A Comparative Study on the Growth Characteristics of Three Wetland Sedges in Dairy Wastewater

R.T. Nilusha*[1,3], S.M.W. Ranwala[2], W.R.K. Fonseka[1], D.M.H.S. Dissanayake[1]

[1]Environmental Technology Section, Industrial Technology Institute, 363, Bauddhaloka Mawatha, Colombo 07, Sri Lanka

rathmalgodage@gmail.com

ABSTRACT

Selection of appropriate plant species for Constructed Wetlands (CW) is a vital factor that significantly contributes to enhance the treatment efficiency of CW. In the present study potential use of Schoenoplectus grossus, Eleocharis dulcis, and Fimbristylis dichotoma (Family Cyperaceae) in removal of nutrients in dairy wastewater was assessed. Plants (n=16 per species) were established in plastic pots (10L) containing natural wetland bog soil (N: P: K, 10:2.5:1) and a mixture of top soil and compost (N: P: K, 2:2:1).Tillering capacity, tiller diameter and height of plants were recorded weekly for seven weeks. Thereafter plants were fed with diary wastewater for next seven weeks in which one liter of diluted and neutralized dairy wastewater was added on weekly basis per pot. The COD of dairy wastewater varied in the range of 45mg/L-435mg/L.Control groups (n=8) were maintained with addition of tap water. Plant dry biomass was recorded at the end of 14th week. Results affirmed that substrate type has not significantly impacted on the growth of three wetland sedges species at P >0.05. Application of dairy wastewater has not affected the growth of all three plant species when grown in mixed substrate (P > 0.05). Nevertheless Fimbristylis dichotoma plants grown in bog soil indicated a significant difference in growth compared to others by increasing Root/Shoot ratio reflecting its ability to withstand dairy wastewater in CW. Further research is needed to examine the threshold dairy wastewater concentration for Fimbristylis dichotoma and its removal efficiency of nutrients.

Keywords: *Constructed Wetland technology, Dairy wastewater, Wetland sedges*

INTRODUCTION

Constructed Wetlands (CW) play a vital role in effectively removing pollutants in domestic (Arivoli, 2013), industrial (Feleke, 2011), urban (Leto et al., 2013) and agricultural (Higgins et al., 1993) wastewaters. They are simple engineered systems designed to mimic the functions of natural wetlands. Despite the popularity of CW in worldwide, few studies have been carried out on CWs in Sri Lanka. It has been well documented and demonstrated that there is a wider potential of this technology to remove organic matter in different types of wastewaters such as dairy (Perdomo et al. , 2000; Drizo et al., 2006), landfill leachate (Benyamine et al, 2004), petrochemical (Wallace., 2002) and many more industries (Vymazal, 2010). A constructed wetland comprises of a properly-designed basin that contains water column and wetland vegetation on a growing medium as main elements (Dordio et al., 2008). Thus vegetation is an integral and conspicuous feature of CWs that significantly contributes for removal of nutrients primarily via phytoremediation. Therefore selection of an appropriate plant for phytoremediation in CW is a vital factor. Generally plants are selected on the basis of previous research, expert opinions, and local availability and after use values (Mojiri, 2012). Simultaneously, selection of suitable growing media for establishment of plants in CW becomes equally important in management of CWs (Shasikala et al, 2010).

Applicability of CWs in treatment of dairy wastewater was given special attention by scientists over the last years due to the threatening impacts of untreated diary wastewater (Kolhe and Power, 2011).

[2] *Department of Plant Sciences, Faculty of Science, University of Colombo,*
[3] *Faculty of Graduate Studies, University of Colombo*

Eutrophication and deterioration of water quality, and subsequent damage to aquatic fauna and flora in aquatic systems are the most pronounced and serious impacts commonly reported (Gerber et al, 2005) as untreated dairy wastewater contains dissolved sugars and proteins, fat residues, additives and microbial assemblages.

