Effects of Kaolin Clay Coating on Mango Leaf Gas Exchange, Fruit Yield and Quality

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ABSTRACT

The depressions of midday net photosynthesis (P_n) and stomatal conductance (g_s) in mango are related to environmental stresses such as high temperature and drier conditions at this time. Kaolin, a white clay, has been used to mitigate the negative effects of those stresses on plant physiology and productivity. The objectives of this experiment were to study the effects of a kaolin leaf coating on photosynthesis in term of the gas exchange, fruit yield and quality in mango (*Mangifera indica* L.) cv. Mahajanaka. The results showed that a kaolin coating on the mango leaves could insulate against high irradiance, reduce leaf temperature (T_{leaf}), and decrease $VPD_{leaf\text{-}air}$ as T_{leaf} was decreased, which resulted in increasing both P_n and g_s. The total number of fruit and the total fruit weight from the kaolin-sprayed mango trees were increased by 40.79% and 44.40%, respectively. Furthermore, kaolin coating affected the ripe fruit peel colors, especially redness, and reduced the severity of anthracnose and fruit rot during the post-harvest ripening period. This suggested that kaolin coating could be considered as a useful technology for improving mango plant photosynthesis and quality in an environment of high temperature and excess solar radiation.

Keywords: kaolin, stomatal conductance, leaf gas exchange, midday depression, mango

INTRODUCTION

Environmental stresses such as a high midday temperature and high irradiance result in a midday depression of photosynthesis. It is well known that when leaves are usually exposed to high irradiance and a high air temperature (T_{air}), plants do not always gain their full photosynthetic capacity (Yamada *et al.*, 1996; Goldschmidt, 1999; Hirasawa and Hsiao, 1999). Severe midday depression of photosynthesis under high photosynthetic photon flux density (PPF) and T_{air}, reduce the growth, fruit yield and fruit quality in many plants such as citrus (Goldschmidt, 1999; Jifon and Syvertsen, 2001; Hu *et al.*, 2007) and tomato (Leonardi *et al.*, 2000; Adams *et al.*, 2001). Stomatal closure is the major physiological factor responsible for this midday depression, which decreases the CO_2 concentration in the intercellular spaces (C_i) (Tenhunen *et al.*, 1984; Xu

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and Shen, 2005). Thus, the closure of stomata may contribute to the decrease in the net photosynthetic rate (P_n) by limiting the CO_2 supply.

The temperature increase during the midday depression of photosynthesis impacts on the CO_2 and H_2O exchange by altering the leaf-to-air vapor pressure deficit (VPD $_{leaf\text{-}air}$). This causes particular sensitivity of the stomatal conductance (g_s) of leaves to the change in VPD_{air} (Chamchaiyaporn *et al.*, 2013). Iio *et al.* (2004) reported that P_n, g_s and the transpiration rate (E) of *Fagus crenata* Blume. decreased more than 50% under a VPD_{air} value of about 2.5 kPa compared to the VPD_{air} value of about 1.0 kPa even under well-watered conditions. In addition, the midday depression of photosynthesis was reported to be the result of midday stomatal closure caused by high VPD $_{leaf\text{-}air}$ (Iio *et al.*, 2004). Moreover, stomatal responses to VPD_{air} were mediated by E, and then affected the leaf water status or the gradient in the water potential between the guard cells and other epidermal cells (Gunasekera and Berkowitz, 1992). Nevertheless, this feedback mechanism was not consistent with observations of enhanced leaf water potential (Saliendra *et al.*, 1995) and stomatal closure at high VPD_{air}, with concomitantly lower transpiration (Farquhar and Raschike, 1978). More recently, Hu *et al.* (2007) reported that decreased E and g_s at midday were interpreted as a combined feed-forward effect from the increased VPD_{air}.

Jifon and Syvertsen (2001, 2003) reported that leaf temperature (T_{leaf}), VPD $_{leaf\text{-}air}$, and photoinhibition during the midday period were reduced by moderate shade and particle film applications, and consequently g_s and P_n were increased in shaded leaves compared to sunlit leaves. In addition, the excess radiation and high temperatures of leaves caused water deficits and reduced the efficiency of light-use leading to reduced P_n, lower growth, less fruit yield and poorer fruit quality (Goldschmidt, 1999). Reducing the sink capacity by removing fruit could result in a greatly diminished rate of net photosynthesis in many species of fruit trees, such as apple and plum (Gucci *et al.*, 1991, 1995). However, inconsistent effects resulting from the removal of reproductive sinks were observed on net photosynthesis (Nautiyal *et al.*, 1999).

