EFFECTS OF DRENCHED-APPLIED PACLOBUTRAZOL AND POTASSIUM NITRATE ON THE LEAF AREA AND PHYSIOLOGICAL RESPONSE OF *XANTHOSTEMON CHRYSANTHUS* (F. MUELL.) BENTH.

Ahmad Nazarudin, M.R.
Tsan, F.Y.

ABSTRACT

A study was conducted to determine the effects of paclobutrazol (PBZ) and potassium nitrate (KNO_3) on the leaf area and physiological response in Xanthostemon chrysanthus (F. Muell.) Benth., planted in an urban area. A field trial was carried out at Metropolitan Batu Recreational Park, Kuala Lumpur. Nine treatments i.e. T1(0 gl^{-1} PBZ + 0 g KNO_3), T2(0 gl^{-1} PBZ + 100 g KNO_3), T3(0 gl^{-1} PBZ + 200 g KNO_3), T4(0.125 gl^{-1} PBZ + 0 g KNO_3), T5(0.125 gl^{-1} PBZ + 100 g KNO_3), T6(0.125 gl^{-1} PBZ + 200 g KNO_3), T7(0.25 gl^{-1} PBZ + 0 g KNO_3), T8(0.25 gl^{-1} PBZ + 100 g KNO_3) and T9(0.25 gl^{-1} PBZ + 200 g KNO_3) with nine replicates were arranged in a Completely Randomized Design. Monthly, leaf area was measured, while the changes in photosynthetic rate, transpiration rate and stomatal conductance were recorded at sixth and twelfth month after the treatments. Reduced leaf area due to inhibition effect of PBZ was observed. Photosynthetic rate, transpiration rate and stomatal conductance were also decreased with the existence of PBZ. Reduced stomatal conductance might be helpful in controlling water lost from the leaves of the treated trees and beneficial for trees grown in a harsh urban environment.

Keyword: Plant growth regulator, ornamental tree, urban forestry, environmental stress

Introduction

Physiological dysfunctions in plants are often occurring as a response to abiotic interferences. Although plants are able to adapt to their environment accordingly, plant death due to physiological dysfunctions is a result of severe exposure to extreme environmental stress (Kozlowski *et al.,* 1991). Soil compaction, air and soil pollutants (oxides of S and N, SO_2, polychlorinated biphenyls), heavy metals (Zn, Cu, Cd), atmospheric particulates, ozone, drought or water logging, retard tree growth through reduced translocation of photosynthates to roots, impaired stomatal function, premature leaf senescence, clogged lenticels, branch dieback, stem or trunk lesions, leaf scorch and eventual tree death (Percival *et al.,* 2006). Urban area is often associated with compact and infertile soil, lack of nutrients and exposure to heat stress, resulting in poor growth quality of plants (Lorenz and Lal, 2009; Pickett and Cadenasso, 2009; Rahman *et al.,* 2011; Weltecke and Gaertig, 2012). Previous study showed that urban soil within Kuala Lumpur had unpredictable substances which contained more than 65% of sand, insufficient nutrients and water, and high penetration resistance (Ahmad Nazarudin *et al.,* 2014a). Soil containing great amount of sand has high permeability which affects the growth performance of plants.

Plant growth regulators (PGRs) have been widely used in many aspects of plant growth and development. This triazole is used for controlling excessive growth, improving flower and increasing drought and salinity tolerance of various plant species. One of the most effective PGRs is paclobutrazol (PBZ), [(2RS, 3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1H-1,2,4-triazol-1-yl) pentan-3-ol]. PBZ has growth-regulating effects on plant such as inhibition of gibberellins (GAs) biosynthesis, reduction of cell elongation, stimulation of rooting, increment of chlorophyll content, and amelioration of phytohormone such as abscisic acid (ABA) and cytokinin (Kamountsis and Chronopoulu-Sereli, 1999; Fletcher *et al.,* 2000; Tekalign and Hammes, 2004; Jaleel *et al.,* 2007; Urban *et al.,* 2008). PBZ was also effective in protecting plants from various abiotic stresses that interfere with their normal physiological processes (Fernandez *et al.,* 2006; Sankar *et al.,* 2007).

Potassium (K) is an essential nutrient and is required for desirable growth and reproduction of plants. K has indirect role in plant growth, meaning that it does not make up any plant part (Zubair *et al.,* 2006). However, it involves in both uptake of water through plant roots and release of water via stomata. K element is also known to enhance plant tolerance to drought conditions (Thomas and Thomas, 2009; Kim *et al*., 2010). It is also pivotal in activating enzymes responsible for protein and starch synthesis, as well as many growth related enzymes in plants (Mengel, 2007; Patil, 2011).

