GROWTH PERFORMANCE AND FLOWERING OF *XANTHOSTEMON CHRYSANTHUS* AT TWO URBAN SITES IN KUALA LUMPUR, MALAYSIA

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AHMAD NAZARUDIN MR, TSAN FY, NORMANIZA O & ADZMI Y. 2014. Growth performance and flowering of *Xanthostemon chrysanthus* at two urban sites in Kuala Lumpur, Malaysia. A study was conducted to investigate the growth performance and flowering of *Xanthostemon chrysantus* at two urban sites, namely, Metropolitan Batu Park (MBP) and Pusat Bandar Manjalara (PBM). Soil physical and chemical properties of the sites were inspected. Growth attributes such as tree height, diameter at breast height, canopy diameter, leaf area, leaf area index and relative chlorophyll content were recorded monthly. Flowering occurrence was scored as abundance of flowers. Differences in diameter at breast height and canopy diameter at both sites were observed throughout the study period. Tree height and relative chlorophyll content had no variations. Leaf area and leaf area index only differed for several months when higher amounts of rainfall were received. On the other hand, flower abundance was significantly different in December 2010, July 2011 and August 2011. Trees at PBM flowered throughout the year, unlike trees at MBP. Soil properties, rainfall and individual tree condition (vegetative or flowering phase) may cause variations in growth and flowering of the species. The results showed that *X. chrysanthus* was suitable for urban landscape as it was able to tolerate the harsh urban environment.

Keywords: Flower abundance, ornamental tree, urban landscape, urban forestry, urban soil

INTRODUCTION

The climate in Malaysia is characterised by uniform temperature, high humidity and copious rainfall with an annual weather pattern of dry and wet seasons (Malaysia Meteorological Department 2012). Environmental factors such as water, nutrient and light are essential resources for plant growth (Toledo et al. 2011). Other important factors which stimulate plant performance are soil physio–chemical properties. Better plant growth rate is evident on nutrient-rich soil (Russo et al. 2005). However, urban soil is often greatly modified and of poor quality (Lorenz & Lal 2009). Urban soil is also highly compacted (Lehmann & Stahr 2007, Smetak et al. 2007, Pitt et al. 2008, Sinnett et al. 2008, Pickett & Cadenasso 2009). Highly compacted soil is associated with heavy usage or development such as roadside, highway, walkway, playground and parking area. Severe compaction reduces soil pore area, thus increasing bulk density. High bulk density hinders plant growth, increases overland flow of storm waters leading to erosion and flooding, and alters biogeochemical cycling (Scalenghe & Marsan 2009). When bulk density increases, shoot growth slows down and leaf size is reduced (Taylor & Brar 1991, Masle 1992, Mulholland et al. 1999). Compaction alters soil texture, influencing moisture regime, which further impedes root penetration into the soil. As a consequence, the tree will not be able to absorb water and nutrients.

In urban areas, different soil types usually occur within the same planting site as different soil sources are placed together during land development and earthwork. The substances of urban soil are unpredictable. Some may be rocky and sandy, while adjacent areas may be clayey. In addition, in urban areas, plants are normally planted within restricted planting hole where roots have difficulty spreading and penetrating the compacted soil. Some species may eventually develop roots laterally or restrict themselves to less compacted soil (Hamza & Anderson 2005). Planting trees in such soil conditions results in poor vertical root system, which will weaken tree growth and increase the risk of windthrow.

Xanthostemon chrysanthus or golden penda belongs to the family Myrtaceae. This species originates from tropical northern Australia, New Guinea, Indonesia and the Philippines (Sosef et al. 1998). In Malaysia, this species is planted at roadsides, urban parks and residential areas for beautification due to its distinctive flowers.

This study was aimed at investigating the growth performance and flowering of *X. chrysantus* at two selected urban sites in Kuala Lumpur. Their growth and performance were studied in relation to rainfall and soil conditions.

MATERIALS AND METHODS

Study location and plant materials

Two sites in Kuala Lumpur were selected for the study, namely, Pusat Bandar Manjalara, PBM (3° 11' N, 101° 37' E) and Metropolitan Batu Park, MBP (3° 12' N, 101° 40' E). Both sites are situated within the radius distance of about 5 km from the meteorological station. Rainfall and temperature data were obtained from the Malaysian Meteorological Department.