If the goal of the CW is to treat dairy wastewater, the ability of plant species to uptake and tolerate dairy wastewater should be clearly understood before introducing into CW (Kostinec, 2001). During the process of phytoremediation in a CW, a physiological stress on plants could be expected at the time when plants are exposed to dairy wastewater. Therefore it is necessary to identify the ability of growth tolerance of plants in the presence of dairy wastewater before recommending them for use in CW. Wetland plant species have been already used for phytoremediation purpose in CW once they had demonstrated tolerability to growth depending on the type, amount and frequency of application of pollutants that they had received (Taylor, 2009).

However plant growth can be inhibited or accelerated upon receiving of such pollutants. More than 150 plant species had been experimented for the treatment of different types of wastewater in CW (Vymazal, 2007). Among them cattails, reeds, rushes, bulrushes and sedges are the most commonly used higher plants (Cristina et al, 1995).

This study aimed to identify responses of plant growth when exposed to dairy wastewater. The first objective was to examine the effect of vegetative growth of three common wetland sedges namely *Schoenoplectus grossus* (Giant bulrush), *Eleocharis dulcis* (Chinese water chestnut) and Fimbristylis *dichotoma* (Tall fringed rush) exposed to dairy wastewater. The second objective was to identify the most suitable growing medium for effective phytoremediation (Bog soil and artificial substrate mixture).

MATERIALS AND METHODS

Study site

This study was conducted under controlled conditions in the premises of Industrial Technology Institute (ITI) (latitude 06° 54' 18"N, longitude 079° 52' 14"W), 363, Baudhaloka Mawatha, Colombo 07, Sri Lanka from May-November 2014.The mean air temperature of study site ranged from 27^{0}C to 31^{0}C, light intensity 8200lx to 48300lx 12h daylight, humidity from 66% to 86% over four month experimental period. Plant pots were kept outdoor exposed to the sun but avoided exposure to rains.

Test plant species

Rhizomatous cuttings of *Schoenoplectus grossus* (Giant Bulrush), *Eleocharis dulcis* (Chinese water chestnut) and *Fimbristylis dichotoma* (Fringe-rush) of family *Cyperaceae* were obtained from Rush and Reed Conservation Centre, Horana. Selection of plants was based on literature, expert opinions and knowledge, local availability and after use values.

Growth condition and experimental design

This study was conducted in two phases (Phase I and Phase II). In the first phase thirty two rhizomatous cuttings of each species approximately 15 cm size of were obtained from living plants. Sixteen cuttings from each species were planted in 10L black plastic pots (two per pot) containing 6L of natural wetland bog soil in which pH: 6.5, N: 0.2% P: 0.05% K: 0.02% (N:P:K, 10:2.5:1) respectively. Another set of sixteen cuttings from each species were planted in pots (two per pot) containing 6L of mixture of compost and top soil (1:2 ratio) in which pH: 7.4 N: 0.1% P: 0.1% K: 0.05% (N: P: K, 2:2:1) respectively, i.e. as per soil chemical analysis procedures by Jackson (1958). Pots were arranged in completely randomized design with 8 replicates. Plants were acclimatized for ten days prior to monitoring of plant growth parameters (tiller capacity, tiller/shoot diameter and height of plant) which were recorded weekly for seven consecutive weeks.

In the second phase, pots containing each species established in natural bog and soil + compost mixture, were divided into control and treatment groups (n=4).Treatment included exposure of plants to dairy wastewater, neutralized and diluted prior to addition. Addition of tap water was considered as the control. The wastewater was added every week from 7th to 14th weeks. The Chemical Oxygen Demand (COD) of wastewater fluctuated within the range of 45mg/L-435mg/L. This could not be maintained at a specific value as dairy wastewater was obtained directly from the industrial waste.

Pots of treatment were saturated with 1L of, dairy wastewater of each of COD levels .The retention time was 7 days. Plant growth measurements mentioned above were recorded for the following seven weeks.