Thus, this study was conducted to determine the effects of PBZ and potassium nitrate (KNO_3) on the leaf area and physiological response in a landscape tree, *Xanthostemon chrysanthus* (F. Muell.) Benth (Myrtaceae). This species is native to tropical northern Australia, New Guinea, Indonesia and the Philippines (Sosef *et al.,* 1998). It is locally known as jambu kuning and planted widely as ornamental tree in Malaysian cities due to its morphologically unique yellow florals.

Materials and Methods

Study Site and Plant Materials

A study site consisted of 81 *X. chrysanthus* tree was established at Metropolitan Batu Recreational Park, Kuala Lumpur (3° 12' 49" N; 101° 40' 43" E). During the observation period of 12 months (April 2012 till March 2013), the total precipitation received was 3,181.7 mm with temperature of about 22.9-33.3 ^oC and 76.4% relative humidity.

These trees were six years after planting at the start of the study, with the average height and average stem diameter at breast height of about 6 m and 10 cm, respectively. They were planted as roadside trees in the park. Nine treatments i.e., T1(0 gl^{-1} PBZ + 0 g KNO_3), T2(0 gl^{-1} PBZ + 100 g KNO_3), T3(0 gl^{-1} PBZ + 200 g KNO_3), T4(0.125 gl^{-1} PBZ + 0 g KNO_3), T5(0.125 gl^{-1} PBZ + 100 g KNO_3), T6(0.125 gl^{-1} PBZ + 200 g KNO_3), T7(0.25 gl^{-1} PBZ + 0 g KNO_3), T8(0.25 gl^{-1} PBZ + 100 g KNO_3) and T9(0.25 gl^{-1} PBZ + 200 g KNO_3), with nine replicates were arranged in a Completely Randomized Design. PBZ was soil drenched at an application volume of 1 l per tree, while the control plants were treated with plain water at the same amount. Application of PBZ was carried out one time at the start of the study. KNO_3 (13.7:0:38.4) was applied at three months intervals.

Data Collection

Randomly, the first three fully expanded leaves of five trees of each treatment were selected for the measurements of photosynthetic rate (A), transpiration rate (E) and stomatal conductance (g_s). These measurements were recorded at sixth and twelfth month after treatment (MAT) using a Portable Photosynthesis System, Li-6400XT (LICOR Nebraska, USA). A, E and g_s were recorded between 9.00 a.m. to 11.30 a.m. in sunny condition. The measurement was made at ambient humidity at 28 ^oC. The measurements were taken at 1200 μmol photon $m^{-2}s^{-1}$ of quantum flux and the concentration of CO_2 was between 360 to 400 μmol $m^{-2}s^{-1}$. The A was measured in μmol $m^{-2}s^{-1}$, while E and g_s were measured in mmol $m^{-2}s^{-1}$ and mol $m^{-2}s^{-1}$, respectively.

Changes in leaf area (LA) were recorded monthly. The first fully expanded leaves were plucked from three randomly selected developing branches of each tree. The LA was measured using a Leaf Area Meter (CI 202, CID. Inc., USA). LA was measured in squared centimeter (cm^2). The relative growth rate (RGR) of LA was then calculated using the formula by Hunt (1982) as below:

$$RGR = (\ln V_t - \ln V_o)/t_t - t_o$$

Where:

$\ln V_o$:	natural logarithm of parameter measurement at initial time
$\ln V_t$:	natural logarithm of parameter measurement at t time
t_o:	initial time
t_t:	t time

Data Analysis

All data were subjected to ANOVA and the treatment means were then compared using Duncan's Multiple Range Test (DMRT). The Pearson correlation was performed to investigate the degree of association between leaf area and the physiological attributes.

