

Influence of Water Regimes and Potassium Chlorate on Floral Induction, Leaf Photosynthesis and Leaf Water Potential in Longan

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Abstract

This study verifies the influence of water regimes and potassium chlorate (KClO₃) on photosynthetic rate, flower emergence and media moisture content of longan trees. The trees were grown in 150 liters lysimeter tanks filled with fine sand. The experimental design was a 2x2 factorial in completely randomized design (CRD) with 2 factors; 1) two levels of water regimes (well-watered and water deficit) and 2) two levels of KClO₃ at 10 and 0 g. The results revealed that the well-watered treatment produced faster days of terminal bud break than that of the water deficit treatment. The 10 g KClO₃ treatment induced 91 % flower emergence at 35 days after commencing the treatment, while the 0 g KClO₃ treatment had 82 % leaf flushing and had no flower emergence. Water deficit or KClO₃ treatments reduced the net carbondioxide (CO₂) exchange, transpiration and stomatal conductance rates. Moreover, the combination of well-watered and 0 g KClO₃ treatments gave the greatest values of the parameters. The well-watered treatment had higher volumetric water content in the growing medium and leaf water potential than the water deficit treatment, while for the 10 g and 0 g KClO₃ treatments had similar the media moisture content.

Keywords: potassium chlorate, water deficit, the net CO₂ exchange rate

1. Introduction

Longan (*Dimocarpus longan* Lour.) is one of the most popular fruit crops of northern Thailand. Longan flowers from late December to late February and is harvested from late June to August. At the present, the main region of longan cultivation is in the upper northern part of the country, such as 'Daw', 'Haeo', 'Bieo Khieo' and 'Si Chomphu'. Floral induction is an important step of flowering and fruiting. Due to the fact that the soil moisture levels and levels of KClO₃ used vary from place to place, induction of flowering at certain times is necessary in longan production. There are many factors that control flowering in longan, such as temperature, tree health, cultivar, water stress and potassium chlorate. (Subhadrabandhu, 1990; Manochai et al., 2004; Davenport & Stern, 2005; Sritontip et al., 2005).

Water constitutes a major part of the tissue mass and is required for growth and development. Plant water status is a good indicator of plant health and how well adapted the plant is to its environment. Plant water status can provide information on potential crop yield or be used for irrigation strategy. The water potential of a plant governs transport across cell membranes. Water potential can be used to evaluate the water status of a plant and provides a relative index of water stress. Technological advancements have increased the relative ease and number of variations to measure water potential in plant or plant leaves. Water is the most important factor among the environmental factors affecting growth; it may reduce the growth rate, metabolic activities and leaf area

(Metheney et al., 1994). Soil water content should be correlated with physiological responses; growth and fruit production in fruit crops, to determine the appropriate amount of water to apply to the crop. Irrigation intervals and water supply for the vegetative growth reduction have counter relationships (Blum, 1996). However, a few studies have indicated that water limitation can have economically beneficial consequences on fruit production (Caspari et al., 1994; Chalmers et al., 1981; Shackel et al., 2000). In Asian pear, water stress reduces vegetative growth but increases return bloom and decreases flesh to dry weight ratio (Caspari et al., 1994; Shackel et al., 2000). A water deficit condition reduces plant growth and affects photosynthesis and that, in turn, reduces leaf area, enhances stomata closure, decreases water status in the leaf tissue, reduces the rate of CO_2 assimilated, causes ultra structural changes in chloroplasts, affects electron transport and CO_2 assimilation reaction and alters the level of photosynthesis in tissues (Dubey, 1997; Fitter, 1987). In 1998, Thai longan growers have begun to apply potassium chlorate (KClO_3) to induce off-season flowering, the methods applied potassium chlorate by soil drench, foliar spray and stem injection (Sritontip et al., 2005; Davenport & Stern, 2005; Manochai et al., 2005). However, the Chlorate group chemical is a strong oxidizing agent and considered phytotoxic to all the green parts of plant cell (Stecher et al., 1960; Thomson, 1993). The KClO_3 is dissociated into potassium ion (K^+) and chlorate ion (ClO_3^-) when dissolves in water. Chlorate or chlorine is chemically analog of nitrate (NO_3^-) and used widely as a herbicide. The reduction products, chlorite (ClO_2^-) and hypochlorite (ClO^-) have been shown to be rapidly acting toxins that poisoned all cell types. Root growth is severely inhibited and leaf is yellow, withered and die (LaBrie et al., 1991). It was previously shown that the low temperature and KClO_3 applications decreased leaf photosynthesis in longan tree (Sritontip et al., 2010). Although, KClO_3 has been extensively used to promote flowering in longan production, the mode of action and mechanism of flower induction is not yet clear. However, the effect of water deficit and/or KClO_3 on flower induction of longan is still lacking. Thus, this research studies what effects water deficit and (KClO_3) applications have on leaf photosynthesis change and flower induction in longan.

