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RESEARCH NOTE

The appearance of two duckweed species in sewage effluents in Yaoundé (Cameroon), and their possible use for sewage treatment and feed production

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Summary

1 The ecological and the economic significance of the spontaneous occurrence of *Lemna aequinoctialis* and *Wolffia arrhiza* (Lemnaceae) in some sewage effluents in Yaoundé is studied.

2 Physico-chemical analyses and laboratory scale experiments revealed the suitability of the effluents in supporting the growth of the two plant species. The standing biomass of the species was 5–12.5 kg fresh weight m^{-2}.

3 The nutrient contents of the Lemnaceae suggest their ability to produce biomass of good quality in these effluents. Farming of such crops will serve both as cost-effectively treatment of domestic sewage and provide cheap animal feed.

Keywords: *Lemna aequinoctialis, Wolffia arrhiza,* biomass, sewage, feed

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Introduction

Duckweeds (Lemnaceae) are the smallest flowering plants, often growing to form a thick blanket on still nutrient-rich freshwater (Skillikorn *et al.* 1993). Though ubiquitous, they grow fastest under warm sunny conditions (Templet & Valez 1987) typical for tropics regions. About 40 species belonging to four genera (*Lemna, Spirodela, Wolffia* and *Wolffiella*) are known (Hubac *et al.* 1984). These plants exhibit an enormous growth potential, doubling their biomass in less than four days (N.A.S. 1976; Hubac *et al.* 1984). Yields of 0.5 to 1.5 t ha^{-1} d^{-1} of fresh matter have been recorded from commercial cultivation of *Spirodela, Lemna* and *Wolffia* in Bangladesh (Skillikorn *et al.* 1993). Such a high productivity also indicates considerable capacity to remove nutrients from polluted water (Culley & Epps 1973; Rodgers *et al.* 1978; Culley *et al.* 1989; Oron & Willers 1989). They are also able to accumulate toxic chemicals such as 2,3,5-triiodobenzoïc acid, organochlorinated insecticides, chlorinated hydrocarbons and trace elements (Templet & Valez 1985, 1987). Except methionine, duckweed proteins satisfy the FAO amino acid requirement (Hubac *et al.* 1984; Skillicorn *et al.* 1993). Because of the high protein content duckweeds produce valuable feed for animals (Blake & Dubois 1982; N.A.S. 1976; Edwards 1990; Skillikorn *et al.* 1993).

Duckweeds are still entirely neglected plants in Cameroon; only two species (*Lemna aequinoctialis* and *Spirodela polyrhiza*) have been reported so far. Iketuonye (1988) identified and described aquatic plants in Cameroon but did not mention the existence of *Wolffia*. In 1992, this plant suddenly appeared in the settlement tanks of some domestic sewage treatment systems in Yaoundé, growing in association with *Lemna aequinoctialis*. This spontaneous occurrence is significant economically and ecologically, especially because of current interest in cost-effective sewage treatment technologies and associated applications (Agendia 1995; Agendia *et al.* 1988).

This research note presents some physicochemical characteristics of the sewage effluents in which *Lemna aequinoctialis* and *Wolffia arrhiza* were found. It also describes their growth potential and the chemical composition in these effluents. In connection with the acute problems of sewage treatment and provision of cheap protein-rich animal feed in a local context, the ecological and economic significance of their occurrence in these effluents are discussed.

Material and methods

STUDY SPECIES AND SITE

Wolffia arrhiza and *Lemna aequinoctialis* (= *L. paucicostata* Hegelm. ex Hegelm = *L. perpusilla* Torrey) were identified in the settlement tanks of three sludge systems in Yaoundé using the key in Hubac *et al.* (1984). The sludge systems were constructed in the early days of independence to treat sewage from the University Teaching Hospital, the Cité Verte and the Messa residential quarters but have since ceased to function due to poor maintenance. The break down of the aeration devices stopped water disturbance in the tanks which now support dense mats of *W. arrhiza* and *L. aequinoctialis*, probably transported there by aquatic birds.