Particle film technology with inert reflective materials such as kaolin has recently been used in agricultural crops to reduce heat stress, solar injury of fruits and water stress and has also been involved in pest control and disease incidence suppression (Glenn *et al.*, 1999, 2003; Jifon and Syvertsen, 2003; Erez and Glenn, 2004; Catore *et al.*, 2009). Kaolin, a white clay mineral, can disperse in water and be sprayed on the leaf or fruit surface to form a protective particle film. It also causes light reflection on the leaf surface which contributes to a lower leaf temperature, and prolonged stomatal opening during high VPD in the air (Jifon and Syvertsen, 2003). In addition, using kaolin particle film can contribute to high quality fruit production (Glenn and Puterka, 2005). The efficiency of kaolin particle film to mitigate the negative effects of heat stress has been reported in various circumstances—increased P_n, g_s and water use efficiency in citrus (Jifon and Syvertsen, 2003), increased P_n and g_s in apple (Glenn *et al.*, 2002) and an increased rate of whole canopy carbon assimilation under high T_{air} (Glenn *et al.*, 2003). However, Lombardini *et al.* (2005) reported that kaolin did not affect E, g_s and P_n in pecan. Kaolin reduced T_{leaf} and $VPD_{leaf\text{-}air}$ in walnut and almond, but did not affect g_s (Rosati *et al.*, 2006). In addition, the physical barrier formed by the particle film prevents contact between pathogenic microorganisms and plant surfaces and thereby reduces infection and disease (Glenn *et al.*, 1999; Puterka *et al.*, 2000). Thus, it is becoming a popular way to improve fruit yields and reduce fruit loss.

In the current study, a kaolin coating on mango leaves was investigated for improving the physiological characteristics such as photosynthetic activity. The effects of the kaolin application on mango fruit yield and quality were also evaluated.

It was hypothesized that a kaolin application could increase photosynthetic gas exchanges under excess solar radiation and high temperature. The increase in photosynthesis resulting from the heat-load reduction by the kaolin coating could lead to yield and quality improvements.

MATERIALS AND METHODS

Experimental plant preparation

The research was carried out at the Kasetsart University Research Station, Kanchanaburi province, Thailand (14°14'47.38"N, 99°14'3.21"E). Uniform mango (*Mangifera indica* L.) trees cv. Mahajanaka aged 10 yr were used with a height of 2.5 m and a 12–15 cm stem diameter. Trees were planted at 2.5 m within rows and 3 m between rows. The trees received about 1 hr of soaker hose watering twice a week. When the trees reached the mature-leaf stage with glossy, dark green leaves, they were sprayed with an aqueous suspension of Indonesia kaolin 325 mesh (Bullazia Agrifluids Co., Ltd.; Nonthaburi, Thailand) using a power sprayer. Four trees were selected and were sprayed twice a week with 60 $g.L^{-1}$ of aqueous kaolin suspension while the other four control trees were not sprayed. Each tree was sprayed with 0.7 L of aqueous kaolin suspension, in order to have all leaves of the entire canopy uniformly coated as observed by the white clay coating on all leaves. The duration for kaolin application was after flowering with fruit set of 1 cm (25 February 2009) until fruit matured at week 2 before harvesting (17 April 2009) to maintain a uniform film coating.

Gas exchange measurements

Gas exchange measurements were performed twice—on 25 March (160 d leaf age) and 10 April 2009 (174 d leaf age)—to compare the physiological characteristics of the mango trees after kaolin treatment on a sunny day and cloudy day, respectively. The photosynthetic measurement was performed every hour during 0800 to 1600 hours using a portable photosynthesis system (LI-6400; LI-COR Inc.; Lincoln, NE, USA). Two mature expanded leaves per tree were chosen randomly from the exterior of the canopy following the sunlight direction and four representative trees of 160 and 174 d leaf age were sampled. Each leaf was clamped inside the leaf chamber of the portable photosynthesis system with the upper leaf surface inside the chamber being fully exposed to natural PPF. The flow rate of CO_2 concentration was controlled at 400 $\mu mol.mol^{-1}$. The measurement parameters consisted of the photosynthetic photon flux (PPF), air temperature (T_{air}), relative humidity (RH), net photosynthesis (P_n), stomatal conductance (g_s), transpiration rate (E), leaf temperature (T_{leaf}), leaf-to-air vapor pressure deficit ($VPD_{leaf\text{-}air}$) and intercellular CO_2 concentration (C_i). The air vapor pressure deficit (VPD_{air}) was then calculated from the records of air temperature and relative humidity, according to Goudriaan and van Laar (1994).

Yield and fruit quality

The total number of fruit per tree was counted immediately after harvest and the total weight per tree was recorded.

