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GROWTH OF ORNAMENTAL PLANTS IN CONSTRUCTED WETLANDS OF KUCHING CITY: ECOLOGICAL SANITATION

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ABSTRACT

Two common ornamental plant species *Syzygium campanulatum* and *Ficus microcarpa* were planted into small-scale constructed wetlands receiving grey water. Partially treated black water from septic tanks and grey water are discharged into storm water drains and subsequently into the rivers in Kuching. Discharge from households is the main pollution source of the Sarawak River. The option of urban ecological sanitation was explored by the Sarawak Government which involves separating wastewater at the source and recycling of nutrients. Grey water from selected households were channeled to a grease trap and then pumped to biofilters before flowing through a constructed wetland grown with two species of ornamental plants before discharge. The results indicated no major limitations to the use of municipal wastewater as an irrigation source in urban tree growth. The high photosynthetic rates of both species grown in the constructed wetland compared to the control plants indicated that the plants are able to utilize the available nutrient in the constructed wetland and perform normal physiological processes necessary for plant growth compared to the control plants. Height and diameter breadth height (dbh) of both species were relatively higher than the control plants indicating that the wastewater also serves as a source of fertilizer for the plants to grow. The growth performance of *S. campanulatum* was better compared to *F. microcarpa* in the constructed wetland and both species exhibited better growth performance compared to the control plants.

Keywords: constructed wetlands, ecological sanitation, urban tree, *Syzygium campanulatum, Ficus microcarpa*

INTRODUCTION

Constructed wetlands of many kinds are receiving much attention where alternatives to failing septic tank-soil drain field systems are needed. The wetlands provide a low-cost of easily managed system that can treat water to acceptable levels for discharge waterways (USEPA 1997). Good aesthetic properties and effective treatment capabilities make subsurface flow wetlands an appropriate choice for small-scale, individual or small group residential situation (Knight et al.

1993; Steiner & Combs 1993). Application of treated wastewater for irrigation of plants and crops is gradually becoming a common practice world wide (Angelakis et al. 1999). It is beneficial for a number of reasons: (a) water shortage can be resolved; (b) large amounts of wastewater can be disposed of during the entire year; (c) high quality resources could be used for potable uses; and (d) economic benefits attributed primarily to the nutrient content of the wastewater are possible (Oron et al. 1995). Moreover, in general, distribution of municipal treated wastewater for irrigation over large areas causes minimal pollution hazard. Treatment of domestic wastewater in the Kuching City with 21% of the 2.4 million population of Sarawak is a challenge. Partially treated black water from septic tanks and grey water are being discharged into storm water drains and subsequently into the rivers. It was reported that the main pollution source of the Sarawak River was the discharge from households (NREB 2001). Ling et al. (2005) reported that wastewater flow at two major housing areas in Kuching was 82.5 l c^{-1} d^{-1} and loadings of BOD_5, and phosphate were found to be 1,825 mg c^{-1} d^{-1} and 519 mg c^{-1} d^{-1}, respectively.

The option of urban ecological sanitation was explored by the Sarawak Government due to the high cost of implementing a centralized wastewater treatment with a pilot project of ecological sanitation implemented in Kuching, Malaysia (Bjerregaard 2004). Grey water from those households were channeled to a grease trap and then pumped into biofilters before flowing it through a constructed wetland with two species of ornamental plants raised in the constructed wetland before being discharged. Ecological sanitation involves separating excreta at source and recycling of the nutrients (Winblad & Simpson-Herbert 2004). In this system, human excreta are treated as a resource and are sanitized before being recycled as fertilizer. The grey water from kitchens, baths and laundries, though not mixed with the toilet water, still has to be treated before being reused as a resource. A hard substrate was provided for bacterial attachment and it is effective in reducing ammonia nitrogen in wastewater (Persson et al. 2002). Constructed wetland was found to be effective in treating municipal wastewater in Czech Republic (Vymazal 1996), USA (Neralla et al. 2000) and Mexico (Whitney et al. 2003).

