can be used to calculate light use efficiency.

(4) Dry Matter Increase = LUE×LI

Which *DM* = daily dry matter production (g/m^2), *LUE*= Light use efficiency constant (g/MJ), *LI* = Light energy intercepted by the crop (MJ/m^2). When we measure LI using PAR-meter tools and dry matter accumulation in plant, we can plot produced dry matter against LI and the slope of the line will be the radiation use efficiency (Rosati et al., 2007). Two major determinants of high productivity in trees are their ability to produce high levels of assimilates in the photosynthetic process and to efficiently partition a high proportion of those assimilates into economically important organs. Here we try to the allocation of plant produced assimilates in fruits, so beside the whole canopy weight, only fruit weight used in the LUE calculation formula. Because the pistachio crop is consumed dried, accumulated dry weight of fruits at the end of season, used for calculation of RUE (Radiation use efficiency) in equations.

MATERIALS AND METHODS

Plant material: In this study, 4 local pistachio cultivars ohadi, sepid, kalehghoochi and akbari selected. Uniform and same aged trees of each cultivar being sprayed (using agricultural sprayer) with a 6% suspension of processed Kaolin particle film. Kaolin suspension spray repeated during growing season for 2 to 3 times to keep powder film thickness on plant organs steady.

Canopy light absorption: The PAR transmitted by and reflected from the canopy was measured using a solar active radiation and power meter for each cultivar and in both kaolin treatments and controls. For the reflected PAR, the light bar was held with the sensors orientated downwards about 2 m above the highest part of the canopy; for the transmitted PAR, the light bar was held at ground level, with the sensor orientated upwards.

Leaf area index calculation: LAI was calculated using hemispheric photographs taken by fish-eye lens equipped camera (Jonckheere et al., 2005). We used the scientific image processing software, Gap Light Analyzer (GLA) Version 2.0 developed by Frazer et al. (1999, 2000), to process and analyze the digital hemispheric canopy images. The software extracts canopy structure data (gap fraction, canopy openness, effective LAI) and gap light transmission indices based on a user-specified day of interest. The simplified radiation model within GLA assumes that when the sun position is obstructed by the canopy, the direct radiation is zero, and when unobstructed, direct radiation is equal to the above-canopy value (Frazer et al., 1999; Hardy et al., 2004).

Light Absorbance Coefficient: K the coefficient of light absorbance (Light absorbance factor), RUE of all pistachio cultivars in different kaolin treatments calculated using equation one.

Radiation use efficiency: RUE of each treated tree calculated using equation four based on dry fruit weight production.

Data Analysis: Experimental procedure was a complete block design with three blocks and one tree of each pistachio cultivar for each kaolin treatment. Totally 27 pistachio trees being treated during experiment.

RESULTS AND DISCUSSIONS

Leaf area data, calculated using Gap light analyzer showed in Table 1. Only differences in *Akbari* cultivar were significant between kaolin and control and in other studied cultivars there were no significant differences between kaolin treatments.

Table 1. Effect of kaolin treatment on LAI, K and LUE in different pistachio cultivars

Kaolin Treatment	Cultivar	LAI	K	LUE
Control	Akbari	1.598^{a}	0.609^{b}	0.355^{ab}
	Ohadi	1.138^{c}	0.876^{a}	0.267^{b}
	Sefid	1.423^{b}	0.669^{b}	0.400^{a}
	Kalehghoochi	1.493^{b}	0.629^{b}	0.248^{b}
6 %	Akbari	1.448^{b}	0.725^{b}	0.396^{a}
	Ohadi	1.076^{c}	0.914^{a}	0.378^{a}
	Sefid	1.361^{b}	0.731^{b}	0.433^{a}
	Kalehghoochi	1.411^{b}	0.744^{b}	0.468^{a}

Data with different letters in each column have significant differences (P≤5%)

For K, the light extinction coefficient, all kaolin treated trees have higher levels but they were not significantly differ from control. *Ohadi* in both treatments had the highest K (Table 1).

Generally, LUE was higher in kaolin treated pistachios, although differences between kaolin treatment in *Akbari* and *sepid* were not significant. Light use efficiency of pistachio cultivars showed significant differences for *Kaleghoochi* and *Ohadi* between kaolin and control (Table 1, Figure 1). In fact, top-canopy leaves often operate near light saturation and their LUE is improved at lower light, while inner-canopy leaves operate more often at low light and their LUE is improved at higher light (Hirose and Bazzaz, 1998). Skewing the light distribution towards inner-canopy leaves, as kaolin application did (Figure 2), would therefore result in improved canopy LUE, as previously found in Almont and Walnut (Rosati et al., 2007) or Prunus under water stress (Lampinen et al., 2004).