MEASUREMENTS

The standing biomass of the two species was estimated by randomly harvesting and weighing the total fresh matter per m^2. The physicochemical characteristics (temperature, pH, conductivity, total dissolved solids, suspended matters, phosphates, ammonia, nitrates, COD, BOD5) of the sewage effluents were measured by routine methods described in Water Analysis Handbook (Hach 1992). Samples were collected from the inlet pipe of the different settlement tanks twice daily (8 a.m. and 2 p.m.) for 30 days in January and February 1996.

Chemical characteristics of the plants growing in the University sewage (water, K, N, P, and chlorophyll content) were also investigated on four randomly collected samples. Weighted fresh plants were oven dried till constant weight and their water content (% fresh matter) was calculated from weight differences. After wet-ashing 0.2 g of dry pulverised plant sample, the K content was determined by flame photometry, while N and P contents were determined using Nessler and Phosphovanadate methods respectively (Hach 1992). Crude protein was estimated on the basis of the nitrogen content (crude protein = N x 6.25). Chlorophyll was extracted in 80% acetone at 4 °C and the absorbance taken at 645 nm and 663 nm using a spectrophotometer. Arnon's method (1949) was then used to calculate the chlorophyll content of fronds.

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Table 1. Physico-chemical characteristics of different sewage effluents supporting the growth of Lemna paucicostata *and* Wolffia arrhiza *(means ± 1SE;* n = *60)*

Physico-chemical parameters	Cité Verte	University	Messa
Temperature (°C)	20.0 ± 0.0	24.0 ± 0.0	23.5 ± 0.1
pH	7.3 ± 0.1	7.1 ± 0.2	7.1 ± 0.2
Conductivity (CND, µS Cm^{-1})	388 ± 16	193 ± 8	818 ± 90
Total Disolved Solids (TDS, mg l^{-1})	195 ± 8	97 ± 5	436 ± 36
Suspended Solids (SS, mg l^{-1})	18 ± 1	25 ± 7	158 ± 54
Colour (PtCo units)	180 ± 6	112 ± 40	478 ± 115
Chemical Oxygen Demand (COD, mg l^{-1})	56 ± 10	123 ± 34	237 ± 68
Dissolved Oxygen (DO, mg l^{-1})	2.4 ± 0.1	5.9 ± 2.2	1.9 ± 0.0
PO_4^{3-} (mg l^{-1})	1.9 ± 0.6	5.4 ± 1.3	24.9 ± 9.4
NO_3^- (mg l^{-1})	3.4 ± 0.3	7.9 ± 1.2	8.3 ± 2.4
SO_4^{2-} (mg l^{-1})	8.5 ± 0.5	15.1 ± 2.1	19.7 ± 3.3
NH_4^+ (mg l^{-1})	28.3 ± 2.3	34.8 ± 3.3	43.7 ± 13.9

GROWTH EXPERIMENT

Laboratory studies were conducted to evaluate the growth potential of the Lemnaceae in the sewage effluents. Three experimental media with three repetitions containing tap water (control), the University and the Cite Verte wastewaters were prepared in 2000 ml plastic containers in which 20 individuals of each plant were cultivated at room temperature (25 °C) and a photoperiod of 12 hours. Growth of the plants was evaluated every five days for a month from the number of new plants produced.

Results and discussion

PHYSICO-CHEMICAL CHARACTERISICS OF THE EFFLUENTS

The two species grew in nearly neutral effluents (pH 7.1–7.3) of moderate (University sewage) to high pollution (Messa sewage) under warm sunny conditions (Table 1). The Messa effluent was highly mineralised (CND 818 µs cm^{-1}) with much solids (SS 158.5 mg l^{-1}; TDS 436 mg l^{-1}) and organic matter (COD 237 mg l^{-1}) but low dissolved O_2 content (1.86 mg l^{-1}). The Cité Verte sewage effluent was lowly mineralised (CND 388 µS cm^{-1}) with less suspended (18 mg l^{-1}) and dissolved solids (195 mg l^{-1}). The University effluent showed moderate level of mineralisation (CND 193 µS cm^{-1}) and content of dissolved solids (TDS 97 mg l^{-1}). Calm permanent waters rich in decaying organic matter, like these effluents, are known to support the growth of duckweeds (Raynal-Roques 1980; Skillicorn *et al.* 1993).