Plant growth measurements

The distance from the ground to the top most internode of the shoot/tiller was considered as the height. Shoot/Tiller diameter was recorded in each tiller/shoot using digital vernier caliper and an average value was obtained per plant. Number of tillers/shoots per plant (tillering capacity) was also obtained. At the end of the experiment all plants were uprooted carefully, washed, air dried and dry weight of shoots and roots were recorded after oven drying for 48 hours at 80^{0}C until constant weight was observed.

Data analysis

Analysis of Variance (ANOVA) General Linear Model (GLM) was performed to compare tiller/shoot capacity, tiller/shoot height and diameter at 43 days after (7th week, end of Phase I) and another 44 days of treatment (14thweek, end of Phase II) and dry weight at the end of the experiment under the effect of two substrate types and addition of dairy wastewater. Tukey Post-hoc analysis was performed to compare means of respective growth parameters. All statistical analysis tests were performed at 5% significance level using MINITAB 14 software package.

RESULTS

Tables 01 and 02 summarize the significant growth responses of *Schoenoplectus grossus, Eleocharis dulcis* and *Fimbristylis dichotoma* plants to substrate types and treatments in Phase I and Phase II respectively. Tillering capacity, tiller height and diameter of different species of plants have shown different responses to substrate type and treatments.

The effect of substrate on the plant growth (Phase I)

Comparison of differences growth parameters of sedges with respect to substrate types are presented in Table 03. It was identified that tillering capacity was comparatively high in *Eleocharis dulcis* plants in both substrate types and the highest tillering capacity was obtained when grown in the mixed substrate. But *Fimbristylis dichotoma* plants were the tallest among other species when grown in both substrate types. *Schoenoplectus grossus* plants when grown in mixed substrate were taller than when they were grown in bog soil. Tiller diameters of *Schoenoplectus grossus* were also higher in both substrate types [Figures 01(a) and (b)].

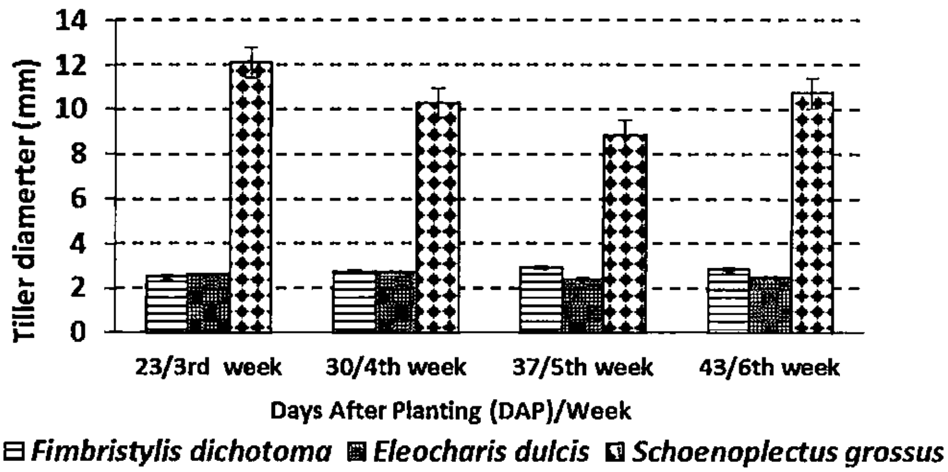

Figure 01(a): Tiller diameter of three wetland sedges grown in bog soil for 43 days, of seven weeks (Means of 16 replicates ± SE represented)