Fruit quality parameters were determined from 40 representative fruits per tree. After harvest, all fruits were stored to promote postharvest ripening at room temperature for 4 d. Peel brightness and the colors of fruit pericarps on both sides of 20 fruit samples were measured twice with a color difference meter (model CR-400; Konica Minolta Inc.; Osaka, Japan) using the Hunter *L* (brightness), *a* (redness) and *b* (yellowness) system (Hunterlab, 2008).

Total soluble solids (TSS) and titratable acidity (TA) were analyzed using 20 fruits. The TSS content in the juice was determined using a refractometer and expressed as °Brix at 20 °C, while the TA (expressed as milliequivalents and measured by titration with a 0.1 N NaOH solution up to a pH 8.1 endpoint) was reported as the citric acid content.

Visual observations of anthracnose and fruit rot symptoms on the fruit surface were carried out on day 7 after harvest. The levels of disease severity were numerically expressed as 0, 1, 2, 3 and 4 for no disease spots (healthy fruit), 1–25%, 26–50%, 51–75% and 76–100% disease area, respectively.

Data analysis

The numerical data on photosynthetic gas exchange, yield and fruit quality were analyzed using a *t*-test. Data were presented as mean ± SE (n = number of measurements).

RESULTS

Microclimate

All microclimatic data were significantly higher ($P \leq 0.05$ for PPF; $P \leq 0.01$ for RH, T_{air}, T_{leaf}, VPD_{air} and $VPD_{leaf\text{-}air}$) on the sunny day than on the cloudy day (Table 1). The first measurement was conducted on 25 March 2009. The average value of PPF on the leaf surface reached 1,476.75 μmol PPF $m^{-2}.s^{-1}$ from 1000 to 1400 hours (Figure 1a, Table 1). The RH was high in the morning and decreased rapidly after 1000 hours, while the average RH around midday was 44.02%. (Figure 1c, Table 1). The T_{air} value increased along with the increase in PPF and reached 29 °C by 0800 hours and was 37–39 °C from around midday until 1600 hours (Figure 1e, Table 1). During the morning, the VPD_{air} value was 1.00 kPa at 0800 hours, then increased sharply to 3.74 kPa at midday and maintained high values throughout the afternoon (Figure 1g, Table 1). The leaves were exposed to increasingly high PPF, T_{air} and VPD_{air}, upon which the values of T_{leaf} and $VPD_{leaf\text{-}air}$ also increased and reached 40.79 °C and 4.62 kPa at midday, respectively (Figures 1a, 1c, 1e and 1g). Thus, based on these climatic conditions, this day can be described generally as a sunny day. In the second measurement (10 April 2009), the average value of PPF was 1,170.05 μmol PPF $m^{-2}.s^{-1}$ from 1000 to 1400 hours (Figure 1b, Table 1). The relative humidity was high and fairly constant between 60 and 70% throughout the day (Figure 1d, Table 1). The values for T_{air} and VPD_{air} around midday were low being 30.39 °C and 1.67 kPa, respectively. Furthermore, the T_{leaf} and $VPD_{leaf\text{-}air}$ values were also low (32.86 °C and 2.23 kPa, respectively) and fairly constant throughout the day (Figures 1f, 1h, Table 1). Thus, the climatic conditions on this day were considered to be consistent with a cloudy day.

Gas exchange

On the sunny day, the leaf gas exchange parameters in both treatments showed the same trend in diurnal change with the exception of the E value (Figure 2). All leaf gas exchange data

Table 1 Average microclimatic factors from 1000 to 1400 hours.

	PPF (μmol PPF $m^{-2}.s^{-1}$)	RH (%)	T_{air} (°C)	T_{leaf} (°C)	VPD_{air} (kPa)	$VPD_{leaf\text{-}air}$ (kPa)
Sunny day (25 March 2009)	1,476.75±49.19*	44.02±1.06**	38.09±0.28**	40.79±0.41**	3.74±0.11**	4.62±0.18**
Cloudy day (10 April 2009)	1,170.05±104.84	61.27±0.52	30.39±0.11	32.86±0.21	1.67±0.02	2.23±0.04

PPF = Photosynthetic photon flux, RH = Relative humidity, T_{air} = Air temperature, T_{leaf} = Leaf temperature, VPD_{air} = Air vapor pressure deficit., $VPD_{leaf\text{-}air}$ = Leaf-to-air vapor pressure deficit.

* = $P \leq 0.05$, ** = $P \leq 0.01$ based on *t*-test. Values are shown as mean ± SE.

in the kaolin treatment were higher than in the control particularly the g_s and E values at 1100 hours (Figures 2a, 2c, 2e and 2g).