The use of reclaimed wastewater for plant irrigation represents an interesting alternative source of water and it could be an economic way of irrigating, decrease pollution of surface waters and provide ground water recharge (Maurer 1993). A research on the impact of using reclaimed irrigation water on the growth of selected species of commonly used landscape ornamental plants were carried out in the city of St. Petersburg (Florida). The 10 experimental plant species showed widely different responses to the experimental treatments. The plant growth showed to be strongly affected by the irrigation method and the chloride concentration of the irrigation method (Parnell 1998). Similar results were obtained by Gori et al. (2000) working on three different species (*Abutilon* "Kentish Belle", *Viburnum tinus* "French White", *Weigelia florida* "Bouquet Rose"), which showed different behaviors in response to irrigation with reclaimed wastewater. *Weigelia* was most responsive whilst *Abutilon* the least. In a further study on nine widely grown ornamentals, it was found that plant growth after 3 months with waste water irrigation was strongly controlled by species (Wu et al. 1995). The tolerance ratio (percentage of growth under waste water to the growth under the control treatment) varied between Lace fern (*Athyrium filixfemina*) and Nandina (*Nandina domsetica*), which showed the lowest value (0.08% and 25%, respectively), while Jasmine (*Jasminum sambac*) and Raphiolepis (*Raphiolepis indica*) recorded the highest percentage (115% and 119%, respectively). The objective of this study was to compare the growth performance of two common species of ornamental plants grown under a constructed wetland.

MATERIALS AND METHODS

Study site

Hui Sing Garden is one of the residential areas located 4.5 km from downtown of Kuching City, Sarawak. Dark water from toilet flows into the storm drain after partial treatment in the septic tanks. With the implementation of the pilot project for ecological sanitation in 2003 that involved 9 houses, the septic tanks were converted into holding tanks. Low-flush toilets were installed. The content of the holding tank was emptied periodically and transported to Kuching's sludge treatment center. The grey water flows through an oil and grease separator before pretreatment with biofilter. With the help of a pump, wastewater is transported to four biofilters where it is sprayed on top of a lightweighted material (expanded clay). Outflow from the biofilter enters a horizontal subsurface flow constructed wetland (SFW) with limestone as particle filter and two species of ornamental plant seedlings growing on it. Treated effluent flows to the storm water drain.

Plant material and field experiments

Syzygium campanulatum and *Ficus microcarpa* are two common ornamental tree species native to tropical south-east Asia and are most widely grown ornamental plant species in Malaysia. One year–old uniform seedlings in terms of height and diameter of *S. campanulatum* and *F. microcarpa* were selected for the experiment. The experimental design was completely randomized with 15 seedlings for each species planted at the constructed wetland and another fifteen planted outside the wetland as a control with tropeptic haplorthox soil series (Table 1).

Physiological and morphological measurement

A Li-COR 6200 Photosynthesis System (Lincoln NE, USA) was used in recording the gas exchange parameters. Six seedlings per treatment were selected for this measurement, which was taken between 1030 and 1630 hours on 2 clear days of 2 October, 2005 and 3 March, 2006. Measurements were made on mature fully expanded leaflets (once for every seedling) in a 500–mL Plexiglass curvette for the 2 species and the control seedlings. From these measurements, net photosynthesis, transpiration rate and stomatal conductance were automatically computed. Height and diameter of the seedlings were measured every three months for a period of twelve months. Total height was measured with the aid of a metre ruler from the base of the stem at the soil surface level to the terminal bud of the main stem. Collar diameter was measured at the root collar with the help of a vernier caliper to the nearest 0.01 mm. Immediately after physiological measurement, six plants of each species were randomly selected for harvesting, and roots and shoots were excised. Total leaf area and fresh weights were recorded immediately, and dry weights of the vegetative material were oven dried at 60°C until constant weight was achieved. All the data were subjected to analysis of variance using SPSS and treatment means were separated by LSD with $P < 0.05$ level of significance.

Table 1. Treatments combination of seedlings planted at the constructed wetland and as control.

Treatments	Description of treatments
SW	*Syzygium campanulatum* seedlings planted at the constucted wetland.
SC	*Syzygium campanulatum* seedlings planted outside the constucted wetland as control.
FW	*Ficus microcarpa* seedlings planted at the constucted wetland.
FC	*Ficus microcarpa* seedlings planted outside the constucted wetland as control.

RESULTS

Physiological responses

Figure 1 shows the average photosynthetic photon flux of experimental days with values ranging from 1350 µmol $m^{-2}s^{-1}$, reaching a peak to a value of 2350 µmol $m^{-2}s^{-1}$ at 14.00 hr and declining to a value of 1480 µmol $m^{-2}s^{-1}$ at 18.00 hr. *S. campanulatum* seedlings planted at the constructed wetland recorded the highest photosynthetic rates with a value of 9.6 µmol $m^{-2}s^{-1}$ at 14.00 hr compared to *F. microcarpa* and plants planted outside the constructed wetland as control (Figure 2). Photosynthesis rates for both species planted at the constructed wetland (SW and FW) showed similar trends to stomatal conductance gradually increasing from 10.00 reaching a peak at 14.00 hr and decreased thereafter (Figure 2, 3). However, seedlings of both species grown under constructed wetland had higher photosynthetic values of 28 and 16% more compared to the control (SC and FC) (Figure 4). Likewise, *S. campanulatum* seedlings planted at constructed wetland had higher transpiration rate compared to *F. microcarpa*, with values of 12.9 µ mol $m^{-2}s^{-1}$ at 14.00 (Figure 5).