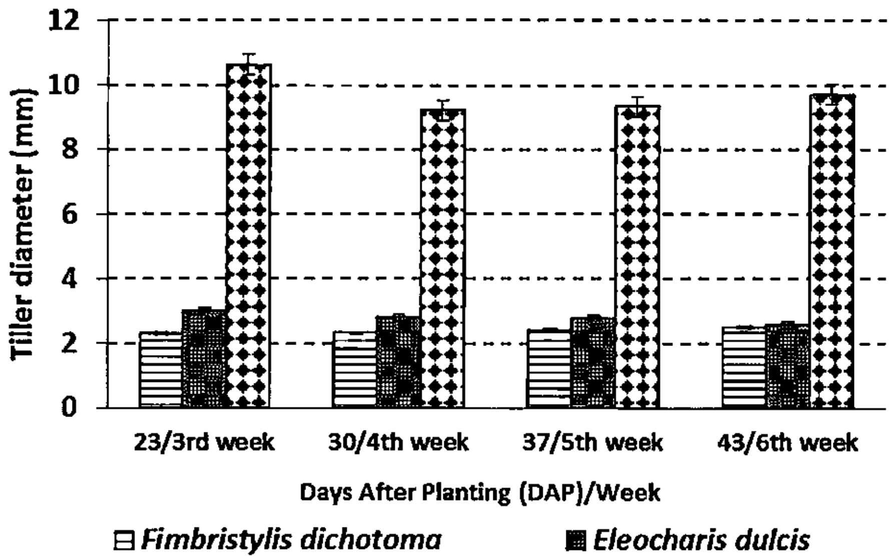

Figure 01(b): Tiller diameter growth of three wetland sedges grown in substrate mixture for 43 days or seven weeks (Means of 16 replicates ± SE represented)

Table 01: Summary of [illegible] different substrate types at the end of Phase I (7 weeks) (DAP denotes Days After Planting)

Growth Parameter	Source	P	Significance	Comments
Tillering capacity	Species	0.000	***	*Eleocharis dulcis* plants showed the highest tiller capacity than other two species in both substrates
	Days After Planting (DAP)	0.000	***	*Eleocharis dulcis* plants have shown rapid tiller growth
	Substrate type	0.866	ns	-
	Species x DAP	0.000	***	*Eleocharis dulcis* plants have shown highest tillering capacity in both substrates
	Species x Substrate type	0.033	***	*Eleocharis dulcis* plants showed higher tillering capacity in mixed substrate than other two species
	DAP x Substrate type	0.861	ns	-
	Species x DAP x Substrate type	1.000	ns	-
Tiller/Shoot height	Species	0.000	***	*Fimbristylis dichotoma* plants showed higher tiller height and *Schoenoplectus grossus* plants have showed the lowest in both substrate types
	DAP	0.000	***	Tiller height growth of *Fimbristylis dichotoma* plants was stagnated around fifth week (37DAP) in bog soil
	Substrate type	0.228	ns	-
	Species x DAP	0.010	***	*Fimbristylis dichotoma* plants showed higher tiller height with time
	Species x Substrate type	0.000	***	*Fimbristylis dichotoma* plants showed higher height in bog soil than the other two species
	DAP x Substrate type	0.666	ns	-
	Species x Day x Substrate type	0.711	ns	-
Tiller/Shoot diameter	Species	0.000	***	*Schoenoplectus grossus* plants showed highest diameter growth than other two species in both substrates
	Substrate type	0.014	***	Tiller diameter of *Schoenoplectus grossus* was higher in bog soil than other two species
	DAP	0.000	***	Diameter growth of *Schoenoplectus grossus* plants was suppressed around fifth week (37DAP) in both substrates
	Species x Substrate type	0.001	***	Tiller diameter of *Schoenoplectus grossus* was higher in bog soil than in the mixture than the other two species
	Species x DAP	0.000	***	Diameter of *Schoenoplectus grossus* plant was suppressed around fifth week in (37 DAP) bog soil
	Substrate type x DAP	0.235	ns	-
	Species x Substrate type x DAP	0.31	ns	-

Table 02: Summary of growth responses of *Schoenoplectus grossus, Eleocharis dulcis* and *Fimbristylis dichotoma* plants established in two different substrate types after 44 days of treatment with dairy wastewater (End of Phase II-Week 14)