On the cloudy day, the diurnal changes in the values of P_n, g_s and E in both treatments had the same pattern. In addition, these values in the kaolin application were higher than in untreated leaves, especially from 1000 to 1100 hours and then from 1300 until 1600 hours (Figures 2b, 2d and 2h). The C_i values only showed a similar pattern in both

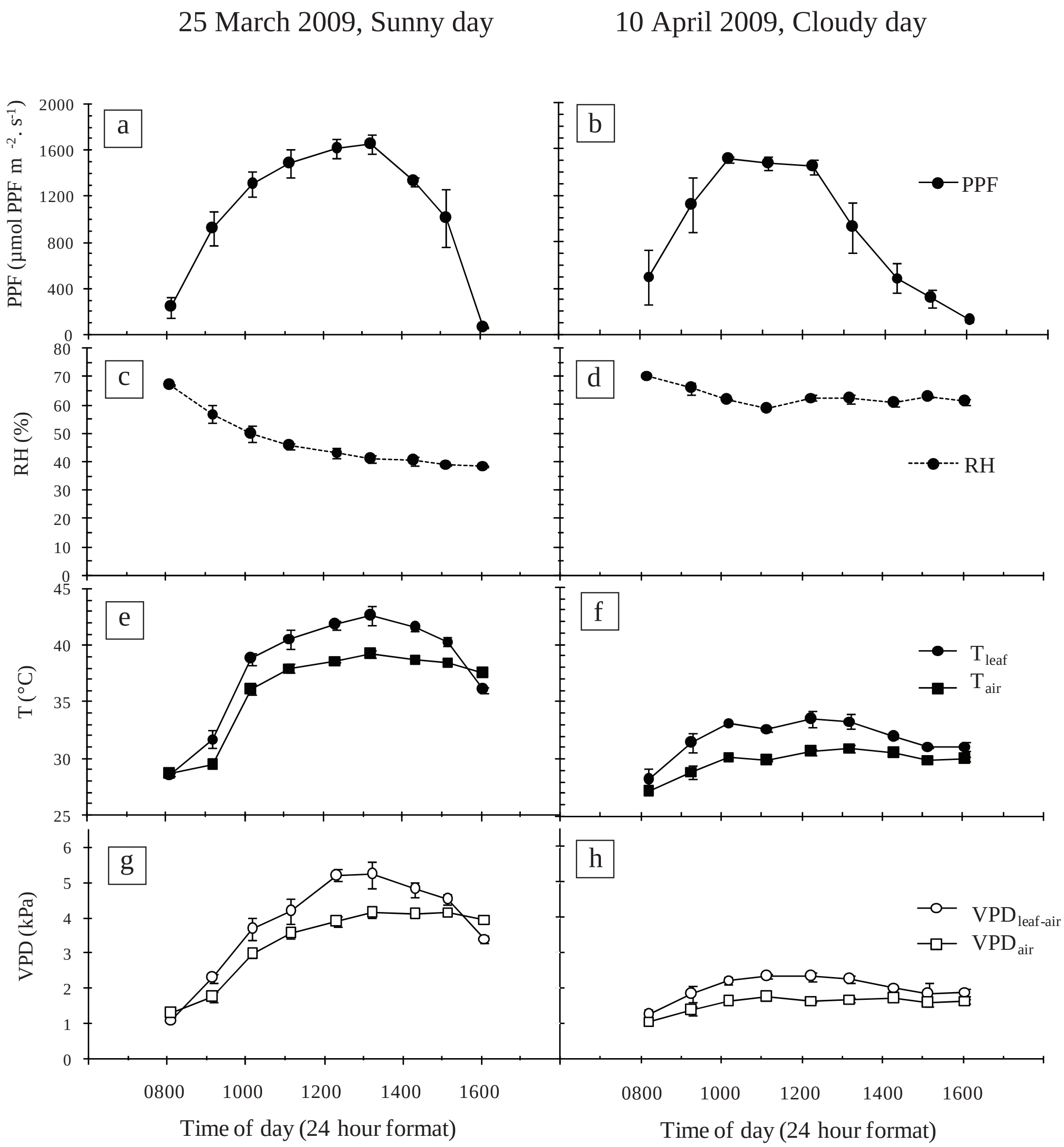

Figure 1 Diurnal course of parameters on a sunny day (25 March 2009) and a cloudy day (10 April 2009), respectively, for: (a,b) Average photosynthetic photon flux (PPF), (c,d) Relative humidity (RH), (e,f) Leaf temperature (T_{leaf}) and air temperature (T_{air}), (g,h) Leaf-air vapor pressure difference ($VPD_{leaf\text{-}air}$) and (g,h) Air vapor pressure deficit (VPD_{air}). Vertical bars indicate mean ± SE.

