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Study of the Impact of Phyto-treatment of Domestic Wastewater on Biochemical Content of *Chrysopogon zizanioides* L. Roberty (Vetiver)

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Abstract

Phytoremediation is an ideal method to treat domestic wastewater. In this technique, plants absorb nutrients from polluted water. Biochemical analysis was carried out to study the impact of phyto-treatment on the biochemical content of *Chrysopogon zizanioides* used in phytoremediation. Roots, stem and leaf samples were analyzed for moisture, total minerals, Crude fiber, Energy, Crude protein, Crude fat and carbohydrates, essential metals and non-metals along with trace elements. The study revealed no significant impact of domestic wastewater on the biochemical content of C*hrysopogon zizanioides.* indicating its safe economic and ecofriendly use.

Key words: Biochemical content, Domestic wastewater, Nutrients, Phytoremediation

Green plants play a major role in nutrient uptake from soil and water. These inorganic nutrients are absorbed in the form of macro and micro-elements, converting them into biomolecules in the process of photosynthesis, translocating these biomolecules in different plant organs and serving as basis of food chain. A plant's nutrient uptake ability from the surrounding environment is utilized in phytoremediation techniques for removing nutrients or hazardous substances from soil, surface or groundwater and from domestic or industrial wastewater [23]. In one comparative study samples of trees, grasses, crop residues and experimental feeds were collected from Uttarakhand, India for analyses of crude proteins, ether extract, crude fibers, total ash, acid insoluble ash, neutral detergent fibers, nitrogen-free extract and dry matter [3]. Current agronomic practices showed great variability in the chemical composition of grasses [27]. This study discussed the causes of those variations and agronomical practices for possible nutrient loss. Some grass species from Poaceae obtained from the ungrazed forest range in Northern Bulgaria showed adequate concentrations of mineral, crude protein and acid detergent fiber to meet livestock needs. This study suggested that these species from ungrazed forests can be cultivated in similar ecological conditions to obtain these nutrients for fodder purposes [26].

Studies on *Vossia cuspidata* (Roxb.) Griff. (hippo grass) along Ismalia Canal, Egypt shows that there is a seasonal impact on nutrient concentration having maximum nutrients at the beginning of the growing season during winter. Thus, harvesting of hippo plants from polluted water bodies should be done at the time when it has maximum nutrient content and can be used as fodder [6]. Results on nutritional studies showed that *Chrysopogon zizanioides* (vetiver grass) has potential as nonconventional feedstuff for small ruminants [24]. The state of nutrient contents of *Chrysopogon* (Vetiver grass) changes according to seasons, types of soil conditions, growth stages and mowing times [32]. Thus number of studies related to the analysis of biochemical composition are restricted to crops of agricultural importance to find out their nutritive value either for human consumption or fodder purposes. Also, most of the work related to phytoremediation either focuses on the efficiency of plants in removing pollutants from the surrounding environment or developing new techniques. Very little attention has been given to the effect of phyto-treatment on the biochemical content of plants used in phytoremediation. Therefore, this study aims to evaluate the impact of phyto-treatment of domestic wastewater on the biochemical content of *Chrysopogon*.

MATERIALS AND METHODS

Phytoremediation assemblies were set up for a) control having tap water, b) domestic wastewater originating from an individual house, c) Ladies' Hostel wastewater of an educational institute and d) the river water. Plant samples of *Chrysopogon zizanioides* L. *Roberty* (Vetiver) were collected at regular time intervals from phyto-treatment units. These phyto-treatment assemblies were designed to study the efficiency of plants in wastewater treatment for various kinds of wastewater from different sources. Roots, stem and leaves were subjected to analyses of bio-chemical contents as per the methods given in the manual of Food Safety and Standards Authority of India (fssai) i.e., Manual of Methods of Analysis of Foods- Cereal and Cereal Products- 2nd edition (2023) and Manual of Methods of Analysis of Foods-Metals (2016).

Root samples were analyzed for moisture, total minerals, crude fibers, energy, crude proteins, crude fats and

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carbohydrates. Stem and leaf samples were analyzed for crude proteins, crude fats, carbohydrates, nitrogen, phosphorous, potassium, calcium, magnesium, iron, manganese, zinc, copper, chlorophyll 'A', chlorophyll 'B' and total chlorophyll content. In this study the values obtained from bio-chemical analysis of plant material from phyto-treatment units are compared with the values of the control unit.

RESULTS AND DISCUSSION

As mentioned earlier most of the literature regarding chemical composition in plants during phytoremediation treatments is restricted to the plants having consumed by human beings or used for fodder purposes. A very less literature is available for chemical composition of plants especially grasses grown on domestic wastewater. So, in this study obtained data is compared with the plants used for fodder purposes. The bio-chemical content of *Chrysopogon* for different phyto-treatment units is shown in (Table 1).

