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Effect of Kaolin Film Particle Applications (Surround WP®) and Water Deficit on Physiological Characteristics in Rose Cut Plants (*Rose spp* L.)

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ABSTRACT

The effect of foliar applications of a kaolin clay particle film (Surround WP) on leaf temperature (T_{lf}), chlorophyll fluorescence (Fv/Fm), shoot length, production and water relations in well-irrigated and water-stressed rose cut plants (Rose spp) were studied during ten weeks. Plants were sprayed twice at first and fifth week after the experiment started with aqueous suspensions of Kaolin (Surround) at a dose of 5% (w/v). The interaction between Kaolin applications and water status did not showed significances. Water stress decreased the stomatal conductance (g_s), leaf water content (LWC), shoot length and the number of marketable floral stems. Kaolin sprays did not affect on SPAD readings, chlorophyll fluorescence, g_s, LWC and shoot length. Kaolin reduced leaf temperature by 2.5˚C approximately at midday compared to plants non-sprayed with kaolin. These results show that kaolin foliar applications could be considered an useful tool at early growth stage in improving rose plant acclimation to high temperatures levels under greenhouse conditions in tropical regions.

Keywords: *Surround WP, Leaf Water Content, Stomatal Conductance, Leaf Temperature, Shoot Length*

1. Introduction

Rose is one of the main ornamental plants in the world [1], being Colombia the first roses-producing country in Latin American and the second roses-exporting country in the world with a exportation of 59,499 tons of rose for cutflower during 2009 [2].

Temperatures are often higher than optimal in ornamental production systems. This situation may stress plants, causing a reduction of quality and/or yield of ornamental crops [3]. The high solar radiation and temperatures cause high rates of plant water loss and plants regularly show symptoms of burn or withering in leaves or fruits [4]. In Colombia, it is common find high temperatures (above 35˚C) in greenhouses during dry season (period of time without rains) or the Niño phenomenon [5]. High temperatures may reduce flower quality because of excessive plant transpiration and respiration [6]. On the other hand, low leaf water content causes negative effect on leaf area, CO_2 assimilation rate, stomatal conductance and yield in rose plants [7]. To diminish the negative influence of water and heat stress on plant physiology and productivity, particle film applications such as kaolin have been used [8]. Kaolin cools tissues and protects plants from extreme heat and ultraviolet radiation by increasing leaf reflectance and reducing transpiration rate [9,10].

Kaolin has been tested in different horticultural crops and its response has been heterogeneous [8]. Kaolin showed a reduction on leaf temperature in apple trees [11], and improved light-saturated CO_2 assimilation rate (A_{max}) and stomatal conductance (g_s) in citrus at midday [12]. However, kaolin has no effect on gas exchange parameters in pepper [13] and did not suffice to mitigate the adverse effects of heat and water stress on photosynthesis in almond and walnut [8], and enhanced water loss from fruit in tomato [9]. Combined studies on the influence of kaolin particle film applications and water stress have been limited in ornamental plants. Only, the literature stated studies performed by Moftah and Al-Humaid [14] that the kaolin sprays enhanced water status, water use efficiency (WUE) and the photosynthetic activity in an ornamental plant (*Polianthes tuberosa* L.) under water deficit. However, there are not studies that have evaluated the use of foliar applications of kaolin on ornamental plants established under water deficit conditions in tropical regions.

For that reason, the aim of the present work was to study and compare the influence of kaolin film particle applications and the water status on the stomatal conductance, chlorophyll fluorescence, chlorophyll content, shoot length, yield of marketable stems, leaf water content and leaf temperature in rose cut plants.

2. Materials and Method

This study was carried out at "Centro de Biotecnologia del SENA" in Mosquera, Colombia (latitude 4.7˚ N, longitude 74.2˚ W) for 10 weeks under greenhouse conditions. The greenhouse conditions during the experiment were the following: maximum temperature 35.5˚C, minimum temperature 10˚C, solar radiation 85.41 W/m^2, relative humidity between 50% - 90% and a photoperiod of 12 h, approximately. Four-year-old "Charlotte" rose plants grafted on "Natal Briar" were used. Two plants were cultivated into 8-l plastic pots containing rice husk (burnt at 65%) as substrate. The plants received routine horticultural care suitable for commercial production such as weed and pest control.