Growth Parameter	Source	P	Significance	Comments
Tillering capacity	Species	0.000	***	Tillering capacity of *Eleocharis dulcis* was higher than the other species
	Days After Planting (DAP)	0.000	***	Tillering capacity of *Eleocharis dulcis* was higher over time
	Substrate type	0.026	***	Tillering capacity of *Eleocharis dulcis* was higher in mixed substrate
	Treatment	0.370	ns	-
	Species x DAP	0.023	***	*Eleocharis dulcis* plants showed higher tillering capacity than other two species while tillering capacity of *Fimbristylis dichotoma* plants' was suppressed in the fifth week in treatment group in mixed substrate
	Species x Substrate type	0.001	***	Tillering capacity of *Eleocharis dulcis* was higher than the other species in mixed substrate
	DAP x Substrate type	0.001	***	Tillering capacity of *Schoenoplectus grossus* plants was decreased in mixed substrate in the fifth week
	Species x Treatment	0.009	***	*Eleocharis dulcis* plants grown in bog soil showed high tillering capacity among three species.
	Species x DAP x Substrate type	0.958	ns	-
Tiller/Shoot height	Species	0.000	***	*Fimbristylis dichotoma* plants showed the highest tiller height in treatment group in both substrates *Eleocharis dulcis* plants showed the lowest tiller height
	DAP	0.101	ns	-
	Substrate type	0.264	ns	-
	Treatment	0.749	ns	-
	Species x DAP	0.022	***	*Fimbristylis dichotoma* plants showed the greatest tiller height over time
	Species x Treatment	0.008	***	*Fimbristylis dichotoma* plants performed better after treatments added
	Species x Substrate type	0.743	ns	-
	DAP x Substrate type	0.703	ns	-
	Species x Day x Substrate type	0.747	ns	-
Tiller/Shoot diameter	Species	0.000	***	*Schoenoplectus grossus* plants showed high tiller diameter growth in both substrates whereas *Eleocharis dulcis* showed the lowest.
	Substrate type	0.285	ns	-
	DAP	0.43	ns	-
	Treatment	0.102	ns	-
	Species x Substrate type	0.439	ns	-
	Species x DAP	0.736	ns	-
	Species x Treatment	0.327	ns	-
	Substrate type x DAP	0.925	ns	-
	Species x Substrate type x DAP	0.932	ns	-

	Species x Substrate type x DAP	0.932	ns	-

Growth Parameter	Source	P	Significance	Comments
Tiller/Shoot dry weight	Species	0.000	***	*Schoenoplectus grossus* plants showed higher shoot dry weight than others
	Substrate type	0.092	ns	-
	Treatment	0.553	ns	-
	Species x Substrate type	0.214	ns	-
	Species x Treatment	0.764	ns	-
	Substrate type x Treatment	0.951	ns	-
	Species x Substrate type x Treatment	0.898	ns	-
Root dry weight	Species	0.000	***	*Fimbristylis dichotoma* plants under treatment grown in bog soil showed high root dry weight *Schoenoplectus grossus* plants showed high root dry weight in mixed substrate in both control and treatment. *Eleocharis dulcis* plant showed lowest root dry weight in all both substrate types
	Substrate type	0.480	ns	-
	Treatment	0.265	ns	-
	Species x Substrate type	0.163	ns	-
	Species x Treatment	0.080	ns	-
	Substrate type x Treatment	0.088	ns	-
	Species x Substrate type x Treatment	0.335	ns	-
Root/Shoot dry weight ratio	Species	0.001	***	*Fimbristylis dichotoma* plants grown under treatments group in both substrates have showed high Root/Shoot dry weight ratio than other two species in both substrates. *Eleocharis dulcis*plant showed the lowest Root /Shoot dry weight in both substrate types
	Substrate type	0.078	ns	-
	Treatment	0.598	ns	-
	Species x Substrate type	0.380	ns	-
	Species x Treatment	0.171	ns	-
	Substrate type x Treatment	0.226	ns	-
	Species x Substrate type x Treatment	0.554	ns	-

able 03: Growth parameters of *Schoenoplectus grossus, Eleocharis dulcis* and *Fimbristylis dichotoma* established in bog and mixed substrate after 43 days (End of Phase I)-See Table 01 for comments