2. Method

2.1 Plant Material and Lysimeter Tank Facility

The sixteen of two-years-old air layered longan trees cv. Daw were grown in lysimeters with a capacity of 150 liters consisting of special containers filled with sand and connected by a tube to a 30 liter plastic container with nutrient solution as indicated in Figure 1.

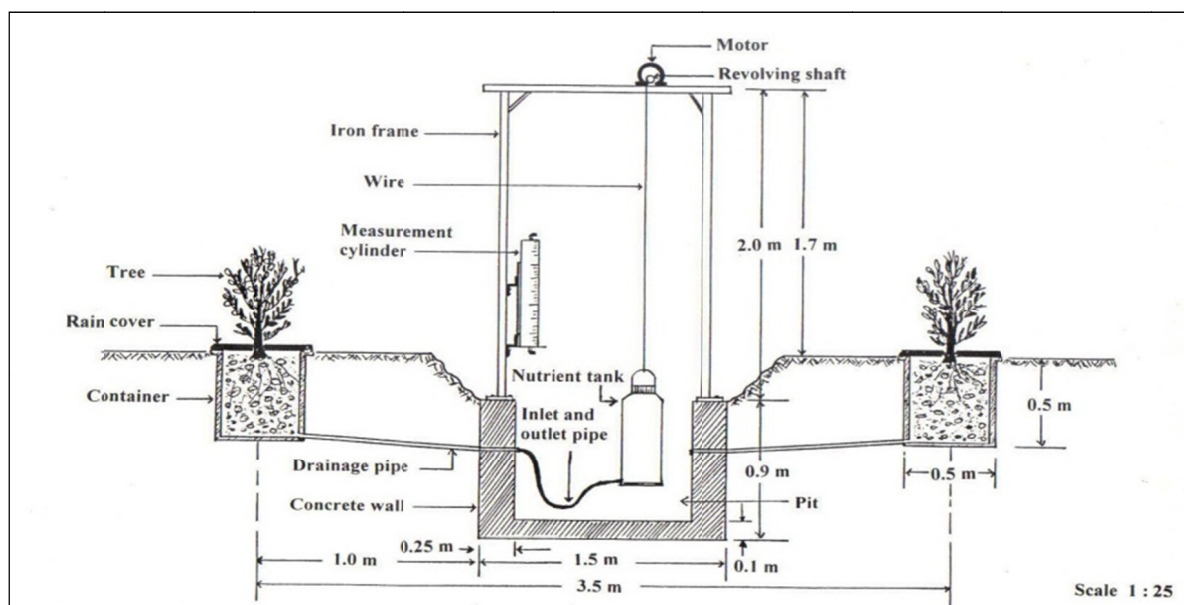


Figure 1. Schematic cross-section diagram of the lysimeter facility

A lysimeter facility was built at the Agricultural Technology Research Institute, Rajamagala University of Technology Lanna, Lampang in 1999 to study the water relationships of fruit crops. For precise measurement of water use by fruit crops in a lysimeter the soil-water status can be controlled more accurately than in the field. The ion concentration of the applied nutrient solution is indicated in Tab 1.

Table 1. Composition of the standard nutrient solution* used for longan trees growing in lysimeters

Cations	meq/l	Anion	meq/l
Ca ²⁺	7.0	NO ₃ ⁻	7.0
K ⁺	4.0	PO ₄ ⁻	3.0
Mg ²⁺	4.0	SO ₄ ⁻	8.0
NH ₄ ⁺	1.0		
H ⁺	2.0		
Total	18.0	Total	18.0

*Micronutrients were added according to [11], the nutrient solution pH was adjusted weekly to 6.5 by addition of H₂SO₄.