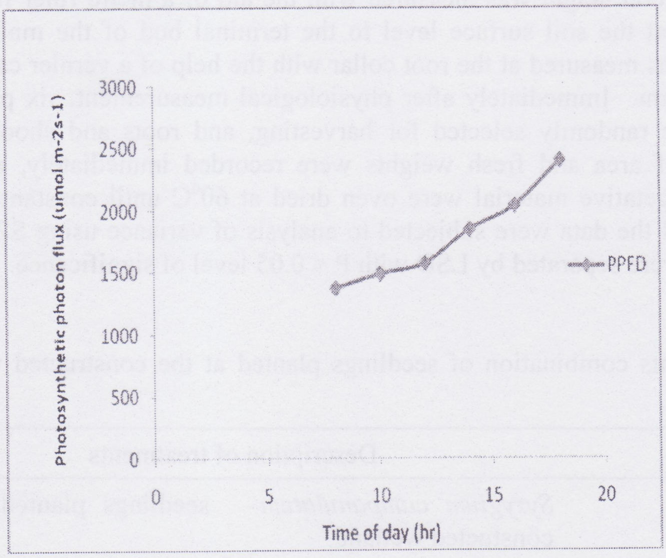

Figure 1. Average photosynthetic photon flux of experimental days, 2 October, 2005 and 3 March, 2006.

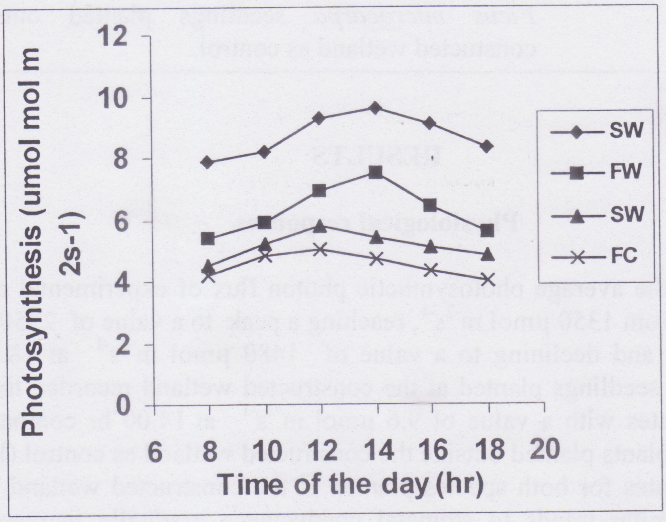

Figure 2. Photosynthetic rates of *F. microcarpa* and S. *campanulatum* seedlings planted at the wetland and outside the wetland as control. Results are mean of six measurements per treatment. Treatments are as in Table 1.

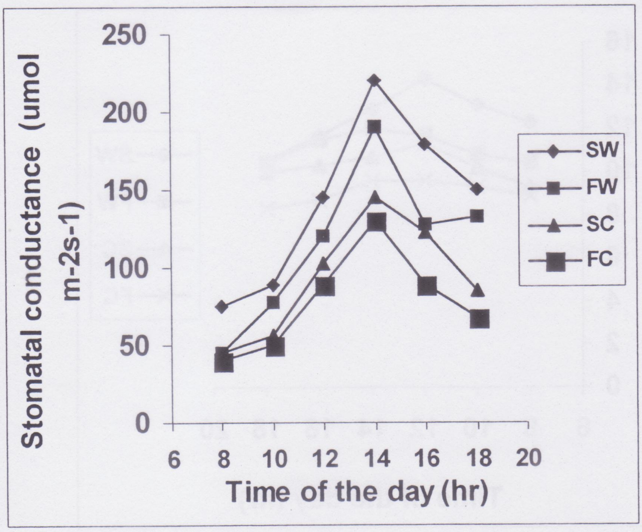

Figure 3. Stomatal conductance of *F. microcarpa* and S. *campanulatum* seedlings planted at the constructed wetland and outside the wetland as control. Results are mean of six measurements per treatment. Treatments are as in Table 1.