Species	Growth in substrate mixture types					
	Tillering capacity		Tiller height		Tiller diameter	
	Bog	Mixed	Bog	Mixed	Bog	Mixed
Fimbristylis dichotoma	1.93 ± 0.21^{b1}	1.19 ± 0.13^{b1}	47.63 ± 0.23^{a1}	41.04 ± 1.83^{a1}	2.80 ± 0.06^{b1}	2.41 ± 0.04^{b1}
Eleocharis dulcis	2.98 ± 0.26^{a2}	3.64 ± 0.33^{a3}	25.99 ± 1.01^{b1}	24.9 ± 0.86^{b1}	2.55 ± 0.04^{b1}	2.79 ± 0.04^{b1}
Schoenoplectus grossus	0.82 ± 0.09^{b1}	0.80 ± 0.06^{b1}	18.27 ± 1.58^{c1}	30.74 ± 2.8^{c1}	10.57 ± 0.66^{a2}	9.63 ± 0.27^{a3}

*Numbers followed by same number in each row are not significantly ($P < 0.05$) different. **Numbers followed by same letter in each column are not significantly ($P < 0.05$) different. ***Values indicate the Mean ± Standard Error of Mean (Mean±SEM), of eight replicates of pots

Table 04: Differences in growth parameters in *Schoenoplectus grossus, Eleocharis dulcis* and *Fimbristylis dichotoma* plants when fed with dairy wastewater (End of Phase II) See Table 02 for comments

Species	Growth with and without dairy wastewater											
	Tillering capacity				Tiller height				Tiller diameter			
	Bog		Mixed		Bog		Mixed		Bog		Mixed	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
Fimbristylis dichotoma	2.84 ± 0.40^{b1}	4.90 ± 0.57^{b1}	3.91 ± 0.41^{b1}	4.39 ± 0.41^{b1}	25.25 ± 1.12^{a2}	29.69 ± 1.08^{a3}	25.51 ± 1.29^{a2}	28.08 ± 1.30^{a3}	0.64 ± 0.05^{a1}	0.64 ± 0.05^{b1}	0.86 ± 0.04^{a1}	0.82 ± 0.04^{b1}
Eleocharis dulcis	11.54 ± 1.27^{a1}	9.31 ± 0.94^{a1}	7.82 ± 0.82^{a2}	6.22 ± 0.68^{a2}	13.58 ± 0.41^{b1}	18.42 ± 0.57^{b1}	13.88 ± 1.37^{b1}	16.17 ± 0.45^{b1}	0.39 ± 0.03^{c1}	1.17 ± 0.70^{c1}	0.33 ± 0.02^{c1}	0.40 ± 0.04^{c1}
Schoenoplectus grossus	1.76 ± 0.18^{b1}	0.88 ± 0.09^{b1}	1.47 ± 0.14^{b1}	0.95 ± 0.13^{b1}	27.43 ± 3.20^{c1}	18.01 ± 1.88^{c1}	20.33 ± 2.89^{c1}	21.98 ± 2.59^{c1}	3.34 ± 0.07^{b1}	5.54 ± 1.23^{b1}	2.92 ± 0.30^{b1}	3.61 ± 0.63^{b1}
	Shoot dry weight				Root Dry weight				Root/Shoot dry weight ratio			
	Bog		Mixed		Bog		Mixed		Bog		Mixed	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
Fimbristylis dichotoma	4.30 ± 1.39^{a1}	6.94 ± 2.32^{a1}	5.77 ± 0.98^{a1}	6.94 ± 1.01^{a1}	3.79 ± 0.54^{a1}	8.62 ± 1.02^{b2}	3.93 ± 1.59^{a1}	3.05 ± 0.76^{b2}	1.03 ± 0.14^{b1}	1.91 ± 0.57^{b1}	0.84 ± 0.18^{b1}	0.97 ± 0.56^{b1}
Eleocharis dulcis	3.69 ± 0.71^{a1}	3.53 ± 0.57^{a1}	3.61 ± 0.83^{a1}	4.58 ± 0.31^{a1}	1.94 ± 0.30^{c1}	1.29 ± 0.23^{c1}	1.97 ± 0.60^{c1}	1.76 ± 0.15^{abc1}	0.58 ± 0.08^{c1}	0.40 ± 0.08^{c1}	0.51 ± 0.09^{c1}	0.39 ± 0.04^{c1}
Schoenoplectus grossus	8.05 ± 2.70^{b1}	7.43 ± 2.02^{b1}	12.37 ± 3.10^{b1}	12.52 ± 2.89^{b1}	4.60 ± 1.17^{a1}	5.76 ± 0.96^{a1}	5.78 ± 1.75^{a1}	5.77 ± 0.74^{a1}	1.00 ± 0.38^{a1}	1.07 ± 0.24^{ab1}	1.00 ± 0.27^{a1}	0.68 ± 0.14^{a1}