2.2 Experiment Treatment

The experimental design was a 2x2 factorial in completely randomized design (CRD) with 4 replications, total of 16 longan tree pots, with water regimes of well-watered (WW) or water deficit (WD) and KClO₃ at 10 and 0 g. pot⁻¹. The WW treated plants were supplied daily with a constant volume of water of 30 liters throughout the experimental period. The WD treated plants received a starting amount of water of 15 liters (in the 30-liter capacity container) and were supplied daily until the water container was empty. Then, the container was refilled to the starting volume of 15 liters. The nutrient solution was replaced every 15 day. The longan trees at the fully mature leaf stage were treated with 10 g pot⁻¹ KClO₃ mixed into the nutrient solution containers. The study was conducted in the lysimeters at the Agricultural Technology Research Institute, Rajamangala University of Technology Lanna, Lampang, Thailand from November 1, 2008 to January 31, 2009.

2.3 Data Collection

1. Percentage of flowering, the sixteenth longan trees were sampled for data. These data were the percentage and days to visible active buds. The data collection lasted 49 days after treatment.
2. Leaf photosynthesis and chlorophyll fluorescence were measured immediately after KClO₃ application and then monitored at 1, 4, 7, 10, 13, 17, 21, 28 and 35 days after KClO₃ application (4 leaves per tree were sampled). The measurements were made on the 3rd or 4th leaf position of the fully expanded mature compound leaves at 09.00 to 10.00 a.m. Chlorophyll fluorescence (F_v/F_m) was measured at the leaf using a plant efficiency analyzer (Model PEA, Hansatech Instruments, UK.). On the same leaf, net CO₂ exchange, transpiration, and stomatal conductance rates were measured using a portable steady-state leaf photosynthesis system at an irradiance of 1,200 $\mu\text{mol m}^{-2}\text{s}^{-1}$ PAR (Model LCA-4 with the PLC-4 leaf chamber; Analytical Development Company Ltd. (ADC), UK).
3. The moisture content in each growing media was measured with a moisture meter (Type HH2, Delta-T Devices Ltd., UK) and profile probe (Type PR2-UM-2.0, Delta-T Devices Ltd., UK) at 1, 4, 7, 10, 13, 17, 21, 28 and 35 days after KClO₃ application.
4. Longan trees were measured for leaf water potential by a pressure bomb (Plant Water Status Console-Model 3005, Soilmoisture Equipment Corp, USA)) at 1, 4, 7, 10, 13, 17, 21, 28 and 35 days after KClO₃ application.

2.4 Data Analysis

The data was analyzed for statistical significance by using the Statistic 8 analytical software package (SXW Tallahassee, FL). The Least Significant Difference (LSD) was used to compare treatment differences with ANOVA ($P < 0.05$).

3. Results

3.1 The Effects of Water Regimes and KClO₃ on the Physiology of the Trees

The longan trees that were treated with well watered produced terminal bud break significantly earlier than that of water deficit. Different water regimes had no differences on percentage of floral emergence or leaf flushing measurements after commencement of treatment. Those treated with 10 g KClO₃ had greater floral emergence and lower leaf flushing. However, the 10 g and 0 g KClO₃ were similar in the days of terminal bud break. There was no interaction between the water regimes and KClO₃ treatments on days of terminal bud break, percentage of flower emergence or leaf flushing after treatment (Table 2).

Table 2. Changes in terminal bud break, floral emergence and leaf flushing after start of the treatments

Factors	Days of terminal bud break	Percentage of floral emergence after treatment	Percentage of leaf flushing after treatment
Water (A)			
WW	26 b	47.82	45.89
WD	35 a	43.34	44.95
KClO₃ (B)			
10 g	32	91.00 a	8.84 b
0 g.	29	0 b	82.00 a
A	*	NS	NS
B	NS	*	*
A x B	NS	NS	NS

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

3.2 Changes in the Leaf Photosynthesis Characteristics Caused by Water Regimes and KClO₃

The water deficit longan trees had efficiency of photosystem II lower at 7, 10, and 28 days after commencement treatment. Moreover, the 10 g KClO₃ reduced the efficiency of photosystem II at 4, 7, 10 and 28 days after application (Table 3). The interaction effect showed that the well water with 0 g KClO₃ had the highest value for the efficiency of photosystem II (Table 4).