Results and Discussion

Physiological Changes

A of the first fully developed leaf differed significantly between the control and PBZ treatments at sixth MAT (Table 1). Second cycle of physiological measurement at twelfth MAT found that the control tree had higher A than all the other treatments. Trees treated with PBZ alone and combination of PBZ and KNO_3 gave lower A compared to the untreated control tree. At sixth MAT, A of the control tree was 5.61 µmol $m^{-2}s^{-1}$, while T7-treated tree had has 3.06 µmol $m^{-2}s^{-1}$, showing a difference of 45.45%. At twelfth MAT, there was no difference in A among the treatments where PBZ existed. However, the A values were lower than those recorded with T1, T2 and T3. It shows that PBZ influenced the physiological performance of the tree. Reduced A were also reported in *Mangifera indica* (Shivashankara and Mathai, 2000; Urban *et al.*, 2004). According to Urban *et al.* (2004), reduced A in *M. indica* was due to neither a decreased in g_s and the associated decreased in intercellular partial pressure of CO_2. PGR-treated plants normally had a moderate restraining consequence on CO_2 exchange rate, thus minimizing the A (Gaussoin *et al.,* 1997). The highest E was observed in T1 compared to other treatments (Table 1). Significant differences were also recorded among the control and other treatments. For example, at sixth MAT, E of the control tree was 2.46 mmol $m^{-2}s^{-1}$ whereas T9 had E of 0.73 mmol $m^{-2}s^{-1}$, giving a great difference of approximately 70.33%. The difference of E between T1 and other treatments was consistently observed at twelfth MAT. Observation also found that the existence of PBZ reduced E as compared to the control and KNO_3 treatments.

Significance difference in g_s was only recorded between T1 and treatments where PBZ was present (Table 1). It reveals that PBZ was able to control the stomata aperture which further influenced the gas exchange in the leaf. Hence, trees treated with PBZ usually had lower rate of biochemical processes as compared to other treatments without PBZ. However, KNO_3 showed no effects on g_s as it gave similar results to T1. The reduction in A would also cause reduction in E as both processes are closely connected with stomata behaviour and leaf size (Salisbury and Ross 1992; Abod and Jeng 1993). The decline in E would subsequently decrease the amount of water release through stomata. According to Olsen and Andersen (1995), reduction in E would prevent the plant against abiotic stress due to water limitation or drought episode. Besides affecting GAs, PBZ also increased other phytohormone, ABA and cytokinins (CK) contents concomitant with leaf water potential change in *M. indica* to elicit flowering responses (Upreti *et al.,* 2013). Increased ABA, on the other hand, has frequently been associated with the level of plant tolerance towards various stresses (Nambara and Marion-Poll, 2005). In potted *Syzygium myrtifolium*, PBZ reduced A and E but the g_s was not affected (Ahmad Nazarudin *et al.,* 2012). PGRs-treated plants showed reduction in E, used less water and may be able to survive drought better than untreated plants (Fletcher *et al.,* 2000). In this study, the existence of PBZ reduced A, E, and g_s which benefit the trees planted in extreme environment such as urban areas.

Table 1: Physiological changes in *X. chrysanthus* at sixth and twelfth months after treatment with PBZ and KNO_3

Trt	Photosynthetic rate (μmol m^{-2}s^{-1})		Transpiration rate (mmol m^{-2}s^{-1})		Stomatal conductance (mol m^{-2}s^{-1})	
	6th Month	12th Month	6th Month	12th Month	6th Month	12th Month
T1	5.61 a	6.54 a	2.46 a	2.93 a	0.13 a	0.15 a
T2	5.11 a	5.27 b	2.02 b	2.03 b	0.11 a	0.12 a
T3	5.11 a	5.24 b	1.99 b	1.97 b	0.12 a	0.12 a
T4	3.88 b	3.55 c	0.77 c	0.79 c	0.05 b	0.05 b
T5	3.97 b	3.67 c	0.77 c	0.80 c	0.05 b	0.04 b
T6	3.87 b	3.77 c	0.75 c	0.75 c	0.04 b	0.02 b
T7	3.06 c	3.47 c	0.73 c	0.74 c	0.03 b	0.03 b
T8	3.41 bc	3.39 c	0.75 c	0.76 c	0.02 b	0.03 b
T9	3.26 c	3.35 c	0.73 c	0.74 c	0.03 b	0.03 b

Means followed by the same letter(s) within column do not differ ($p<0.05$) by DMRT; Trt=treatment; n=15/treatment

Leaf Area Changes

Differences in LA were initially noted in June 2012, where the highest and the lowest LA were measured in the control and tree treated with T9, respectively (Table 2). At this stage, LA of the control tree was about 40.2 cm^2 while it was only 34.56 cm^2 for trees treated with T9, indicating a difference of approximately 14.03%. Results also showed that treatment with PBZ, or combination of PBZ and KNO_3, had a persistent inhibition effect on leaf expansion of the species. These treatments also resulted in a smaller LA than those treated with T1, T2 and T3 from August 2012 onwards until the end of the study period.