*Numbers followed by same number in each row are not significantly (P <0.05) different. **Numbers followed by same letter (a,b.c) in each column are not significantly (P <0.05) different. ***Values indicate the Mean ± Standard Error of Mean (Mean±SEM), of four replicates of pots .a b and c denote the differences in means

The effect of dairy wastewater on plant growth (Phase II)

Summary of effect of dairy wastewater on growth of sedges is shown in the Tables 02, 03 and 04.The results indicated that tillering capacity of *Eleocharis dulcis* plant was high compared to other species in especially in mixed substrate type.

In the mixed substrate *Fimbristylis dichotoma* plants grew taller than others (Table 04) whereas *Schoenoplectus grossus* was comparatively short. In case of the tiller diameter, the highest was shown by *Schoenoplectus grossus* in both substrate types under the treatment of dairy wastewater. The results obtained for the shoot dry weight indicated that biomass of Schoenoplectus *grossus* was higher among plant species grown in two substrate types. According to the results (Table 02), remarkably high root biomass was recorded in *Fimbristylis dichotoma* plants in the bog soil. Root biomass of *Eleocharis dulcis* was the lowest among the three species in both substrate types. When considering Root/Shoot ratio, high values were reported by *Fimbristylis dichotoma* while *Eleocharis dulcis* had the lowest Root/Shoot ratio among the sedges tested in this experiment.

DISCUSSION

As growing conditions provided by substrates in CWs is not always natural, morphological, ecological and physiological attributes of plant species utilized for phyto-remediation cannot be expected to be same (Brisson, 2015).The initial phase of this study mainly demonstrated the variations of growth responses to the substrate type in absence of treatment and would have reflected the morphological and physiological traits of species. Accordingly considerable high tiller capacity was demonstrated by *Eleocharis dulcis* plants in both substrate types. It was reported that formation of shoots /tillers can also be affected by the type of cutting of the rhizome, activity of auxins and the function of meristematic tissues (Pratt et al., 1984). The degree of impact of these factors on growth would have also been collectively demonstrated by different plant species. Environmental conditions also affect the formation of new shoots/tillers. Comparatively low tillering capacity of plants in bog soil of *Eleocharis dulcis* may be due to low nitrogen immobilization in bog soil compared to that of mixed substrates (Varvinia, 1996). Comparatively low tiller formation in both substrate types indicated by *Schoenoplectus grossus* plants during establishment could also be due to species specific morphological and physiological attributes. It was observed that formation of new tillers from *Schoenoplectus grossus* generally occurred after drying back of older tillers, however the appearance of new tillers was comparatively slow.

Height of *Fimbristylis dichotoma* plants in both substrate types may also be due to species specific traits and favorable habitat niche characteristics. However the stagnation of height growth shown by *Fimbristylis dichotoma* plants after 37 DAP could be a consequence of tradeoff due to increasing of number of shoots/tillers in pots as a result of competition for resources (Wang et al., 2005).