Table 3. Chlorophyll fluorescence (Fv/Fm) changes of 'Daw' longan trees after KClO₃ and water regime treatments

Factors	Time after application (days)								
	1	4	7	10	13	17	21	28	35
Water (A)									
WW	0.69	0.70	0.70 a	0.68 a	0.63	0.69	0.69	0.65 a	0.62
WD	0.66	0.66	0.61 b	0.58 b	0.59	0.63	0.64	0.56 b	0.54
KClO₃ (B)									
10 g	0.66	0.64 b	0.61 b	0.59 b	0.58	0.64	0.64	0.56 b	0.55
0 g.	0.69	0.72 a	0.70 a	0.67 a	0.64	0.68	0.69	0.64 a	0.61
A	NS	NS	*	*	NS	NS	NS	*	*
B	NS	*	*	*	NS	NS	NS	*	NS
A x B	NS	NS	*	*	NS	*	*	*	*

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

Table 4. Interaction effect of KClO₃ and water regime on chlorophyll fluorescence (Fv/Fm) of 'Daw' longan trees after treatment

Treatments	Time after application (days)								
	1	4	7	10	13	17	21	28	35
WW+ KClO ₃	0.66	0.66	0.64 ab	0.62 b	0.60	0.65 ab	0.68 ab	0.60 b	0.60 ab
WW-KClO ₃	0.71	0.75	0.76 a	0.74 a	0.66	0.72 a	0.71 a	0.69a	0.65 a
WD+ KClO ₃	0.65	0.62	0.57 b	0.55 b	0.56	0.62 b	0.61 b	0.52 b	0.51 b
WD- KClO ₃	0.67	0.69	0.65 ab	0.60 b	0.62	0.64 ab	0.67 ab	0.59 b	0.57 a
F-test	NS	NS	*	*	NS	*	*	*	*

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

The water deficit treatments decreased the net CO₂ exchange rate during 1 to 35 days after treatment and the 10 g KClO₃ had a net CO₂ exchange rate that was lower than the 0 g KClO₃ at 4, 7, 10, 13, and 21 days after treatment (Table 5). The interaction effect between water regimes and KClO₃ rates showed that the well water with 0 g KClO₃ had the greatest effect on the net CO₂ exchange rate of those treatments (Table 6).

Table 5. Effects of water regimes and KClO₃ rates on the net CO₂ exchange rate ($\mu\text{mol M}^{-2}\text{S}^{-1}$) after treatment

Factors	Time after application (days)								
	1	4	7	10	13	17	21	28	35
Water (A)									
WW	5.58 a	3.95 a	3.90 a	5.12 a	4.75	7.36 a	5.61 a	4.12 a	4.84 a
WD	2.99 b	2.62 b	2.05 b	2.68 b	1.91	3.71 b	3.96 b	2.80 b	3.08 b
KClO ₃ (B)									
10 g	3.87	2.17 b	1.89 b	2.20 b	2.26 b	4.32	3.82 b	3.06	3.67
0 g.	4.70	4.40 a	4.07 a	5.60 a	4.41 a	6.75	5.75 a	3.85	4.25
A	*	*	*	*	*	*	*	*	*
B	NS	*	*	*	*	NS	*	NS	NS
A x B	NS	*	*	*	*	*	NS	NS	NS

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

Table 6. Interaction effect of water regimes and KClO₃ rates on the net CO₂ exchange rate ($\mu\text{mol M}^{-2}\text{S}^{-1}$) after treatment

Treatments	Time after application (days)								
	1	4	7	10	13	17	21	28	35
WW + KClO ₃	4.81	2.10 b	2.43 b	3.06 b	3.90 b	5.63 ab	4.40	3.83	4.40
WW - KClO ₃	6.34	5.80 a	5.38 a	7.18 a	5.60 a	9.08 a	6.82	4.40	5.28
WD + KClO ₃	2.94	2.24 b	1.36 c	1.34 b	0.62 c	3.00 b	3.25	2.30	2.94
WD - KClO ₃	3.05	3.00 b	2.75 b	4.01 b	3.21 b	4.41 b	4.68	3.30	3.23
F-test	NS	*	*	*	*	*	NS	NS	NS

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

For changes in transpiration rate, the water deficit had lower transpiration rate than the well-watered at 7 and 10 days after treatment and the 10 g KClO₃ treatment depressed the transpiration rate at 4-17 days after treatment (Table 7). The interaction effect between water regimes and KClO₃ resulted that the well-watered with 10 g KClO₃, the water deficit with 10 g KClO₃ and water deficit with 0 g KClO₃ treatments decreased the transpiration rate when compared with the well-watered with 0 g KClO₃ treatment (Table 8).