Table 2: Effects of paclobutrazol and potassium nitrate on leaf area of *X. chrysanthus*

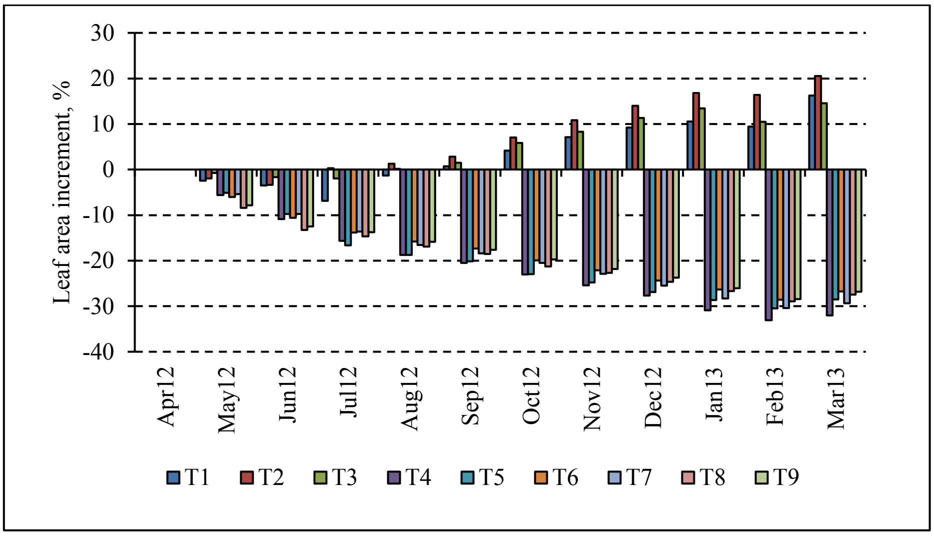
Trt	Leaf area (cm^2)											
	Apr '12	May '12	Jun '12	Jul '12	Aug '12	Sep '12	Oct '12	Nov '12	Dec '12	Jan '13	Feb '13	Mar '13
T1	41.67 a	40.65 a	40.20 a	38.80 ab	41.11 a	41.97 a	43.39 a	44.64 a	45.52 a	46.06 a	45.59 a	48.45 a
T2	37.22 a	36.49 a	35.96 abc	37.33 abc	37.70 a	38.26 b	39.83 b	41.24 b	42.43 b	43.47 a	43.33 a	44.85 b
T3	40.42 a	40.12 a	39.74 ab	39.63 a	40.48 a	41.02 ab	42.78 ab	43.79 ab	45.01 ab	45.84 a	44.65 a	46.29 ab
T4	41.24 a	38.92 a	36.76 abc	34.77 bc	33.50 b	32.79 c	31.75 c	30.75 c	29.83 c	28.51 b	27.59 b	28.02 c
T5	41.99 a	39.85 a	37.89 abc	34.99 bc	34.11 b	33.53 c	32.34 c	31.58 c	30.69 c	29.96 b	29.19 b	30.02 c
T6	39.08 a	36.73 a	34.94 c	33.69 c	32.90 b	32.30 c	31.28 c	30.43 c	29.56 c	28.78 b	27.91 b	28.62 c
T7	39.58 a	37.44 a	35.73 bc	34.19 c	33.02 b	32.30 c	31.46 c	30.53 c	29.49 c	28.37 b	27.55 b	27.95 c
T8	39.96 a	36.59 a	34.66 c	34.11 c	33.19 b	32.56 c	31.47 c	30.91 c	30.10 c	29.29 b	28.39 b	28.98 c
T9	39.48 a	36.39 a	34.56 c	34.05 c	33.23 b	32.51 c	31.68 c	30.86 c	30.11 c	29.20 b	28.26 b	28.90 c

Means followed by the same letter(s) within column do not differ ($p<0.05$) by DMRT; Trt=treatment; n=9/treatment

Reduced size in the newly developed leaves was observed for the first four months after application of PBZ, singly or in combination with KNO_3 of up to 200 g per tree (Figure 1). Smaller LA of the newly expanded leaves in those treatments was continuously observed until March 2013. Nonetheless, bigger LA was observed in trees treated with T1, T2 and T3 as compared to PBZ treatment from September 2012 onwards until the end of the study period. These results show that K element has a great influence in promoting plant growth and development. However, the effects of K in this study were overtaken by PBZ, in all treatments with combination with PBZ, resulting in reduced LA due to cell inhibition effect by this compound.