DUCKWEED YIELD AND CHEMICAL CHARACTERISTICS

In the Cité Verte, the University and the Messa wastewater effluents, yields of 10, 5 and 12.5 kg m^2 of fresh plant biomatter were recorded, respectively, for the two duckweed species. Chemical analyses of the plants (Table 2) revealed high nutrient content, suggesting the ability to produce large quantities of biomass. Indeed, outflows from the settlement tanks were shown to be significantly lower in nutrients (nitrates and phosphates), and this was attributed to the absorption by the plants for growth (Agendia *et al.* 1994). Edwards *et al.* (1992) described also the effec-

Table 2. *Chemical analyses of* Lemna paucicostata *and* Wolffia arrhiza *(means ± 1SE;* n = *4; f-wt, fresh weight; d-wt, dry weight; -, values not measured)*

Nutrients and chlorophyll content	*Lemna*	*Wolffia*
Na (% d-wt)	1.1 ± 0.2	0.03 ± 0.00
K (% d-wt)	7.1 ± 0.5	4.5 ± 0.5
N (% d-wt)	4.8 ± 0.1	-
P (% d-wt)	1.1 ± 0.2	-
Crude protein content (% d-wt)	29.9 ± 0.6	-
Water content (% f-wt)	98.0 ± 0.3	97.0 ± 0.6
Chlorophyll a content (mg g $f\text{-}wt^{-1}$)	2.5 ± 0.1	2.4 ± 0.2
Chlorophyll b content (mg g $f\text{-}wt^{-1}$)	0.8 ± 0.1	0.7 ± 0.0
Chl a + Chl b (mg g $f\text{-}wt^{-1}$)	3.3 ± 0.1	3.1 ± 0.1
Chl a/Chl b	3.1 ± 0.1	3.4 ± 0.2

Table 3. *Growth potential (frond production) of* Lemna paucicostata *and* Wolffia arrhiza *in sewage effluents (means ± 1SE,* n = *3)*

Effluent	0	5	10	15	20	25 days
Lemna aequinoctialis						
Tap water	20 ± 0	69 ± 9	91 ± 26	91 ± 9	87 ± 22	80 ± 22
University sewage	20 ± 0	110 ± 10	333 ± 43	799 ± 51	811 ± 71	1032 ± 120
Wolffia arrhiza						
Tap water	20 ± 0	22 ± 2	22 ± 2	18 ± 2	13 ± 1	17 ± 6
University sewage	20 ± 0	41 ± 9	83 ± 19	153 ± 33	120 ± 4	137 ± 25
Cité Verte sewage	20 ± 0	129 ± 17	207 ± 43	339 ± 59	274 ± 11	66 ± 2

tiveness of duckweeds in accumulating nitrogen and phosphorus, and as a consequence the world-wide applications of duckweed-based technologies for wastewater treatment. The chlorophyll content was within the range observed in other plant species (Heller 1984).

In the laboratory, the effluents also supported the growth of the two duckweeds (Table 3). *Lemna* demonstrated considerable growth in the University effluent and *Wolffia* performed well in the Cite Verte effluent. From 20 *Lemna* fronds initially cultivated, 799 fronds were obtained in 15 days (nearly 40 times more) and by the 25th day, as much as 1032 fronds were produced (almost 52 times higher). *Lemna* grew poorly in tap water (control) due to its lower nutrient concentration. In the Cité Verte effluent, *Wolffia* produced 340 fronds from the 20 originally cultivated individuals in 15 days (17 times more), but this rapid growth dropped thereafter. Similarly, its growth in tap water (control) was poor. Skillicorn *et al.* (1993) reported that individual fronds of a Lemnaceae are capable of producing as many as ten generations over a period of ten days to several weeks before dying. The decreasing growth (frond production) of *Wolffia* observed after 15 days could be due to overcrowding. Indeed, fronds piled up on each other, forming a thick mat on the water surface after this period.