A total of 10 existing *X. chrysanthus* trees which had flowered previously were selected randomly from each site based on completely randomised design. Trees were planted on road median at PBM with planting area of about 2 m width, while trees were grown on grass lawn with bigger planting area at MBP. These trees originated from stem cuttings and were about 6 years old at the time of the study. The average height and diameter at breast height (dbh) of these trees were 6 m and 12 cm respectively.

Data collection

Soil physical and chemical properties

Soil samples were collected at 0–30 cm depth from each site using an auger at the beginning of the study. Soil samples were sealed in plastic bags and sent to the laboratory for analysis. For bulk density (BD) measurement, a 3-inch diameter ring was used to collect soil samples. The ring was driven into the soil until the whole ring was immersed. Using a garden trowel, the ring was carefully dug out to prevent any loss of soil. Excess soil from the ring was removed with a flat knife. Soil samples were oven dried at 105 °C for 24 hours and reweighed. Bulk density was calculated using the formula below.

$$BD = \frac{\text{Soil weight after oven drying (g)}}{\text{Soil volume (cm}^3\text{)}}$$

Soil penetration resistance was measured using a hand penetrometer. This device determines the penetration resistance of top layers. The principle of the hand penetrometer is based on measuring the highest penetration resistance of a cone over a distance of about 10 cm.

Growth performance

Tree height (HT) (m) was measured using a hypsometer. The device was pointed and shot at the base of the tree and at the shoot tip of the tree. Stem dbh (cm) was measured at 1.3 m above the ground using a diameter tape. Crown diameter (CD) (cm) is the mean of the widest and narrowest parts of the crown viewed directly on the ground below the canopy. Crown diameter was measured using a measuring tape.

The first three fully expanded leaves of each tree were collected for leaf area (LA) measurement (cm^2). Leaf area meter was used. Leaf area index (LAI) measurement was performed using a ceptometer. Measurements were recorded under full sunlight and under the tree canopy. Relative chlorophyll content (RCC) was recorded using a non-destructive portable chlorophyll meter. A total of three fully expanded leaves from each tree were selected for measurement. All growth measurements were recorded at monthly intervals starting from November 2010 till October 2011.

Flowering occurrence

The tree canopy was vertically divided into two portions, face A (facing the East) and face B (facing the West). Flower abundance (FLO) in each side of the tree canopy was scored and averaged. Observation was carried out twice a week throughout the study period.

Data analysis

Descriptive analysis was carried out on rainfall, soil property and FLO data. T-test was used to compare growth attributes and FLO of the species between the two sites. Correlation analysis was carried out to investigate the degree of association between vegetative as well as reproductive attributes and rainfall.

RESULTS AND DISCUSSION

Climatic pattern

The total rainfall received was 3180 mm and mean minimum and maximum temperatures were 22.9 and 33.3 °C respectively (Figure 1). There was substantial monthly variation in rainfall. Relative humidity was about 76.4% (result not shown). The monthly rainfall pattern showed two periods of maximum rainfall and two periods of minimum rainfall. The first maximum rainfall occurred in March–April, while the second maximum rainfall, November–December. The first minimum rainfall, on the other hand, occurred in January–February, whereas the second minimum rainfall, June–July. Approximately 45.8 cm of rainfall was received in March–April, while only 21.5 cm of rainfall was collected in January–February, showing 53.1% difference. In November–December, the total rainfall was 42.5 cm, giving a difference of about 7.2% compared with that in March–April. The mean monthly temperature was somewhat consistent throughout the year.

Soil properties

Both soil was categorised as loamy sand, having low clay particle content (Table 1). Soil containing less than 15% clay is classified as loamy sand (Paramananthan 1987). Total sand values of PBM and MBP were 69.46 and 67.19% respectively, entailing high soil pore areas. The soil thus had high permeability which influenced the water holding capacity. This was verified by their low soil moisture contents—5.89% at MBP and only 2.70% at PBM due to high porosity of the soil. The cation exchange capacities were 3.67 at MBP and 3.40 at PBM. The sites also contained higher exchangeable Ca compared with other elements such as K, Mg and Na. Bulk densities of soil at PBM and MBP were relatively similar, i.e. 0.299 and 0.314 g cm^{-3} respectively. Both sites also showed similar penetration resistance of 2.911 and 2.954 MPa respectively.