PBZ was reported to suppress leaf expansion in other plants for example, *Dianthus caryophyllus* (Sebastian *et al.,* 2002), *M. indica* (Yeshitela *et al.,* 2004), *S. myrtifolium* (Ahmad Nazarudin *et al.,* 2014b) and *Lantana camara* (Matsoukis et al. 2014). Fortunately, PBZ dosages used in this study did not give any extremely bad effects on the leaf morphology. There was no formation of abnormal leaves such as curly leaves which could reduce the aesthetic value of the landscape tree although LA reduction was evident with PBZ treatments. In other study, potted ornamental plant of *S. myrtifolium* also demonstrated similar effects on the morphological appearance of the leaves (Ahmad Nazarudin *et al.,* 2012). Thus, K in this study may be useful to improve plant tolerance to drought condition as reported in previous reports by Thomas and Thomas (2009) and Kim *et al.* (2010) rather than to increase the LA of *X. chrysanthus*.

Figure 1: Leaf area increment of *X. chrysanthus* after treated with PBZ and KNO_3



Correlation Analysis

Coefficient determination, R^2 of the physiological attributes shows positive relationships with LA (Figure 2, 3 and 4). It implies that as the LA increased the A, E and g_s were also increased. This is because bigger leaf surface would enhance the capability of the tree to capture the light for its biochemical processes. The existence of PBZ however, modified the morphological of the leaf by reducing the leaf size, which then reduced the physiological performance of the tree. Smaller LA in PBZ-treated *S. myrtifolium* contributed to the reduction of the total leaf surface that absorbs the sunlight for photosynthesis (Ahmad Nazarudin *et al.,* 2012). Reduction of E and g_s were also associated with the decreased LA as shown in Figure 3 and 4.

Anatomical studies showed that PBZ also affected the cells arrangement in the leaves of *S. myrtifolium* (Ahmad Nazarudin *et al.,* 2007), *Catharanthus roseus* (Jaleel *et al.,* 2009) and *X. chrysanthus* (Ahmad Nazarudin *et al.,* 2015). The palisade parenchyma of these plants was tightly packed following PBZ treatment. This could be due to the reduced leaf size forcing the tissues in such arrangement. This kind of cells arrangement would also reduce the intercellular CO_2 in the leaves which further affect the physiological performance of the treated plants as observed in this study.