The rapid growth of duckweeds in nutrient-rich effluents explained the high yields usually recorded, e.g. maximum yields of about 15 g dry wt m^{-2} d^{-1} (equivalent to 55 t dry wt ha^{-2} $year^{-1}$) using domestic sewage have been reported (Gaigher & Short 1986; Oron & Willer 1989).

Conclusions

Because of their high productivity and high nutritional value in wastewater effluents duckweeds have potential ecological and economic significance, i.e. treatment of wastewater, production of high protein animal feed (Traux *et al.* 1972; Culley & Epps 1973) and use in aquaculture. Like most towns in developing countries, Yaoundé (Cameroon) is now faced with the acute problems of cost-effective treatment of the enormous amount of sewage and provision of cheap domestic animal feed in order to produce enough food for the rapid growing population. These duckweeds can successfully be farmed in sewage effluents to alleviate both problems.

Sewage treatment systems with duckweeds are simple lagoons. Cultivated in such systems, the plants act as a nutrient sink, absorbing nutrients from the wastewater. The ions are then removed permanently from the effluent as the plants are harvested (Skillicorn *et al.* 1993). Such systems differ from conventional facilities in that they can achieve a significantly higher level of nutrient removal from the wastewater and remove oxygen consuming substances and pathogenic organisms to an extent comparable to other systems. Successful use of duckweeds in sewage treatment has been reported for many parts of the world. Whitehead *et al.* (1987) described an improvement of 97, 59, 46 and 21% removal for N-NH_3, N-NO_3, N (total) and P, respectively, using a *Lemna*-based wastewater treatment system. According to Hubac *et al.* (1984) duckweeds can absorb and accumulate heavy metals to a concentration factor of 5,000–10,000. They are also efficient in the absorption of chlorinated hydrocarbons (Templet & Valez 1985). Because they are ubiquitous and effective as nutrient sinks, duckweed-based sewage treatment technologies are now exploited in many parts of the world (Edwards *et al.* 1992).

In a tropical country like Cameroon, harvested plants can feasibly be used to produce high protein feed. Such feed can be a suitable protein component in poultry diets, if the problems of toxic substances in the waste water can be avoided. Fish have also been reported to consume duckweed fronds (Hassan 1986) and thus allow aquaculture for fish production. For example in Thailand duckweeds are widely used to feed cows and chickens and in fish culture (Hubac *et al.* 1984). Similar applications may be possible in Cameroon.

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References

Agendia, P. (1995) *Treatment of sewage using aquatic plants. Case of the Biyeme Assi domestic sewage (Yaoundé).* PhD thesis, University of Yaoundé I.

Agendia, P., Charbonnel, Y., & Valet, G. (1988) Preliminary trials of several aquatic plants to treat Biyem-Assi (Yaoundé) domestic sewage. *Cameroon Journal of Biological and Biochemical Sciences,* **1**, 9–16.

Agendia, P., Fonkou, T., Mefenya, R. & Sonwa, D. (1994) Performance of some sewage treatment systems in Yaoundé. *Revue de la Société Camerounaise de Naturalistes,* **1**, 10–25.

Arnon, D.I. (1949) Copper enzymes in isolated chloroplasts. Polyphenoloxydase in *Beta vulgaris. Plant Physiology,* **24**, 1–15.

Blake, G. & Dubois, J.P. (1982) *L'épuration des eaux par les plantes aquatiques.* Association Française pour l'Etude des Eaux, Paris.

Culley, D.D. & Epps, E.P. (1973) Use of duckweeds for waste treatment and animal feed. *Journal of Water Pollution Control Federation,* **45**, 337–347.