Predominantly high tiller diameter growth indicated by *Schoenoplectus grossus* plants could also be due to its unique morphological and physiological traits. However decrease of tiller diameter growth in new tillers down to some extent after 37 DAP could be due to less resource allocation for the formation of the tillers with the simultaneous increment of height. Strikingly during that time the plants had turned in to slight yellowish and brown color patches in stems indicating lack of nutrients in the substrate. Another fact would be the limited space of pots which restricted the free expansion and distribution of tillers (Busnardo et al., 1992).The increase diameter growth of other (two) plant species was not distinct. Hence the biomass allocation of these species would have been directed towards the development of tillers height rather than for the increase in diameter of tillers.

When considering the growth of plants under the effect of dairy wastewater, high growth of tillering capacity observed in *Fimbristylis dichotoma* plants subjected to treatment in both substrate types would be a tolerable growth condition for that species. Similarly tall growth exhibited by *Fimbristylis dichotoma* plant would also be due to nutrient enrichment with the application of dairy wastewater. Widening of diameter in *Schoenoplectus grossus* plants in both substrate types under treatment of dairy wastewater was possibly due to allocation of nutrients/resources in their stem.

High root dry weight recorded in *Fimbristylis dichotoma* plants in the bog soil indicated that nutrient storage capacity of rhizomatous parts of *Fimbristylis dichotoma* was high compared to other species. Hence this species may likely be capable of up taking nutrients and increasing its biomass rapidly upon the application of nutrients. This observation suggests whether the application of dairy wastewater may create optimum environmental conditions (habitat niche) for the growth of *Fimbristylis dichotoma* plants in the CW environment.

CONCLUSIONS

The effect of substrate types was most pronounced for tillering capacity (number of shoots) of *Eleocharis dulcis* and shoot height of Fimbristylis *dichotoma* in bog soil. Treating with neutralized and diluted dairy wastewater suppressed the growth of *Schoenoplectus grossus* plants while enhancing the growth of *Fimbristylis dichotoma* plants in terms of tiller diameter, height and tillering capacity. *Eleocharis dulcis* plants showed moderate growth in two substrate types and during the application of treatment. Hence the eco-physiological tolerability of three plant species can be ranked as *Fimbristylis dichotoma >Eleocharis dulcis>Schoenoplectus grossus.* Therefore according to the findings of this study, *Fimbristylis dichotoma* plant was suggested as a potential plant that could be used to remediate dairy wastewater. However its nutrient removal efficiency in dairy wastewater should be further examined before commercial use.

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substrate types under treatment of dairy wastewater was possibly due to allocation of nutrients/resources in their stem.

High root dry weight recorded in *Fimbristylis dichotoma* plants in the bog soil indicated that nutrient storage capacity of rhizomatous parts of *Fimbristylis dichotoma* was high compared to other species. Hence this species may likely be capable of up taking nutrients and increasing its biomass rapidly upon the application of nutrients. This observation suggests whether the application of dairy wastewater may create optimum environmental conditions (habitat niche) for the growth of *Fimbristylis dichotoma* plants in the CW environment.

CONCLUSIONS

The effect of substrate types was most pronounced for tillering capacity (number of shoots) of *Eleocharis dulcis* and shoot height of Fimbristylis *dichotoma* in bog soil. Treating with neutralized and diluted dairy wastewater suppressed the growth of *Schoenoplectus grossus* plants while enhancing the growth of *Fimbristylis dichotoma* plants in terms of tiller diameter, height and tillering capacity. *Eleocharis dulcis* plants showed moderate growth in two substrate types and during the application of treatment. Hence the eco-physiological tolerability of three plant species can be ranked as *Fimbristylis dichotoma >Eleocharis dulcis>Schoenoplectus grossus*. Therefore according to the findings of this study, *Fimbristylis dichotoma* plant was suggested as a potential plant that could be used to remediate dairy wastewater. However its nutrient removal efficiency in dairy wastewater should be further examined before commercial use.

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