Treatments were established after shoot pinch. Rose plants were split into two groups (well-fertigated (W) and water-stressed (S) plants). Well-fertigated plants were watered daily with 850 ml of a nutrient solution which had the following composition in ppm: N 170, P 35, K 150, Ca 110, Mg 60, S 82, Mn 1, Zn 0.5, Cu 0.5, Fe 3, B 0.5 and Mo 0.1. This volume of irrigation is common used by rose's growers in Colombia [15]. Water-stressed plants were irrigated daily with the 50% of the nutrient solution's volume (475 ml), which also had the same nutritional concentration mentioned above. This water quantity was chosen as water stress treatment because growing is affected [7]. Additionally, water stressed plant received complementary fertilization in order to have plants with similar nutritional conditions. Then, plants in both water statuses were also separated into plants sprayed with kaolin and plants without kaolin. Kaolin foliar applications were performed at 6 and 30 days after shoot pinch (DAP). Foliar applications of kaolin (300 ml/plant) were carried out with an air blast sprayer, wetting the upper and lower surfaces. Foliar applications were performed at early morning at a rate of 5% (w/v) kaolin water suspension (Surround WP, Tessenderlo Kerley, US), with no adhesive or other compounds.

Leaf chlorophyll content and leaf temperature were measured at 15, 30, 45 and 60 DAP on a fully mature expanded leaf using a SPAD chlorophyll meter as a nondestructive tool for estimating leaf Chlorophyll (SPAD-502, Konica Minolta Sensing, Inc., Ramsey, NJ) and an infrared thermometer (MX2SL3U, Cole-Parmer Instrument Company, Vernon Hills, IL), respectively. Leaf temperature readings were carried out at mid-day. Leaf chlorophyll fluorescence was estimated at 60 DAP using a continuous excitation chlorophyll fluorescence analyzer (Handy PEA, Hansatech Instruments, Kings Lynn, UK) in order to evaluate the maximum efficiency of photosystem II (Fv/Fm). Previously, leaves were acclimated to the dark using lightweight leaf clips for at least half an hour before measurements were performed.

Stomatal conductance was measured on a fully expanded mature leaf from the midportion of canopy using a leaf-porometer (SC-1 Decagon Devices, Inc., Pullman, WA). This measurement was performed at 60 DAP between 0900 h and 1500 h.

Fully expanded mature leaves from the midportion of canopy were collected. Leaves were introduced into a cooler with ice to avoid dehydration and then taken to the laboratory where fresh weight (FW) and dry weight (DW) were determined. Leaf water content (LWC) was estimated by the equation: $LWC = 100 \times (FW - DW)/(FW)$. Soil water content (SWC) was also determined by a soil humidity probe (Kelway Soil tester, Kel instruments Co., Inc., Wyckoff, NJ). LWC and SWC were obtained at 15, 30, 45 and 60 DAP. Shoot length was estimated from eight stems per pot and recorded every week starting 15 DAP until harvest. The portion of light intercepted by the canopy was calculated using the technique described by Naab *et al*. [16] at 60 DAP. Leaf area index (LAI) was calculated at the end of experiment by a ceptometer (Accupar LP-80, Decagon Devices, Inc., Pullman, WA). Marketable floral stems were counted at harvesting time. A floral stem was considered marketable when its length was higher than 50 cm.

A factorial experiment with two factors, Kaolin sprays (Kaolin versus without kaolin) and plant water status (well-irrigated versus water-stressed) with four blocks, was established in the above-mentioned greenhouse. The experimental unit was composed of six plastic pots. Analyses of variance were performed on the data to compare the effect of the treatments. All percentage values were transformed using the arcsine transformation before analysis. Where a significant F-test was observed, mean separation between treatments was obtained by Tukey's test. Data were analyzed using Statistix Version 8.0 (Analytical Software, Tallahassee, FL, US).

3. Results and Discussion

Significant interactions were not found between plant water status and kaolin. Nevertheless, significant differences were observed when each factor was analyzed separately (**Table 1**). SWC and LWC were affected by water treatments. Water-stressed plants showed a lower SWC (51.04%) and LWC (74.58%) than well-irrigated plants during 10 weeks, indicating that a group of plants were under water stress conditions for the duration of the experiment. Also, water-stressed plants had a lower stomatal conductance (g_s) than well-irrigated plants. Moftah and Al-Humaid [14] also observed that the g_s of Kaolin-sprayed plants under water stress conditions (plants irrigated with 60% of water added to control well-irrigated treatments) did not reach the values obtained in control plants in ornamental plants such as *Polianthes tuberosa* L. However, some authors stated that kaolin can enhance water use efficiency (WUE) under moderate water stress conditions [10,12,14] in spite of low g_s.