Culley, D.D., Rejmankova, E., Kiet, J. & Frye, J.B. (1989) Production, chemical quality and use of duckweeds (Lemnaceae) in aquaculture, waste management and animal feed. *Journal of the World Mariculture Society,* **12**, 27–49.

Edwards, P. (1990) An alternative excreta-reuse strategy for aquaculture: the production of high protein animal feed. *Wastewater-feed Aquaculture* (eds. P. Edwards & R.S.V. Pullin), pp. 209–221. Environmental Sanitation Information Center, AIT, Bangkok, Thailand.

Edwards, P., Hassan, M.S., Chao, C.H. & Pacharaprakiti, C. (1992) Cultivation of duckweeds in septage-loaded earthen ponds. *Bioresource Technology,* **40**, 109 –117

Gaigher, I.G. & Short, R. (1986) An evaluation of duckweed (Lemnaceae) as a candidate for aquaculture in South Africa. *Aquaculture* (eds. R.D. Walmsley & J.G. Wan), pp. 81–90. Foundation for Research and Development, Pretoria.

Hach (1992) *Hach Water Analysis Handbook.* Hach Company, Loveland, Colorado.

Hassan, M.S. (1986) *Cultivation of duckweeds* Lemna *and* Spirodela *as feed for Nile Tilapia.* MSc thesis, Asian Institute of Technology, Bangkok, Thailand.

Heller, R. (1984) *Physiologie Végétale 1. Nutrition.* Masson II, Paris.

Hubac, J.M., Beuffe, H., Blake, G., Corradi, M., Dutartre, A., Vaucouloux, M. & Vuillout, M. (1984) *Les plantes aquatiques utiles: Les lentilles d'eaux ou Lemnacées. Utilisation en phytoépuration et valorisation.* Association Française pour l'Etude des Eaux, Paris.

Iketuonye, M. (1988) *A contribution to the study of aquatic macrophytes in Cameroon: their biology and phytosociology in natural ecosystems and in phytodepurational systems.* MSc thesis, University of Yaoundé.

N.A.S. (1976) *Making Aquatic Weeds Useful. Some Perspectives for Developping Countries.* National Academic of Science. Washington D.C.

Oron, G. & Willers, H. (1989) Effect of wastes quality on treatment efficiency with duckweed. *Water Science Technology,* **21**, 639–45.

Raynal-Roques, A. (1980) Les plantes aquatiques (plantes à fleurs et fougères). *Flore et Faune de l'Afrique Sahelo-Soudanienne, tome 1* (eds. J.-R. Durand & C. Lévêque), p. 63–152. ORSTOM, Paris.

Rodgers, J.H., Cherry, D.S. & Guthrie, R.K. (1978) Cycling element of duckweed (*Lemna perpusilla*) in an ash settling basin and swamp drainage system. *Water Research,* **12**, 765–770.

Skillicorn, P., Spira, W. & Journey, W. (1993) *Duckweed Aquaculture: a New Aquatic Farming System for Developping Countries.* A World Bank Publication, Washington D.C.

Templet, P.H. & Valez, M. (1985) *Biological Removal of Chlorinated Hydrocarbons from Water.* Louisiana Water Resources Research Institute, Virginia.

Templet, P.H. & Valez, M. (1987) Removal of phenol from water by duckweed (Lemnaceae). *Aquatic Plants for Water Treatment and Resource Recovery* (eds. K.R. Reddy & W.H. Smith), pp. 570–571. Magnolia Publishing, Orlando.

Traux, R.E., Culley, D.D., Griffith, M., Johnsonand, W.A. & Wood, J.P. (1972) Duckweed for chick feed? *Louisianna Agriculture,* **16**, 8–9.

Whitehead, A.J., Lo, K.V. & Bully, N.R. (1987) The effect of hydraulic retention time on duckweed cropping wastewater. *Aquatic Plant for Water Treatment and Resource Recovery* (eds. K.R. Reddy & W.H. Smith), pp. 697–703. Magnolia Publishing, Orlando.

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