Figure 2: Relationship between leaf area and photosynthetic rate

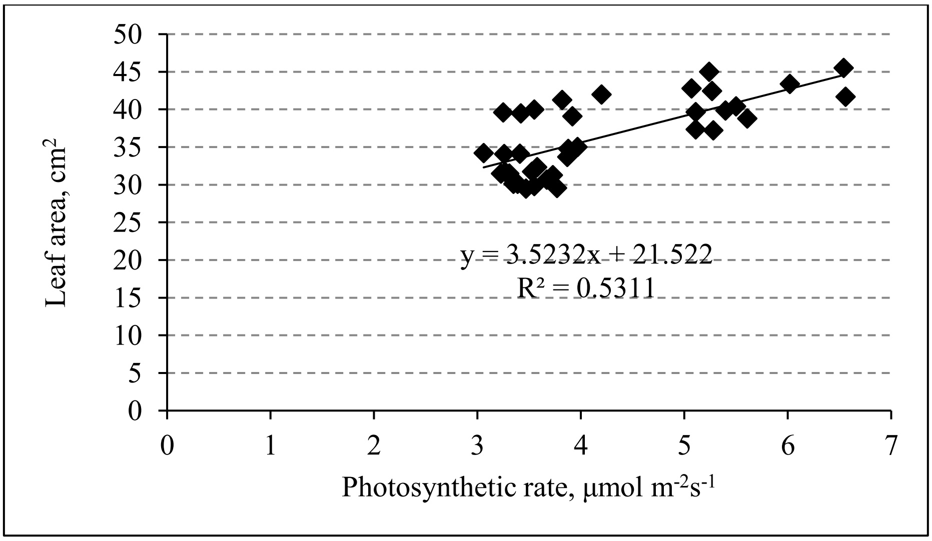


Figure 3: Relationship between leaf area and transpiration rate

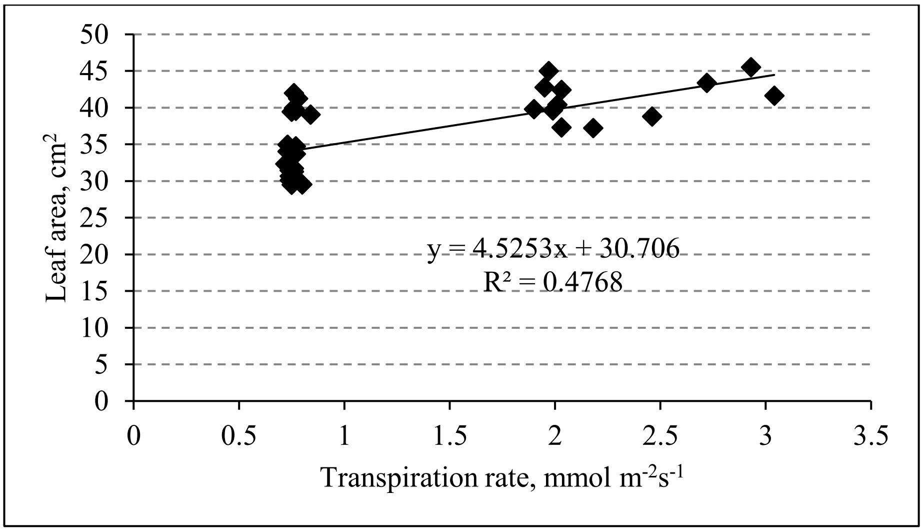
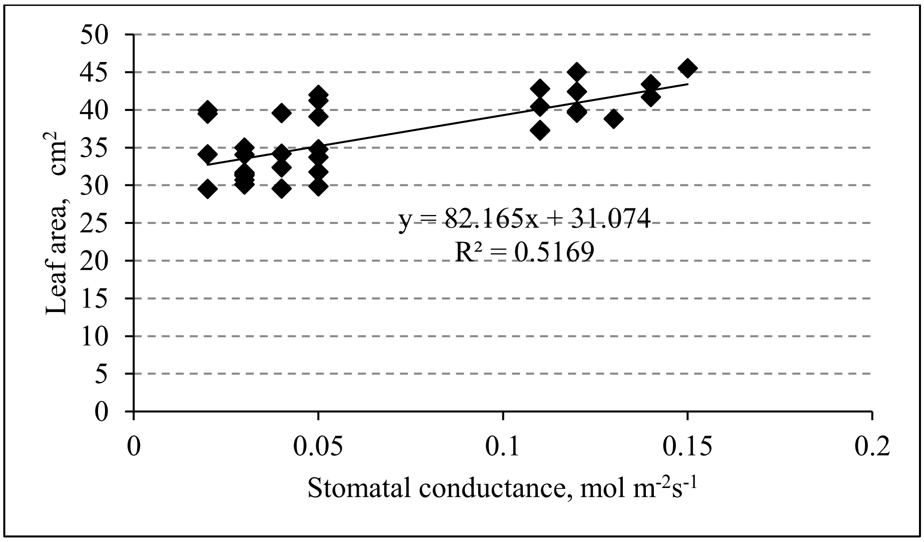


Figure 4: Relationship between leaf area and stomatal conductance



Conclusion

The existence of PBZ reduced the A, E and g_s in *X. chrysanthus* grown at Metropolitan Batu Recreational Park, Kuala Lumpur. In other words, PBZ was able to enhance the plants ability to control water lost via stomata. The ability of controlling the water content is important for plants planted in urban areas which usually exposed to extreme temperature and drought condition. Meanwhile, K in this study may be useful to enhance enzymatic functions in the plant rather than improving the LA and physiological performance. Further experiments on the appropriate application frequencies of this treatments on the species as well as the cost effectiveness of using the treatments are needed. Experiments involving this triazole and other landscape tree species are also required in order to implement this approach as one of the urban tree management strategies under local climate condition.

Acknowledgements

The authors would like to convey gratitude to the Kuala Lumpur City Hall (DBKL) for site permission. This work has been supported by the Ministry of Agriculture and Agro-based Industry Malaysia (Grant 05-03-10-SF1030).

References

Abod, S. A. & Jeng, L. T. (1993). Effects of Paclobutrazol and its method of application on the growth and transpiration of *Acacia mangium* seedlings. *Pertanika Journal of Tropical Agricultural Science, 16(2),* 143-150.