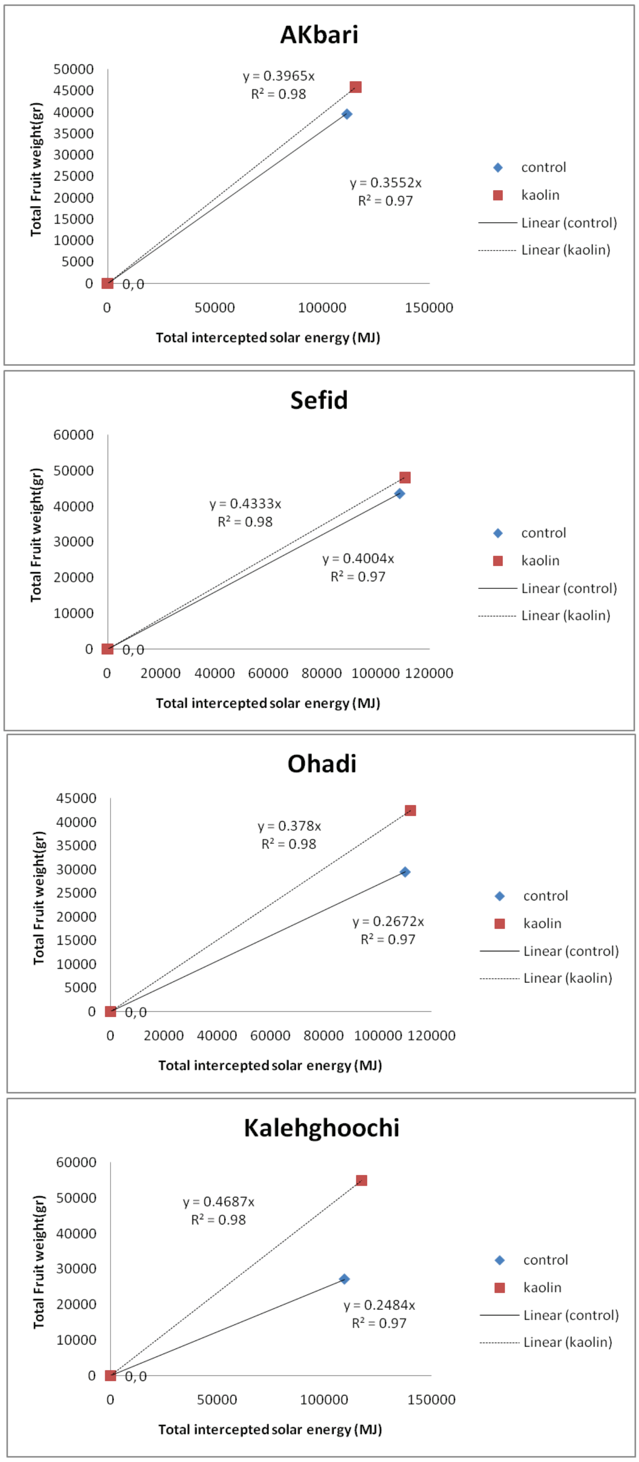

Figure 1. Light use efficiency of different pistachio cultivars (total fruit production basis)

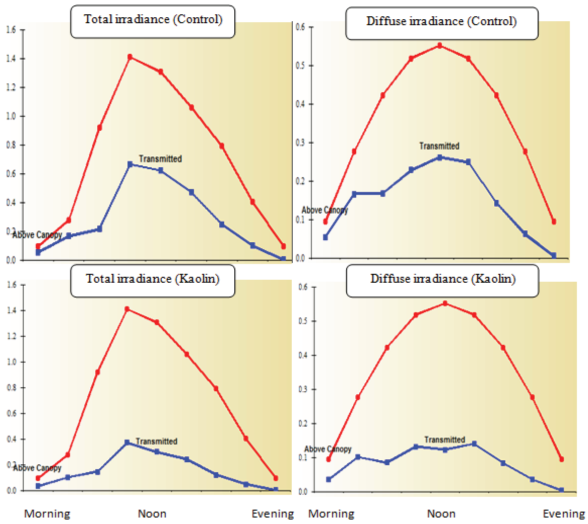

Figure 2. Total and diffuse irradiance in control and kaolin treated pistachio tree during a day. Y axis is solar energy ($MJ.m^{-2}.day^{-1}$)

The most important parameter affected by kaolin in studied pistachio cultivars, was diffuse irradiance. For a given daily incident PAR above the canopy, kaolin application increased the daily PAR incident on individual inner-canopy leaves, as measured by the light meters. Kaolin treatment increased light reflection of leaves. So, light transmission of total and diffuse irradiance was lower in kaolin treated trees. This help tree to intercept more solar energy, however, their leaves covered by kaolin and single- leaf solar energy interception may lower in compare to control. This implies that a great part of the additional PAR reflection at the leaf level is re-intercepted and eventually absorbed within the canopy (Figure 2). These results support the hypothesis that kaolin application affects canopy light distribution (Wünsche et al., 2004). Rosati et al. (2007), reported a 200% increase in inner-canopy leaves PAR incidence in almond and walnut after kaolin application.

In a normal tree, most of the photosynthesis was occurred in outer-canopy leaves, since PAR decreases exponentially with canopy depth. However, most of the leaves in the tree are actually inner-canopy leaves, which thus with an increase in PAR incident with kaolin application, they should began to have higher amount of photosynthesis. Therefore, total dry matter production of tree should increase. This explains the contradiction in the literature of increased yield with kaolin application (Stanhill et al., 1976; Moreshet et al., 1979; Soundara Rajan et al., 1981; Srinivasa Rao, 1985; Glenn et al., 2001), despite an apparent reduction in leaf photosynthesis (Moreshet et al., 1979; Glenn et al., 2003; Grange et al., 2004; Wünsche et al., 2004; Rosati et al., 2006).

CONCLUSIONS

Results of this study showed that greater PPFD interception was occurred in kaolin treated pistachio trees, however, K, the light extinction factor was not significantly changed by kaolin treatment.

By this increase in PPFD interception, we expect an increase in LUE and yield. There was significant increase in some of pistachio cultivars. Since we only use fruit weight for LUE calculation, it might be an increase in other tree parts dry weight as a result of higher solar energy interception which was not calculated.

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