Table 7. Effects of water regimes and KClO₃ rates on the transpiration rate ($\text{m mol M}^{-2}\text{S}^{-1}$) after treatment

Factors	Time after application (days)								
	1	4	7	10	13	17	21	28	35
Water (A)									
WW	1.09	1.08	0.78 a	1.24 a	1.07	0.97	0.98	0.86	1.04
WD	0.95	0.82	0.43 b	0.90 b	0.97	0.82	0.99	0.63	0.95
KClO ₃ (B)									
10 g	0.92	0.79 b	0.47 b	0.75 b	0.84 b	0.65 b	0.90	0.66	0.93
0 g.	1.10	1.08 a	0.72 a	1.33 a	1.16 a	1.08 a	1.05	0.82	1.04
A	NS	NS	*	*	NS	NS	NS	NS	NS
B	NS	*	*	*	*	*	NS	NS	NS
A x B	NS	NS	*	*	*	*	NS	*	NS

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

Table 8. Interaction effect of water regimes and KClO_3 rates on the transpiration rate ($\text{m mol M}^{-2} \text{ S}^{-1}$) after treatment

Treatments	Time after application (days)								
	1	4	7	10	13	17	21	28	35
WW + KClO_3	1.02	0.90	0.54 b	0.81 ab	0.89 b	0.72 b	0.88	0.62 b	0.94
WW - KClO_3	1.17	1.26	1.02 a	1.67 a	1.26 a	1.22 a	1.08	1.10 a	1.15
WD + KClO_3	0.82	0.67	0.39 b	0.68 c	0.79 b	0.59 b	0.93	0.70 b	0.93
WD - KClO_3	1.09	0.97	0.48 b	1.12 ab	1.14 ab	1.04 a	1.06	0.57 b	0.97
F-test	NS	NS	*	*	*	*	NS	*	NS

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

The water deficit reduced the stomatal conductance at 7, 13, 17 and 28 days after treatment. A similar result was obtained with the 10 g KClO_3 where the stomatal conductance declined at 4, 7, 10, 13, 17 and 28 days after treatment (Table 9). The interaction effect between water regimes and KClO_3 rates showed that the well-watered with 0 g KClO_3 treatment had the greatest stomatal conductance after the beginning of the experiment (Table 10).

Table 9. Effects of water regimes and KClO_3 rates on the stomatal conductance rate ($\text{mol M}^{-2} \text{ S}^{-1}$) after treatment

Factors	Time after application (days)								
	1	4	7	10	13	17	21	28	35
Water (A)									
WW	0.06	0.04	0.05 a	0.05 a	0.05 a	0.05	0.06	0.03 a	0.05
WD	0.04	0.03	0.02 b	0.03 b	0.04 b	0.04	0.06	0.02 b	0.05
KClO_3 (B)									
10 g	0.04	0.02 b	0.02 b	0.03 b	0.03 b	0.04 b	0.05	0.02 b	0.05
0 g.	0.06	0.04 a	0.04 a	0.05 a	0.05 a	0.06 a	0.06	0.03 a	0.05
A	NS	NS	*	*	*	NS	NS	*	NS
B	NS	*	*	*	*	*	NS	*	NS
A x B	NS	NS	*	*	*	*	NS	*	NS

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

Table 10. Interaction effect of water regimes and KClO_3 rates and on the stomatal conductance rate ($\text{mol M}^{-2} \text{ S}^{-1}$) after treatment

Treatments	Time after application (days)								
	1	4	7	10	13	17	21	28	35
WW + KClO_3	0.03	0.03 b	0.03 b	0.03 b	0.03 b	0.04 bc	0.05	0.02 b	0.05
WW - KClO_3	0.05	0.07 a	0.07 a	0.07 a	0.07 a	0.07 a	0.06	0.04 a	0.06
WD + KClO_3	0.02	0.02 b	0.02 b	0.02 b	0.03 b	0.03 c	0.05	0.02 b	0.05
WD - KClO_3	0.03	0.03 b	0.04 b	0.04 b	0.04 b	0.06 ab	0.06	0.02 b	0.05
F-test	NS	*	*	*	*	*	NS	*	NS

*Means within the column followed by the same letter were not significantly different at $p=0.05$ by LSD. NS = Non-significant.