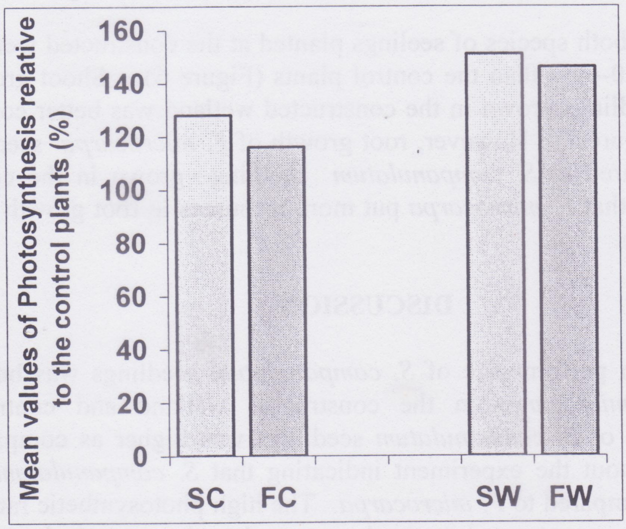

Figure 4. Mean values of photosynthesis of constructed wetland seedlings relative to the control plants. Treatments are as in Table 1.

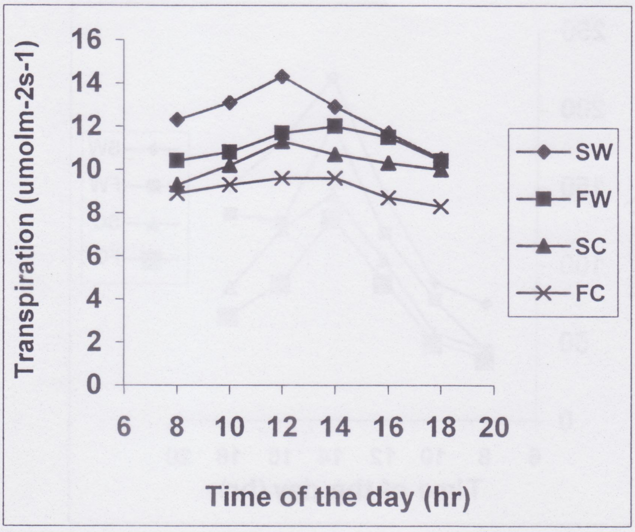

Figure 5. Transpiration rates of *F. microcarpa* and S. *campanulatum* seedlings planted at the constructed wetland and outside the wetland as control. Results are mean of six measurements per treatment. Treatments are as in Table 1.

Morphological responses

Height and dbh of both species of seelings planted at the constructed wetland were relatively higher, 20-40% than the control plants (Figure 6). Shoot growth of *S. campanulatum* seedlings grown in the constructed wetland was better compared to *F. microcarpa (*Figure 7). However, root growth.of *F. microcarpa* seedlings was 52% more compared to *S. campanulatum* seedling grown in the constructed wetland indicating that *F. microcarpa* put more resources in root growth compared to *S. campanulatum*.

DISCUSSION

The overall growth performance of *S. campanulatum* seedlings was better when compared to *F. microcarpa* in the constructed wetland and control. The photosynthetic rate of *S. campanulatum* seedlings was higher as compared to *F. micro*carpa throughout the experiment indicating that *S. campanulatum* is a fast growing species compared to *F. microcarpa*. The high photosynthetic rates of both species grown in the constructed wetland compared to the control plants indicated that the plants were able to utilize the available nutrient in the constructed wetland and perform normal physiological processes necessary for plant growth compared to the control plants. Ling (2006) reported that the constructed wetland contributed 53% of total removal of total suspended solid (TSS), 22-41% of nutrients, 46% of the total increase in dissolved oxygen (DO), 64% of reactive phosphorus and 61% total phosphorus. The results indicate that the waste water contained high level of nutrient useful for plant growth. The highest value of photosynthesis recorded by of *S. campanulatum* seedlings at 14.00 hr concurs with high stomatal conductance and transpiration rates. The higher photosynthetic rates, overall higher height and bigger dbh of seedlings planted at the constructed wetland compared to the control indicates the importance of constructed wetland serving as an alternative of fertilizer and water for landscape plants in an economic way. Since Kuching city aims to become a garden city by 2020, nursery container production of woody plants are likely to be one of horticultural practices with highest water demand per unit area and constructed wetland can serve as an alternative and important source of water. This explains why most nursery producers are now facing increasing pressure to avoid using high quality water supplies for irrigation (Lubello 2004).