No differences were observed by irrigation regime on leaf temperature, chlorophyll fluorescence, and SPAD readings in rose cut plants. Regarding the kaolin-based particle film, significance differences were only observed on leaf temperature. Plants treated with foliar sprays showed a lower leaf temperature than non-sprayed plants. Plants sprayed with kaolin showed a difference approximately of 2.5˚C on leaf temperature at mid-day compared to plants without particle film applications. Our results confirm the stated by Glenn *et al*. [17], who reported that Kaolin reduces leaf temperature by increasing leaf reflectance. Similar results were observed by [11,12], who observed that foliar applications of kaolin reduced leaf temperature at midday ($T_{lf} \approx 3$˚C) in grapefruits and apple leaves, respectively. On the other hand, the interaction kaolin and irrigation regime did not show differences on LAI, shoot length, the portion of light intercepted and the number of marketable stems (**Table 2**). Differences were only found on the number of marketable stems and shoot length under deficit irrigation. Well-irrigated plants had a greater shoot length and marketable stems than water-stressed plants. Raviv and Bloom [7] reported that a low soil water content reduced shoot length in rose cut plants, since water stress caused stomatal closure, thereby reducing the plant's turgidity, which diminish expansive growth.

Table 1. Effect of kaolin film particle applications and water deficit on leaf temperature, chlorophyll fluorescence, SPAD, stomatal conductance, soil water content and leaf water content in "Charlotte" rose plants grafted on "Natal Briar".

	Leaf temperature[a] (˚C)	Chlorophyll fluorescence (Fv/Fm)	SPAD[a]	Stomatal conductance (mmol CO_2 $m^{-2}\cdot s^{-1}$)	Soil water content[a] (%)	Leaf water content[a] (%)
Stress						
Well-watered	20.26	0.83	49.2	172.43 a[b]	61.04 a	76.56 a
Water-stressed	19.18	0.82	47.4	147.25 b	51.04 b	70.58 b
Significance[c]	NS	NS	NS	***	***	**
Kaolin						
No kaolin	21.19 a	0.83	49.0	157.45	55.62	75.43
With kaolin	18.87 b	0.81	47.6	160.25	56.45	75.71
Significance	***	NS	NS	NS	NS	NS
Stress × Kaolin[d]	NS	NS	NS	NS	NS	NS
CV (%)[e]	5.11	4.79	11.54	27.34	13.42	2.87

[a]Values are the average of samples done at 15, 30, 45 and 60 DAP; [b]Within a column and factor followed by different letters are significantly different at $P \leq 0.05$ by Tukey's test; [c]NS, **, ***, Non-significant or significant at $P \leq 0.01$ or $P \leq 0.001$, respectively; [d]Interaction between Kaolin sprays and irrigation regime. NS means non-significant; [e]Coefficient of variation.

Table 2. Effect of kaolin film particle applications and water deficit on shoot length, leaf area index, portion of light intercepted and number of marketable stems in "Charlotte" rose plants grafted on "Natal Briar".

	Shoot length (cm)	Leaf area index (LAI)	Portion of light intercepted (%)	Yield (number of marketable stems)
Stress				
Well-watered	75.41 a[a]	3.06	89	58.9 a
Water-stressed	58.18 b	2.44	88	35.9 b
Significance[b]	**	NS	NS	***
Kaolin				
No kaolin	70.89	2.58	88	48.8
With kaolin	62.71	2.92	88	46.0
Significance	NS	NS	NS	NS
Stress × Kaolin[c]	NS	NS	NS	NS
CV (%)[d]	20.83	17.89	2.70	20.40

[a]Within a column and factor followed by different letters are significantly different at $P \leq 0.05$ by Tukey's test; [b]NS, **, ***, Non-significant or Significant at $P \leq 0.01$ or $P \leq 0.001$, respectively; [c]Interaction between kaolin sprays and irrigation regime. NS means non-significant; [d]Coefficient of variation.

4. Conclusions

In summary, water stress has a negative influence on stomatal conductance, shoot length, and yield quality of a valuable ornamental plant such as rose cut plants, which is an important issue to consider in greenhouse conditions in tropical areas. Application of particle film tended to reduce leaf temperature at midday because of kaolin's ability to reflect most of the radiant energy fall ing on leaf surfaces. From these data, kaolin sprays could be considered as a tool to be used in tropical regions to improve the plant acclimation to high temperature and high radiation levels at early stages of shoot growth in rose cut plants. However, more studies are necessary to estimate the phenological optimal stage and dose of kaolin film particle applications in order to not affect the visual appearance of the stem flower.

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