3.3 Changes of Volumetric Water Content and Leaf Water Potential

The volumetric water content in the growing media after treatment showed that the water deficit reduced the moisture value while there was no effect between 10 g and 0 g KClO₃ treatment. In addition, there was no interaction among all the treatments (Table 11).

The leaf water potential after the start of a treatment showed that the well-watered had higher leaf water potential than that of water deficit at 10 to 35 days after treatment while there was no effect on that from 10 g and 0 g KClO₃. However, there was no interaction effect among treatments (Table 12).

Table 11. Effects of KClO₃ and water regime on the volumetric water content of growing medium after treatments

Factors	Volumetric water content (%)								
	1	4	7	10	13	17	21	28	35
Water (A)									
WW	10.76 a	9.80 a	10.41 a	10.30 a	10.53 a	10.28 a	10.08 a	10.00 a	9.93 a
WD	6.81 b	5.83 b	5.46 b	5.09 b	4.96 b	4.39 b	4.11 b	4.70 b	4.44 b
KClO₃ (B)									
10 g	8.70	7.81	7.69	7.20	7.36	6.75	6.38	6.73	6.53
0 g.	8.88	7.81	8.19	8.19	8.13	7.91	7.81	7.98	7.84
A	*	*	*	*	*	*	*	*	*
B	NS	NS	NS	NS	NS	NS	NS	NS	NS
A x B	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Means within the column followed by the same letter were not significantly different at p=0.05 by LSD. NS = Non-significant.

Table 12. Effects of KClO₃ and water regime on the leaf water potential of longan trees after treatment

Factors	Leaf water potential (MPa)								
	1	4	7	10	13	17	21	28	35
Water (A)									
WW	-1.22	-1.28	-1.25	-1.04 a	-1.02 a	-1.02 a	-0.95a	-1.01 a	-0.92 a
WD	-1.35	-1.46	-1.50	-1.93 b	-2.21 b	-2.20 b	-2.35 b	-2.26 b	-2.28 b
KClO₃ (B)									
10 g	-1.38	-1.38	-1.41	-1.52	-1.65	-1.75	-1.81	-1.77	-1.74
0 g.	-1.23	-1.35	-1.33	-1.45	-1.58	-1.47	-1.49	-1.50	-1.46
A	NS	NS	NS	*	*	*	*	*	*
B	NS	NS	NS	NS	NS	NS	NS	NS	NS
A x B	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Means within the column followed by the same letter were not significantly different at p=0.05 by LSD. NS = Non-significant.

4. Discussion

The full irrigation had faster the days of terminal bud break about 9 days. The well-watered and water deficit treatments gave approximately 43.34-47.82% of all buds flowered and 44.95-45.89% of leaf flushing. The reduction of the water amount had effect on time of terminal bud brake due to water deficiency was a factor that usually causes the limitation of growth and metabolic activity rates of the plant (Boland et al., 1993). Borchert (1994) reported that water deficit inhibited bud break and shoot growth in tropical tree. In the present study, the 91% of all buds flowered at 25–27 days after the application of KClO₃. The off-season flowering in longan trees

was induced by KClO_3 (Sritontip et al., 2005; Hegele et al., 2008; Davenport & Stern, 2005; Manochai et al., 2005). The KClO_3 application induced floral emergence and reduced leaf flushing, whereas the treatments without KClO_3 application did not induce flowering. The efficiency of photosystem II (Fv/Fm), leaf net CO_2 assimilation, transpiration and stomatal conductance rates were reduced in water deficit and KClO_3 application, except for the application of combination of full irrigation and without KClO_3 treatments. In longan trees treated with water deficit, KClO_3 , and a combination of water deficit and KClO_3 leaf photosynthesis decreased because water deficit caused closure of the stomata and reduced CO_2 assimilation and stem extension, leaf expansion, and fruit growth (Flore & Lakso, 1989; Menzel, 2005). The high photosynthesis rate indicated the optimal irrigation management for longan and low value was led to drought stress. The photosynthetic rate of apricot trees daily irrigated to 25% of field capacity was lowered by 55% compared to control trees (100% field capacity), while a 75% reduction in photosynthesis was observed in the rest of water deficit stressed treatments (Ruiz-Sanchez et al., 2000). Diurnal changes in leaf gas exchange in well-water and drought were studied in Tai So litchi trees. Stomata conductance and net CO_2 assimilation reached maximum values at 0700-0800 h, and were lower in drought trees than in the controls for most of the day (Menzel & Simpson, 1994; Menzel, 2005). Water stress decreased the net CO_2 assimilate in papaya (Marler et al., 1994). Induced reduction in net CO_2 assimilated and stomata conductance were also observed in Valencia orange trees (Syvertsen & Lloyd, 1994). In Kensington mango trees effective stomatal closure was reached at -1.2 and -3.0 MPa (Schaffer et al., 1994; Pongsomboon, 1991). The water deficit had a lower leaf water potential in longan trees at 10 days after treatment due to decreasing of moisture content in growing media. The reduction of leaf water potential decreased leaf photosynthesis characteristics in longan tree because water deficit led to decreasing turgor pressure (Akinci & Lösel, 2012). Moreover, Drought conditions are usually associated with a decrease in plant productivity and the course of growth leads to the increase of abscisic acid (ABA) and decrease of indole-3-acetic acid (IAA) and cytokinins (CKs), which may result in the early stoppage of branch growth in comparison with its natural trend (Bradford & Hsiao, 1982; Ferguson et al., 1992).