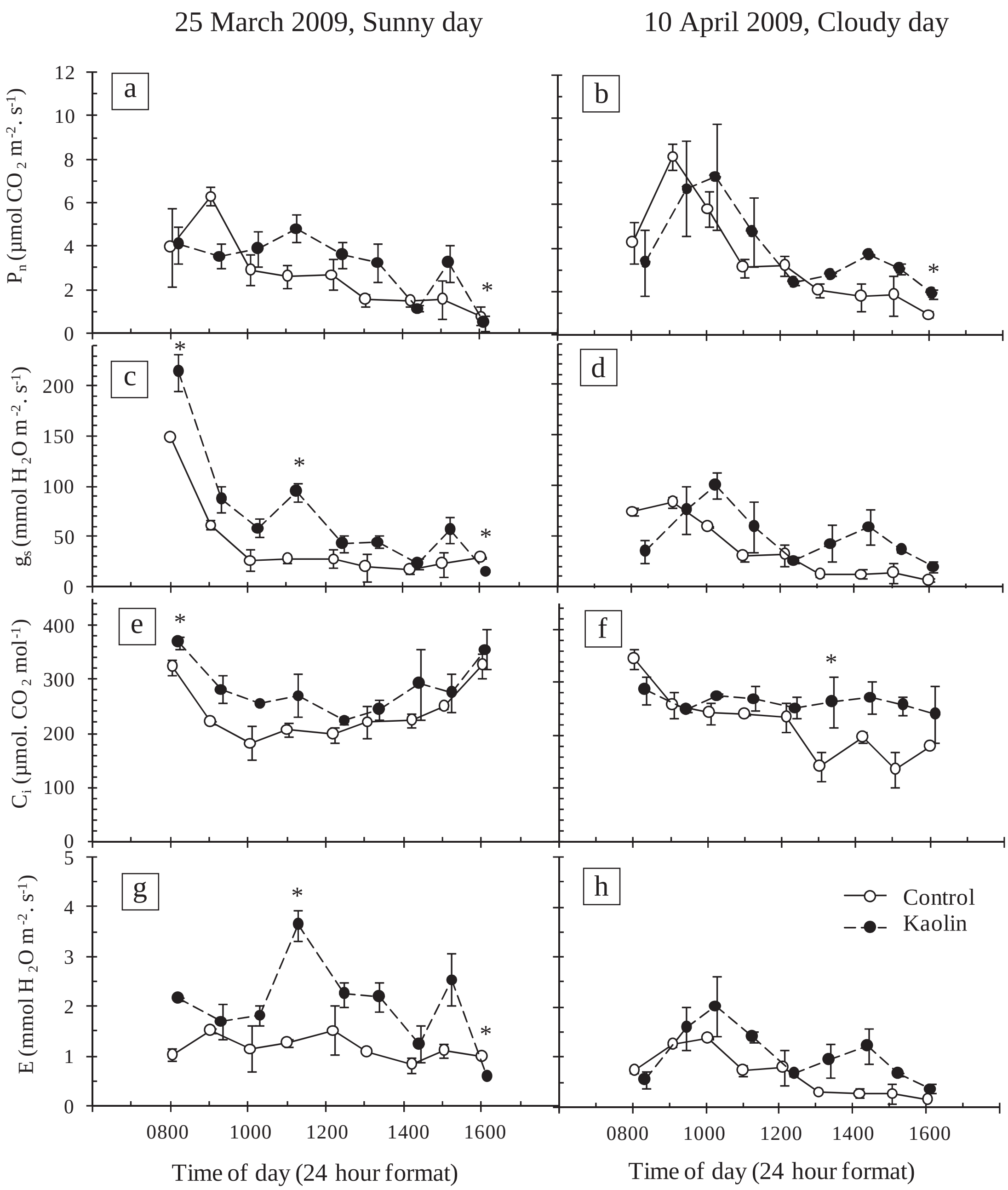

Figure 2 Diurnal changes of parameters measured on kaolin-treated and untreated trees on a sunny day (25 March 2009) and a cloudy day (10 April 2009), respectively, for: (a,b) Average net photosynthesis rate (P_n), (c,d) Stomatal conductance (g_s), (e,f) Intercellular CO_2 concentration (C_i) and (g,h) Transpiration rate (E). Each symbol represents the mean ± SE of two replications. * = $P \leq 0.05$ based on *t*-test.

the kaolin-sprayed leaves and control leaves in the morning from 0800 to 1200 hours. However after 1300 hours, the C_i value of the control leaves dropped substantially while the C_i value of the kaolin-sprayed leaves remained relatively stable (Figure 2f).