Ahmad Nazarudin, M. R., Mohd Fauzi, R. & Tsan, F. Y. (2007). Effects of paclobutrazol on the growth and anatomy of stems and leaves of *Syzygium campanulatum*. *Journal of Tropical Forest Science, 19(2),* 86-91.

Ahmad Nazarudin, M. R., Tsan, F. Y. & Mohd Fauzi, R. (2012). Morphological and physiological response of *Syzygium myrtifolium* (Roxb.) Walp. to paclobutrazol. *Sains Malaysiana, 41(10),* 1187-1192.

Ahmad Nazarudin, M. R., Tsan, F. Y., Normaniza, O. & Adzmi, Y. (2014a). Growth performance and flowering occurrence of *Xanthostemon chrysanthus* in two selected urban sites in Kuala Lumpur, Malaysia. *Journal of Tropical Forest Science, 26(3),* 428-434.

Ahmad Nazarudin, M. R., Tsan, F. Y. & Mohd Fauzi, R. (2014b). Paclobutrazol effects on growth performance and public preference on potted *Syzygium myrtifolium* (Roxb.) Walp. *Journal of Agrobiotechnology, 5,* 17-29.

Ahmad Nazarudin, M. R., Tsan, F. Y., Normaniza, O. & Adzmi, Y. (2015). Growth and anatomical changes in *Xanthostemon chrysanthus* as influenced by paclobutrazol and potassium nitrate. *Sains Malaysiana, 44(4),* 483-489.

Fernandez, J. A., Balenzategui, L., Banon, S. & Franco, J. A. (2006). Induction of drought tolerance by paclobutrazol and irrigation deficit in *Phillyrea angustifolia* during the nursery period. *Scientia Horticulturae, 107,* 277-283.

Fletcher, R. A., Gilley, A., Sankhla, N. & Davis, T. D. (2000). Triazoles as plant growth regulators and stress protectants. *Horticultural Reviews, 24,* 55-138.

Gaussoin, R. E., Branham, B. E. & Flore, J. A. (1997). Carbon dioxide exchange rate and chlorophyll content of turf grasses treated with flurprimidol and mefluidide. *Journal of Plant Growth Regulation, 16,* 73-78.

Hunt, R. (1982). *Plant Growth Curves. The Functional Approach to Plant Growth Analysis*. Edward Arnold (Publishers) Ltd., London.

Jaleel, C. A., Gopi, R. & Panneerselvam, R. (2007). Alterations in lipid peroxidation, electrolyte leakage and proline metabolism in *Catharanthus roseus* under treatment with triadimefon, a systemic fungicide. *Comptes Rendus Biologies, 330(12),* 905-912.

Jaleel, C. A., Gopi, R. & Panneerselvam, R. (2009). Alterations in non-enzymatic antioxidant components of *Catharanthus roseus* exposed to paclobutrazol, gibberellic acid and *Pseudomonas fluorescens*. *Plant Omics Journal, 2(1),* 30-40.

Kamountsis, A. P. & Chronopoulou-Sereli, A. G. (1999). Paclobutrazol affects growth and flower bud production in gardenia under different light regimes. *HortScience, 34(4),* 674-675.

Kim, T. H., Bohmer, M., Hu, H., Nishimura, N. & Schroeder, J. I. (2010). Guard cell signal transduction network: advances in understanding abscisic acid, CO_2, and Ca^{2+} signaling. *Annual Review of Plant Biology, 61,* 561-591.

Kozlowski, T. T., Kramer, P. J. & Pallardy, S. G. (1991). *The Physiological Ecology of Woody Plants.* Academic Press, San Diego.

Lorenz, K. & Lal, R. (2009). Biochemical C and N cycles in urban soils. *Environment International, 35,* 1-8.

Nambara, E. & Marion-Poll, A. (2005). Abscisic acid and catabolism. *Annual Review of Plant Biology, 56,* 165-185.

Matsoukis, A., Gasparatos, D. & Chronopoulou-Sereli, A. (2014). Environmental conditions and drenched-applied paclobutrazol effects on lantana specific leaf area and N, P, K, and Mg content. *Chilean Journal of Agricultural Research, 74(1),* 117-122.

Mengel, S. (2007). *Potassium.* In A.V. Barker & D.J. Pilbean (Eds.), Handbook of Plant Nutrition (pp.395-402). CRC Taylor and Francis, New York.

Olsen, W. W. & Andersen, A. S. (1995). Growth retardation of *Osteospermum ecklonis. Acta Horticulturae, 397,* 129-138.