The treatment with KClO_3 induced the longan flowering process and could be used for off-season longan production. The mechanism of how KClO_3 induces the flowering process in longan is not entirely understood. Some researches claimed that in plants, the chlorate (ClO_3^-) ion competitively inhibited the nitrate reductase enzyme and is reduced to chlorite (ClO_2^-) and hypochlorite (ClO^-) (Duke, 1985; King, 1974). Furthermore, the reduction products chlorite (ClO_2^-) and hypochlorite (ClO^-) were shown to be rapidly acting toxins that poisoned all plant cell types (Aberg, 1947). It was previously shown that KClO_3 application also decreased chlorophyll fluorescence and leaf gas exchange (Sritontip et al., 2010), the leaf photosynthesis considerably decreased up to 6 days after KClO_3 application and remained rather low compared to the control up to 11 days (Hegele et al., 2008), consequently, the detrimental effects of KClO_3 on the plant's photosynthetic system could be caused by the phytotoxic effect of ClO_2^- and ClO^- . Thus, water deficit and KClO_3 treatments seemed to be the inhibiting factors of the photosynthetic efficiency.

Floral initiation in longan is dependent on cool temperature and some chemicals treatment. However, the leaf photosynthesis was reduced during flower induction stage by low temperature and KClO_3 , whereas the longan trees can induce flowering after treatments, which probably account for the depression in leaf photosynthesis rate reposed during the floral initiation in subtropical tree species (Sritontip et al., 2010; Hegele et al., 2008). There is considerable evidence for the regulatory role of plant hormones controlling floral induction, particularly in perennial fruit trees. It has been reported for trees that an increase of CKs stimulates flower induction, while high levels of gibberellic acids (GAs) and IAA result in inhibition (Bangerth, 2009). Furthermore, it was found that CKs concentrations in terminal buds of longan increased, whereas IAA concentrations reduced during the first fourteen days after KClO_3 application and GAs also decreased at twenty days after treatment (Hegele et al., 2008).

Although, water deficit and KClO_3 decreased leaf photosynthesis, water deficit treatment reduced media volumetric water content and leaf water potential, while both KClO_3 concentrations did not significantly affect these parameters.

5. Conclusion

The water deficit delayed time of terminal bud break by 9 days, while, the full irrigation and water deficit treatments gave similar flowering and leaf flushing percentages. Whereas, the longan trees in treatments without KClO_3 application did not have floral emergence. The efficiency of photosystem II (Fv/Fm), leaf net CO_2 assimilation and transpiration rates, and stomata conductance were reduced in water deficit and with KClO_3 treatments. The volumetric water content and leaf water potential declined with the water deficit treatment, while there was no difference between 10 g and 0 g KClO_3 .

Although water deficit impacted on the efficiency of photosystem II (Fv/Fm), leaf net CO₂ assimilation and transpiration rates, and stomata conductance; it did not affect off-season flower induction by KClO₃. Therefore off-season production during dry season or under controlled deficit irrigation seems to be feasible, at least, in terms of how effective KClO₃ is as a flower inducing agent. Irrigation management during further fruit development still requires detailed investigation in order to optimize yield and quality of off-season longan fruit.

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