Growth performance and flowering

Crown diameter and dbh of trees were significantly different (Table 2). As soil properties of both sites did not appear to differ greatly, the planting area might affect growth parameters. Trees at PBM were grown at the road median with limited planting area. Road construction debris such as gravels and pebbles were frequently piled around the trees. No significant difference was observed in HT and RCC.

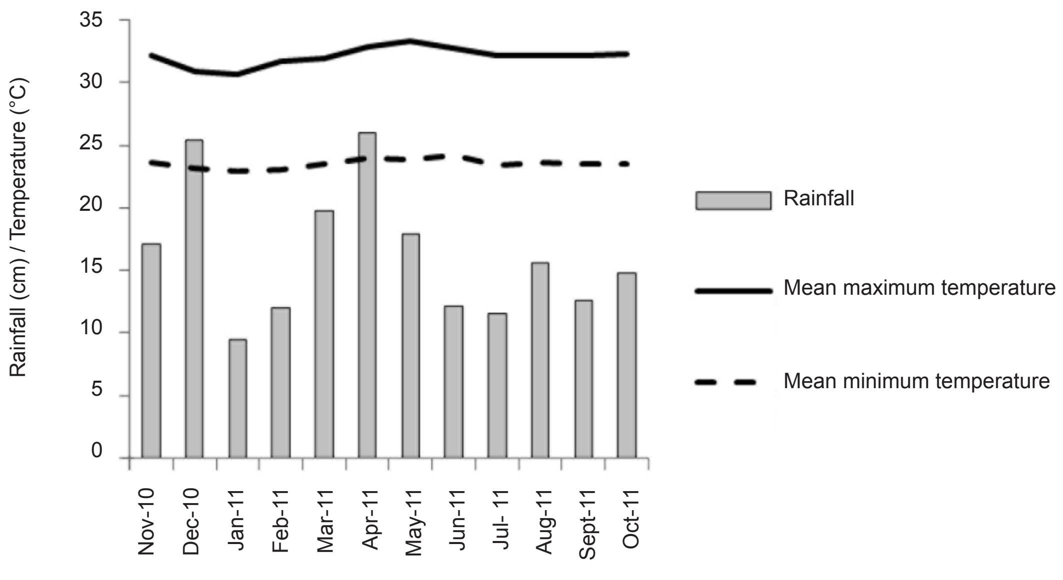

Figure 1 Monthly rainfall and monthly temperature

Table 1 Soil properties at Pusat Bandar Manjalara and Metropolitan Batu Park

Soil property	PBM	MBP
Chemical property		
pH	5.90 ± 0.68	6.15 ± 1.2
Moisture (%)	2.70 ± 0.46	5.89 ± 2.37
C (%)	0.50 ± 0.51	0.60 ± 0.34
N (%)	0.02 ± 0.02	0.06 ± 0.04
Available P (ppm)	6.00 ± 5.61	7.80 ± 5.54
P (ppm)	210.40 ± 18.64	198.13 ± 39.22
Mn (ppm)	140.60 ± 42.39	133.75± 30.52
K (cmol kg^{-1})	0.07 ± 0.04	0.08 ± 0.03
Ca (cmol kg^{-1})	3.72 ± 1.87	2.47 ± 1.77
Mg (cmol kg^{-1})	0.33 ± 0.27	0.66 ± 0.66
Na (cmol kg^{-1})	0.02 ± 0.01	0.01 ± 0.01
CEC (cmol kg^{-1})	3.40 ± 1.92	3.67 ± 1.3
Mechanical property		
Clay (%)	13.94 ± 1.77	15.01 ± 5.89
Silt (%)	16.60 ± 3.25	17.80 ± 5.03
Fine sand (%)	18.98 ± 1.13	35.85 ± 9.27
Coarse sand (%)	50.48 ± 3.89	31.34 ± 12.07
Bulk density (g cm^{-3})	0.299 ± 0.03	0.314 ± 0.04
Penetration resistance (MPa)	2.911 ± 0.13	2.954 ± 0.88
Soil type	Loamy sand	Loamy sand

Values are means ± standard deviations; PBM = Pusat Bandar Manjalara, MBP = Metropolitan Batu Park; CEC = cation exchange capacity