Yield and fruit quality

The total number of fruit and the total fruit weight per mango trees were not significantly ($P >$ 0.05) different between the two treatments (Table 2). However, the kaolin-sprayed trees increased the total number of fruit and the total fruit weight by 40.79% and 44.40%, respectively. The values of peel yellowness (*b*) and brightness (*L*) of the kaolin-treated fruits were higher than those of the control but they did not differ significantly, while the redness (*a*) values of the kaolin-sprayed fruit peels were significantly ($P \leq 0.05$) higher than those of the control (Table 2). There was no significant difference between the juice quality and TSS in fruits from the kaolin-sprayed trees compared with those in the unsprayed control. However, the TA content was significantly ($P \leq$ 0.01) lowered by the application of kaolin (Table 2).

The kaolin film was able to reduce the severity of anthracnose and fruit rot during the post-harvest period. The results showed that the percentage of healthy fruit among fruits coated was significantly ($P \leq 0.05$ for days 2 and 3 of ripening and $P \leq 0.01$ for days 4 to 7 of ripening) higher than that of the control (Figure 3). The comparison between the levels of average severity of anthracnose and fruit rot showed that the severity level of the diseases in kaolin-coated fruits was significantly ($P \leq 0.01$) lower at level 2 (Table 3).

DISCUSSION

On the sunny day, the mango leaves were exposed to high PPF, T_{air} and VPD_{air}. Consequently, T_{leaf} and $VPD_{leaf\text{-}air}$ were increased and were highest during the hottest hours around midday. High T_{leaf} and $VPD_{leaf\text{-}air}$ on this day induced stomatal closure which consequently caused the suppression of photosynthesis (Jifon and Syvertsen, 2003). Moreover, Xu and Shen (2005) pointed out that high VPD_{air} can induce stomatal closure, limit the photosynthetic CO_2 uptake due to decreased CO_2 availability and exacerbate photoinhibition due to excess photosynthesis. The results of the current study showed that the midday depression of P_n and g_s in mango trees under field conditions occurred on the sunny day with high PPF, T_{air} and VPD_{air}. Similar results have been found in many other plant species such as *Citrus grandis* (Veste *et al*., 2000), *Citrus unshiu* Marc. (Hu *et al.*, 2007) and *Eperua gradiflora* (Pons and Welschen, 2003). The VPD_{air} value of 3.74 kPa found in the mango leaves measured on the sunny day indicated heat stress conditions similar to those reported by Yingjajaval (2001) who considered that

Table 2 Effect of kaolin on total number of fruit, total weight, peel colors and juice quality of mango.

Treatment	Total number of fruit[A]	Total weight ($kg.tree^{-1}$)[A]	Peel color characteristics[B]			Juice quality[C]	
			L	*a*	*b*	TSS (°Brix)	TA
Control	254.50±38.87	82.09±15.38	65.91±0.32	6.25±0.56	45.89±0.45	16.18±0.17	0.19±0.006**
Kaolin	324.75±21.98	103.09±8.31	67.31±0.26	9.66±0.48*	46.85±0.37	16.45±0.16	0.16±0.003

Total numbers and total weight per tree were counted and recorded at harvesting time, [A] = Number = 4.
Peel colors: *L* = Brightness, *a* = Redness, *b* = Yellowness, [B] = Number = 160.
Juice quality: TSS= Total soluble solids, TA= Titratable acidity, [C] = Number = 40.
* = $P \leq 0.05$, ** = $P \leq 0.01$ based on *t*-test. Values are shown as mean ± SE.

high VPD_{air} values over 2.5 kPa suggested a dry climate, resulting in reductions of g_s and the rate of photosynthesis in tangerine. On the other hand, the values of P_n, g_s, C_i and E in the kaolin-coated mango leaves were higher than in the untreated leaves. This agreed with previous work in which mango cv. Num Dok Mai leaves sprayed with kaolin had significantly higher average P_n, g_s and E than untreated leaves (Chamchaiyaporn *et al.*, 2013). It may be assumed that kaolin could help reflect excess radiation to avoid the accumulation of heat load inside the leaves and thus not induce stomatal closure. Consequently, the C_i and E of the coated leaves were also increased. It was observed that the untreated leaves had lower g_s values than in kaolin-coated leaves on the sunny day. This suggests that the accumulation of heat inside the control leaves induced stomatal closure in order to minimize dehydration.