1) *Moisture*: In the beginning, root moisture content was 8.72%, after treatment it remained in the range of 61.74% to 75.2%. Similar results of increased root moisture i.e., root biomass was observed while studying impact of hydroponic and conventional methods of fodder production in maize [9]. Higher moisture levels in roots might be due to presence of continuous / and or intermittent wastewater supply to the root complex. In case of *Chrysopogon* increased root moisture is advantageous for tensile strength of the roots. For vetiver grass tensile strength was higher (12.61 to 88.52 MPa) at 79.29% root moisture, which got decreased when moisture content reduced [14]. They also found exactly contrary results in case of *Bermuda* grass roots where with increase in root moisture, tensile strength of roots decreased drastically.

2) *Total minerals*: During the study period total mineral content was between 22.87% to 45.25%. In the twelfth month of sampling, the control and river water unit recorded very low values of minerals i.e., 5.7% and 7.48% respectively.

3) *Crude fibers*: Crude fiber is an insoluble residue consisting of cellulose and insoluble lignin. The crude fiber content in the roots always remained in the range of 25.04% to 49.62%. Earlier studies carried out along Ismalia Canal, Egypt to evaluate the status of nutrients and forage quality of hippo grass revealed that in polluted waters crude fiber content in roots ranged from 33.7% to 48.6% throughout all the seasons [6]. The comparative study of nutritive value in fodder species and industrial by-products found crude fiber content in the range of 26.37% to 36.70% and 3.56% to 10.45% respectively [10]. In this study fodder species such as *Gliricidia*, Guinea grass, $CO_{3,}$ Sorghum, Maize and industrial by-products Coconut poonac, Maize meal, Rice bran, and Soybean meal (SBM) were studied for their nutrient status.

4) *Energy*: The energy in plants is a measure of plants' ability to help themselves and consumers in an ecosystem which are directly or indirectly dependent on the plant for their energy requirements. Generally, energy content in plants is measured for human consumption and fodder purposes. Here energy content in roots of *Chrysopogon* is measured in Kcal/100gm. The initial energy value in control was 159.49 Kcal/100gm. In the control unit itself, after six and twelfth months energy values increased up to 265.32 Kcal/100gm and 280.92 Kcal/100gm respectively. The same trend was observed in domestic wastewater units. However, in Ladies' Hostel unit, there was a decrease in energy value after six months (99.38 Kcal / 100gm) but again it increased to 191.12 Kcal/100 gm after twelve months. There was no significant change in the river water unit after six and twelve-month observations as compared to initial values. If there is higher energy content in a feed, more energy will be available in food chain, further [23].

5) *Crude proteins*: Crude protein indicates the approximate amount of protein in foods, also called total proteins.

Roots: The initial value of crude proteins in the roots of *Chrysopogon zizanioides* in the control unit was about 7.75%. In the control unit after six and twelve months period, it remained in the same range but it got almost doubled in the domestic wastewater unit i.e., 12.85% and 11.28% respectively. Ladies Hostel root samples recorded higher values after six months (13.89%), but resumed the normal range after twelve months. In river water unit, crude protein content was in normal range as compared to control unit, but there was little decrease in concentration after twelve months.

Stem: The initial value of crude proteins in stem samples of control unit was observed as 2.71%. It increased in the range of 7.88% and 8.41% after six and twelve months respectively. In the domestic wastewater unit and Ladies Hostel wastewater unit, it increased in the range of 4.73% to 7.44%. But it remained almost the same in river water unit.

Leaves: In control unit initially leaf samples showed a crude protein amount 9.93% which increased to 13.38% and 12% in respective sampling months. Leaf samples from domestic wastewater units also showed an increase of upto 17.66% and 15.18% respectively. But comparatively lower values of crude protein were observed in Ladies' Hostel unit and river water unit in the twelfth month.

Crude protein values were observed in the range of 11.38 to 25.80% for some fodder species grown hydroponically [18]. Here the dried sample of fodder species contained all the parts of plant such as root, stem and leaf. Potential of Duckweed was assessed as a protein source grown on wastewater [22]. Their study revealed protein content in Duckweed was about 37%, which was supplied with wastewater. Other micronutrients such as iron, zinc, copper was also within normal range. In another study, nutrient concentration was assessed in the leaves of trees, grasses and leguminous plants in the pasture lands of Nepal [15]. They found mean crude protein content as (14.37 and 13.92%) in trees, grasses and legumes respectively. Calcium (2.20 and 0.83%), phosphorous (0.25 and 0.35%) in trees, grasses and legumes respectively. Sorghum was irrigated with domestic wastewater [24]. Observations concluded that irrigation with sewage water increased crude protein and green fodder yield. Biochemical aspects of hydroponically grown *Hordeum vulgare* (barley) fodder having varied water supply were compared with rangeland barley species [11]. They found that hydroponically grown barley had higher content of crude protein as compared to rangeland species but the concentrations of phosphorous, potassium, calcium and magnesium were low.