Patil, R. B. (2011). Role of potassium humate on growth and yield of soybean and black gram. *International Journal of Pharma and Bio Sciences, 2(1),* 242-246.

Percival, G. C., Keary, I. P. & Sulaiman, A. H. (2006). An assessment of the drought tolerance of *Fraxinus* genotypes for urban landscape plantings. *Urban Forestry & Urban Greening, 5,* 17-27.

Pickett, S. T. A. & Cadenasso, M. L. (2009). Altered resources, disturbance, and heterogeneity: a framework for comparing urban and non-urban soils. *Urban Ecosystem, 12,* 23-44.

Rahman, M. A., Smith, J. G., Stringer, P. & Ennos, A. R. (2011). Effect of rooting conditions on the growth and cooling ability of *Pyrus calleryana*. *Urban Forestry & Urban Greening, 10,* 185-192.

Salisbury, F. B. & Ross, C. (1992). *Plant physiology* (4th ed.). New York: Freeman and Worth.

Sankar, B., Jaleel, A., Manivannan, P., Kishorekumar, A., Somasundaram, R. & Panneerselvam, R. (2007). Effect of paclobutrazol on water stress amelioration through antioxidants and free radical scavenging enzymes in *Arachis hypogaea* L. Colloids and Surfaces B: *Biointerfaces, 60,* 229-235.

Sebastian, B., Alberto, G., Emilio, A. C., Jose, A. F. & Juan A. F. (2002). Growth, development and color response of potted *Dianthus caryophyllus* cv. Mondriaan to paclobutrazol treatment. *Scientia Horticulturae, 1767,* 1-7.

Shivashankara, K. S. & Mathai, C. K. (2000). Inhibition of photosynthesis by flowering in mango (*Mangifera indica* L.). A study by gas exchange methods. *Scientia Horticulturae, 83(3),* 205-212.

Sosef, M. S. M., Hong, L. T. & Prawirohatmodjo, S. (1998). *Plant Resources of South-East Asia* No. 5(3). *Timber Trees: Lesser-Known Timbers*. Back-huys Publishers, Leiden. 859 pp.

Tekalign, T. & Hammes, P. S. (2004). Response of potato grown under non-inductive condition to paclobutrazol: shoot growth, chlorophyll content, net photosynthesis, assimilate partitioning, tuber yield, quality, and dormancy. *Plant Growth Regulation, 43,* 227-236.

Thomas T. C. & Thomas A. C. (2009). The vital role of potassium in the osmotic mechanism of stomata aperture modulation and its link with potassium deficiency. *Plant Signaling & Behavior, 4,* 240-243.

Upreti, K. K., Reddy, Y. T. N., Shivu, S. R., Prasad, G. V., Bindu, H. L. & Rajan, J. S. (2013). Hormonal changes in response to paclobutrazol induced early flowering in mango cv. Totapuri. *Scientia Horticulturae, 150,* 414-418.

Urban, L., Lu, P. & Thibaud, R. (2004). Inhibitory effect of flowering on leaf photosynthesis in mango. *Tree Physiology, 24,* 387-399.

Urban, L., Jegouzo, L., Damour, G., Vandame, M. & Francois, C. (2008). Interpreting the decrease in leaf photosynthesis during flowering in mango. *Tree Physiology*, *28,* 1025-1036.

Weltecke, K. & Gaertig, T. (2012). Influence of soil aeration on rooting and growth of the Beuys-trees in Kassel, Germany. *Urban Forestry & Urban Greening, 11,* 329-338.

Yeshitela, T., Robbertse, P. J. & Stassen, P. J. C. (2004). Paclobutrazol suppressed vegetative growth and improved yield as well as fruit quality of 'Tommy Atkins' mango (*Mangifera indica*) in Ethiopia. *New Zealand Journal of Crop and Horticultural Science, 32,* 281-293.

Zubair, M., Ayub, G., Wazir, F. K., Khan, M. & Mahmood, Z. (2006). Effect of potassium on preflowering growth of gladiolus cultivars. *Journal of Agricultural and Biological Science, 1(3),* 36-46.

Ahmad Nazarudin, M.R.
Forestry and Environment Division, Forest Research Institute Malaysia (FRIM),
52109 Kepong, Selangor, Malaysia.
Email: nazarudin@frim.gov.my

Tsan, F.Y.
Faculty of Plantation and Agrotechnology,
Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia.
Email: tsanfuiying@salam.uitm.edu.my