On the cloudy day, the kaolin-sprayed trees still showed higher P_n values than the control trees. The photosynthetic light saturation of mango cv. Num Dok Mai is relatively low at 600 μmol PPF $m^{-2}.s^{-1}$ (Chamchaiyaporn *et al.,* 2013). Thus, the PPF values measured on the cloudy day exceeded this saturation level of mango. Moreover, lower P_n values in the control trees than in the kaolin-treated trees measured on both days indicated that the high T_{leaf} and $VPD_{leaf\text{-}air}$ levels decreased g_s and limited the flux of CO_2 into the leaf. Normally, g_s was always higher in the morning than in the afternoon. However, the g_s

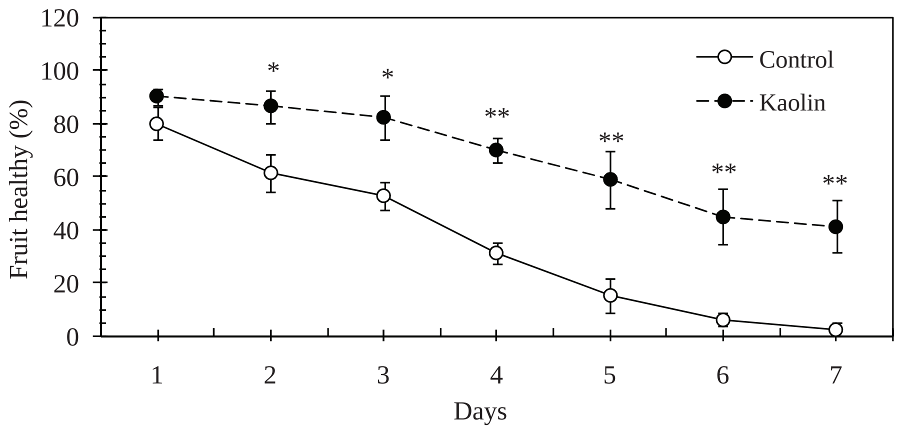

Figure 3 Effect of kaolin coating on healthy fruit (no anthracnose and fruit rot symptoms) in mango during 7 days of ripening. * = $P \leq 0.05$, ** = $P \leq 0.01$ based on *t*-test. Vertical bars indicate mean ± SE.

Table 3 Effect of kaolin on fruit damage by anthracnose and fruit rot disease on the day 7 of ripening.

Treatment	Disease severity of fruit			
	Level 1	Level 2	Level 3	Level 4
Control	71.25±5.91	17.50±5.95**	2.50±1.44	6.25±1.25
Kaolin	51.25±10.48	3.75±2.40	1.25±1.25	2.50±1.44

Each symbol represents the mean value ± SE of four replications (n=4).
Disease severity of fruit: Level 1 = 1–25%, Level 2 = 26–50%, Level 3 = 51–75% and Level 4 = 76–100% disease area.
** = $P \leq 0.01$ based on *t*-test.

value in both measurements was very low. It may be assumed that watering twice a week may not be enough for the growth of mango trees during flowering and fruit development which resulted in water stress. Sen Gupta and Berkowitz (1987) reported that g_s and E tended to decrease in banana plants subjected to water deficit. These results were supported by Siddique *et al*. (2000) who reported that the exposure of plants to water stress substantially decreased the leaf water potential, relative water content and transpiration rate with a concomitant increase in the leaf temperature. The research revealed that the leaf temperature was usually negatively correlated with the transpiration rate. The transpiration rate revealed a decreasing trend throughout the growth period of the crop with increased leaf temperature and stomatal diffusive resistance (Surendar *et al*., 2013).In addition, reduction in the transpiration rate under water deficit conditions leads to a reduced photosynthetic rate by inhibition of CO_2 entry into the chloroplast through the stomata (Surendar *et al*., 2013). The kaolin coating on mango leaves might insulate against high irradiance on sunny and cloudy days when the PPF was higher than the light saturation maximum. Consequently, a reduction in the leaf temperature by reflecting irradiation decreased $VPD_{leaf\text{-}air}$ as the leaf temperature decreased and finally increased both g_s and P_n. Hence, kaolin would be applicable for the reduction of high irradiation on mango leaves. According to Glenn *et al*. (2003), P_n and g_s were increased due to the reduction of T_{leaf} in kaolin-coated apple leaves. Similarly, Jifon and Syvertsen (2003) found that kaolin sprays on leaves reduced T_{leaf} and $VPD_{leaf\text{-}air}$ and increased P_n and g_s in mature, sun-acclimated grapefruit on hot days. Likewise, Glenn and Puterka (2005) suggested that kaolin reflected UV radiation but the formulation and particle distribution significantly influenced the degree of its UV reflection. However, Glenn *et al*. (1999) explained the physical presence of the clay particles which obviously did not inhibit leaf gas exchange, perhaps due to the porous nature of kaolin clay. The higher C_i values in the kaolin application indicated that the kaolin coating did not limit photosynthesis by inhibiting CO_2 supply via stomata.