Table 2 T-test on growth attributes from November 2010 till October 2011

Growth attribute	Significance level											
	Nov '10	Dec	Jan '11	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
HT (m)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Dbh (cm)	***	***	***	***	***	***	***	***	***	***	***	***
CD (m)	***	***	***	***	***	***	***	***	***	***	***	***
RCC	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LA (cm^2)	ns	*	**	*	ns	ns	ns	ns	ns	ns	ns	ns
LAI	*	**	ns	ns	***	***	ns	ns	*	ns	ns	ns
FLO (%)	ns	**	ns	ns	ns	ns	ns	ns	**	**	ns	ns

ns = Not significant, *, **, *** = $p < 0.05$, $p < 0.01$, $p < 0.001$ respectively; HT = tree height, dbh = diameter at breast height, CD = crown diameter, RCC = relative chlorophyll content, LA = leaf area, LAI = leaf area index, FLO = flower abundance

On the other hand, significant difference in LA was found in December 2010 till February 2011. Significant difference in LAI occurred in November 2010, December 2010, March 2011, April 2011 and July 2011. These results suggested that higher amounts of rainfall received in November–December 2010 and April–May 2011 promoted tree growth attributes especially LA and LAI. In general, tree growth increases with rainfall and decreases with drought (Nath et al. 2006, Lola da Costa et al. 2010).

In December 2010 as well as July and August 2011, flowering occurred in all trees, at PBM, whereas none at MBP (Figure 2). As a consequence, FLO between sites was significantly different in those months (Table 2). *Xathostemon chrysanthus* did not have any distinctive flowering season as all trees at PBM flowered throughout the year (Figure 2). Neil and Wu (2006) listed some potential causes of flowering in urban environment, for instance temperature, moisture, humidity and photoperiod. There may be other factors that influence flowering of urban trees such as pollution, heat and water stress. Flowering is also found to be associated with plant stress. For example, Levy and Dean (1998) concluded that flowering was induced by stress conditions such as nutrient deficiency, drought and overcrowding. Advancement in flowering is due to global warming, but urbanisation is more likely to play a role at the local scale since local landscape characteristics (e.g. pattern of built features, vegetation amount) strongly affect microclimatic conditions (Hepper 2003).

In spite of growth differences caused by planting area and microenvironment, *X. chrysanthus* was found to be suitable for urban sites. It was capable of tolerating low soil moisture content, low fertility and site with relatively high penetration resistance. Tree root development was significantly impeded at penetration resistance values of between 2 and 3 MPa (Sinnett et al. 2008). Root growth of *Pinus radiata* seedlings was greatly impeded at penetration resistance values of more than 1.3 (Zou et al. 2001) and 1.5 MPa (Boone & Veen 1994). The root growth of *Gossypium* sp., *Pisum* sp. and *Arachis* sp. was reported to cease when penetration resistance reached 2 (Taylor & Ratcliff 1969) or 3 MPa (Greacen & Sands 1990).

Correlation analysis

At MBP, positive relationships were found between HT and LA, HT and CD, HT and dbh, LAI and LA, LA and CD, LA and dbh as well as CD and dbh (Table 3). These growth attributes were positively correlated, implying that as one variable increased, the other variable also increased. For example, HT was found to be positively correlated with CD (r = 0.999). This would mean that as HT increased, CD also increased, showing a normal growth condition of plant.

At PBM, similar results of positive relationships were also observed among the growth attributes (Table 4). For instance, HT was positively correlated with LA (r = 0.596), demonstrating that as HT increased, LA also increased. On the other hand, at PBM, negative relationships were found between HT and FLO (r = -0.71), CD and FLO (r = -0.758) as well as dbh and FLO (r = -0.74). This showed that higher FLO in comparison with smaller tree size (CD, HT and dbh) was recorded at this site. In this case, other factors such as site location, local microclimate and pollution could be reasons for the occurrence of flower. According to