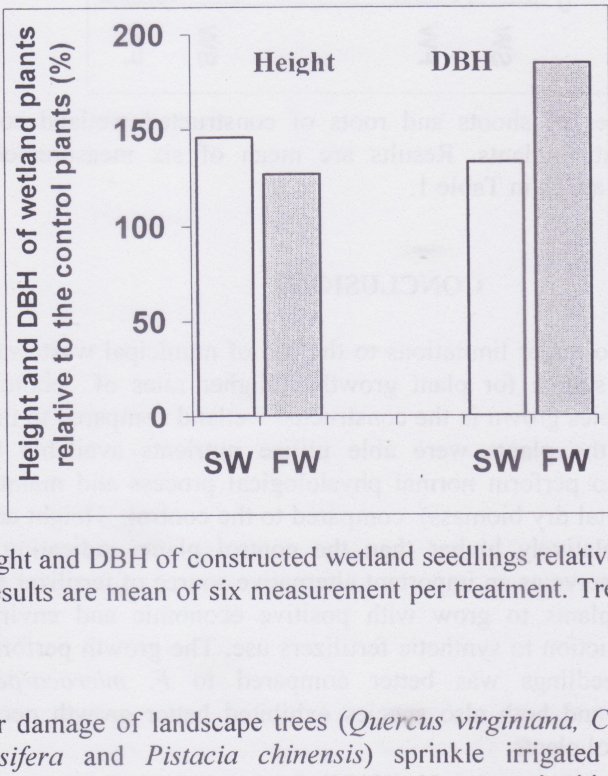

Figure 6. Height and DBH of constructed wetland seedlings relative to the control plants (%).Results are mean of six measurement per treatment. Treatments are as in Table 1.

Foliar damage of landscape trees (*Quercus virginiana, Chilopsis linearis, Prunus cerasifera* and *Pistacia chinensis*) sprinkle irrigated with reclaimed wastewater was reported by Devitt et al. (2003). However, in this experiment both species grew well without any foliar damage. Height and dbh of both species were relatively higher in the constructed wetland than control plants, indicating that the wetlands may serve as a source of fertilizer for the plants to grow as can be seen from the higher shoot and root dry mass of seedlings planted at the constructed wetland.

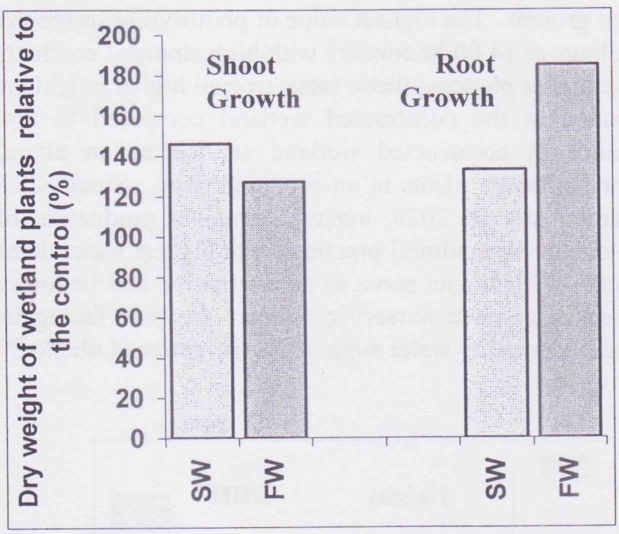

Figure 7. Mean values of shoots and roots of constructed wetland seedlings compared to the control plants. Results are mean of six measurements per treatment. Treatments are as in Table 1.

CONCLUSIONS

The results indicate no major limitations to the use of municipal wastewater as an alternative irrigation source for plant growth. Higher rates of photosynthesis recorded by both species grown in the constructed wetland compared to the control plants indicate that the plants were able utilize nutrients available from the constructed wetland to perform normal physiological process and maintain good growth (in terms of total dry biomass) compared to the control. Height and dbh of both species were relatively higher than the control plants indicating that the constructed wetlands serve as an important alternative source of fertilizer and water for some container plants to grow with positive economic and environmental aspects related to reduction to synthetic fertilizers use. The growth performance of *S. campanulatum* seedlings was better compared to *F. microcarpa* in the constructed wetland, and both also species exhibited better growth performance compared to the control plants.

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