It was hypothesized that an increase in photosynthesis after the kaolin application would increase the fruit yield and quality by increasing the carbohydrate supply. Nevertheless, a number of harvested fruits including the total fruit weight showed no statistical differences among treatments even though the kaolin-sprayed mango produced a greater total number of fruit and total fruit weight by 40.79% and 44.40%, respectively, over the control. This research may have provided limited information since the experiment was conducted for only one crop rotation. Information of the use of kaolin coating to increase mango yield needs to be confirmed.

Peel colors were affected by the kaolin treatment, especially redness (*a*). It is well known that mango cv. Mahajanaka peel has red coloration when ripe due to anthocyanins (Lueangprasert *et al*. 2010; Saengnil *et al*., 2011). The increase of redness in mango cv. Mahajanaka was possibly due to sunlight inducing anthocyanin synthesis and red color formation by stimulating greater phenylalanine ammonia–lyase (PAL) activity (Saengnil *et al*., 2011). Nevertheless, the relationship between the PAL activity and anthocyanin accumulation varied according to the stage of fruit development (Saengnil *et al*., 2011), which was similar to what was reported in the apple exocarp (Ritenour and Khemira, 2007). Glenn *et al*. (2001) reported that the fruit color of apple in Santiago trials could be enhanced by kaolin application. In addition, kaolin-treated fruits show improved anthocyanin color, if the layer applied was not too heavy, indicating a possible promotional effect due to reduced day temperature (Erez and Glenn, 2004). However, the effects of light and temperature depend on the cultivar and the stage of fruit development (Ritenour and Khemira, 2007; Saengnil *et al*., 2011).

With respect to the juice quality, the TA content in the control group was significantly higher than in the kaolin treatment, while the TSS in the control was not significantly different compared to the kaolin treatment. A probable explanation is that mango is a climacteric fruit. The taste development was marked by an increase in gluconeogenesis, hydrolysis of polysaccharides, especially starch, and a decrease in the acidity (Prasanna *et al.*, 2007; Brecht and Yahia, 2009). Thus, the juice quality in the control may have been subjected to less hydrolysis of the polysaccharides than in the kaolin treatment which led to the higher TA content. This may have been a result from the kaolin application increasing the efficiency of photosynthesis leading to the higher production of sugar which can accumulate in a starch form. In addition, more redness in the fruits derived from the kaolin treatment indicated a higher effective PAL activity which parallels the total sugar content in mature fruits. However, maturity at harvest plays an important role for postharvest life and eating quality, in particular for climacteric fruits where ripening is regulated by ethylene (Lelièvre *et al.*, 1997). In the immature fruit, sucrose is almost absent but it increases during ripening and becomes the major carbohydrate constituent in the ripe fruit (Wang *et al.*, 1996). During fruit maturation, starch that accumulates in chloroplasts is hydrolyzed to sucrose, glucose and fructose (Kumar and Dhawan, 1995).

In this study the kaolin coating effectively reduced the severity of anthracnose damage caused by *Collectotrichum gloeosporioides* and fruit rot caused by *Lasiodiplodia theobromae* during ripening at an ambient temperature of 30±2 °C. A reduction in the anthracnose and fruit rot damage in mango resulting from the application of kaolin has not been reported previously, but the reduction of these two diseases by using a plastic roof has been recorded (Jutamanee *et al*., 2013). The current study suggested that the kaolin coating prevented direct contact between pathogenic microbial inocula and plant surfaces by coating the leaves and fruit with barrier films and interfered with spore adhesion, thereby reducing infection and disease. Glenn *et al*. (1999) reported that kaolin contributed to the control of fungal and bacterial plant pathogens by preventing the formation of a liquid film on the surface of pear leaves. Similarily, kaolin controlled the fungal disease, Fabraea leaf spot, caused by *Fabraea maculata* Atk. in grape (Puterka *et al*., 2000).

CONCLUSION

On a sunny day and cloudy day, the PPF exceeded the photosynthetic light saturation level for mango. Spraying kaolin on mango leaves could provide reflection of excess radiation to reduce the heat load inside the leaves. In addition, it could reduce T_{leaf} and $VPD_{leaf\text{-}air}$ which resulted in increased P_n and g_s. Kaolin-sprayed mango could increase the total number of fruit and the total fruit weight by 40.79% and 44.40%, respectively, compared to the control. Kaolin application also induced redness in the peel color. Spraying kaolin on the leaves and fruits commencing from fruit set up until the mature stage reduced the severity of anthracnose and fruit rot diseases during the post-harvest period. Therefore, it is useful for post-harvest technology. The economical benefit of kaolin as a fruit coating material is that it increases fruit quality by reducing fruit diseases during ripening and may prolong the fruit shelf life.

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