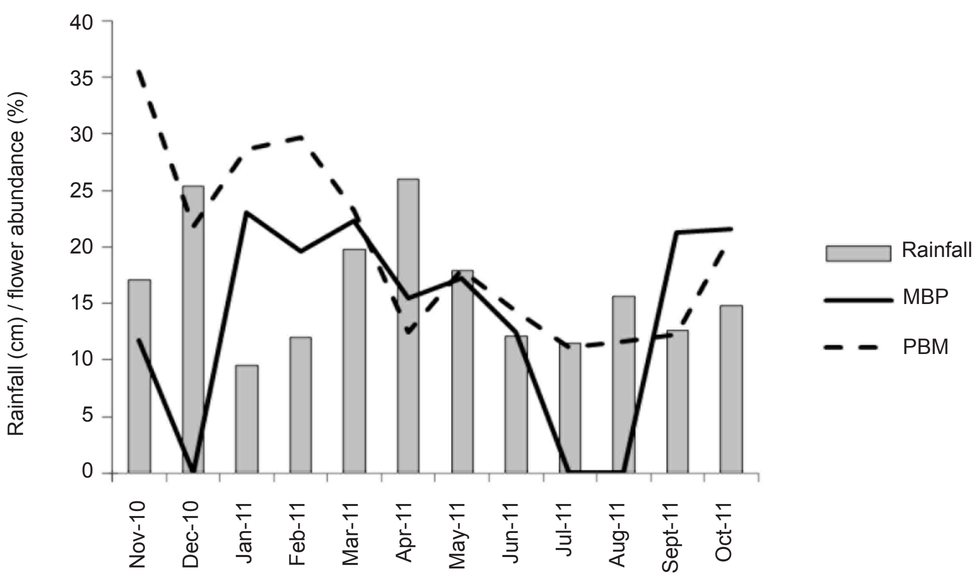

Figure 2 Rainfall and flower abundance of *Xanthostemon chrysanthus*; MBP = Metropolitan Batu Park, PBM = Pusat Bandar Manjalara

Table 3 Correlation matrix for vegetative and reproductive performance of *Xanthostemon chrysanthus* at Metropolitan Batu Park

	HT	RCC	LAI	LA	CD	Dbh	FLO	RAIN
HT	1							
RCC	0.013	1						
LAI	0.431	-0.13	1					
LA	0.94**	-0.052	0.67*	1				
CD	0.999**	0.02	0.453	0.946**	1			
Dbh	0.997**	0.021	0.469	0.954**	0.999**	1		
FLO	-0.192	-0.272	-0.551	-0.317	-0.201	-0.12	1	
RAIN	-0.106	-0.285	-0.13	-0.227	-0.13	-0.149	0.125	1

HT = tree height, RCC = relative chlorophyll content, LAI = leaf area index, LA = leaf area, CD = canopy diameter, dbh = diameter at breast height, FLO = flower abundance, RAIN = rainfall; * $p < 0.05$, ** $p < 0.01$

Table 4 Correlation matrix for vegetative and reproductive performance of *Xanthostemon chrysanthus* at Pusat Bandar Manjalara

	HT	RCC	LAI	LA	CD	Dbh	FLO	RAIN
HT	1							
RCC	-0.249	1						
LAI	0.438	-0.014	1					
LA	0.596*	-0.113	0.707*	1				
CD	0.996**	-0.254	0.441	0.578*	1			
Dbh	0.996**	-0.237	0.466	0.611*	0.998**	1		
FLO	-0.71**	0.142	-0.241	-0.226	-0.758**	-0.74**	1	
RAIN	-0.123	0.483	0.265	-0.268	-0.133	-0.144	-0.018	1

HT = tree height, RCC = relative chlorophyll content, LAI = leaf area index, LA = leaf area, CD = canopy diameter, dbh = diameter at breast height, FLO = flower abundance, RAIN = rainfall; * $p < 0.05$, ** $p < 0.01$

Wada and Takeno (2010), improper nutrients, temperature and light could be regarded as stress factors which induced flowering. In other words, environmental cues which promote flowering will become stress factors that trigger flowering but in an unusual situation. The life processes of a plant are influenced by several environmental factors, which in some constraints may be stressors (Kovács-Bogdán et al. 2010).

CONCLUSIONS

Trees planted at MBP with bigger planting area showed better growth performance than those planted at PBM. Crown diameter and dbh of both sites were significantly different. Leaf area and LAI, on the other hand, were presumed to be influenced by the availability of rainfall. *Xanthostemon chrysanthus* showed no distinctive flowering season as it flowered throughout the year. This species can be considered as a good candidate for urban landscape because it is able to tolerate the harsh urban environment.

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