Experimentally observed crude protein values in root, stem and leaf samples from phyto-treatment units are in accordance with control unit values which indicated that there is no significant impact of domestic wastewater on the crude protein content of *Chrysopogon zizanioides*. Some grass species of Poaceae in natural conditions from ungrazed forest ranges in Northern Bulgaria have shown similar concentrations of crude protein [26].

6) *Crude fats*: Carbohydrates, fats, oils and protein in feed are the main sources of energy. Crude fat refers to the total amount of fat in plant organs. Plant fats have more nutritional value than animal fats as they contain more amount of unsaturated fatty acids.

Roots: The initial value of crude fat in roots of *Chrysopogon zizanioides* was found as 0.49%. In control unit subsequently, it increased upto 0.65% and 0.78% in respective sampling months. But in domestic wastewater unit, Ladies' Hostel wastewater unit and river water unit after six months there were higher values i.e., 1.06%, 1.28% and 1.1% as compared to the observations after twelve months. After the twelfth month crude fat values were recorded in the domestic wastewater unit (0.96%), Ladies Hostel Wastewater unit (0.84%) and river water unit (0.63%).

Stems: The initial value of crude fat in the stem sample was 0.2%. There was an increase in crude fats content in the range of 0.32% to 0.81%. The highest values of crude fats were observed in control unit. These were reported as 0.74% after six months and 0.81% after twelfth month.

Table 1 Results of bio-chemical analysis of *Chrysopogon zizanioides* (*Vetiveria zizanioides*) from phyto-treatment units

a) Control

Parameters	Unit	*Chrysopogon zizanioides*								
		Root			Stem			Leaf		
		Initial	6 months	12 months	Initial	6 months	12 months	Initial	6 months	12 months
Moisture	%	8.72	75.2	61.74						
Total minerals	%	22.87	39.17	5.7						
Crude fiber	%	29.15	30.04	25.04						
Energy	Kcal/100g	159.5	265.32	280.94						
Crude protein (on dry basis)	%	7.75	7.89	7.48	2.71	7.88	8.41	9.93	13.38	12
Crude fat (on dry basis)	%	0.49	0.65	0.78	0.2	0.74	0.81	1.21	0.73	0.8
Carbohydrate on dry basis)	%	31.02	35.22	61	14.5	34.8	35.5	44.35	41.61	42.34
Nitrogen (on dry basis)	%				1.22	1.3	1.34	1.59	2.13	1.92
Phosphorus (on dry basis)	%				0.05	0.12	0.14	0.07	0.11	0.15
Potassium (on dry basis)	%				1.09	1.66	1.71	1.14	0.54	1.81
Calcium (on dry basis)	%				0.19	1.02	1.16	0.24	0.5	1.99
Magnesium (on dry basis)	%				0.13	0.12	0.14	0.13	0.42	0.15
Iron (on dry basis)	ppm				304	324.29	367.47	205.06	21.31	310.18
Manganese (on dry basis)	ppm				100	42.18	58.85	57.65	2.62	49.35
Zinc (on dry basis)	ppm				19.4	61.22	70.65	17.66	3.25	61.45
Copper (on dry basis)	ppm				7.73	48.11	82.44	4.02	12.14	60.73
Chlorophyll A	ppm				98.9	89.02	13.65	2519.8	191.57	51.61
Chlorophyll B	ppm				55.8	45.26	34.48	813.18	51.71	162.59
Total chlorophyll	ppm				155	134.28	48.13	33.33	243.28	214.19

b) Domestic wastewater

Parameters	Unit	*Chrysopogon zizanioides*								
		Root			Stem			Leaf		
		Initial	6 months	12 months	Initial	6 months	12 months	Initial	6 months	12 months
Moisture	%	8.72	73.45	74.06						
Total minerals	%	22.87	40.15	45.25						
Crude fiber	%	29.15	33.27	29.2						
Energy	Kcal/100g	159.5	250.13	230.86						
Crude protein (on dry basis)	%	7.25	12.85	11.28	2.71	7.44	6.23	9.93	17.66	15.18
Crude fat (on dry basis)	%	0.49	1.06	0.96	0.2	0.54	0.63	1.21	1.71	0.68
Carbohydrate on dry basis)	%	31.02	34.21	35.88	1.45	50.33	54.28	44.35	38.2	45.35
Nitrogen (on dry basis)	%				1.22	1.28	1.05	1.59	2.81	2.49
Phosphorus (on dry basis)	%				0.05	0.16	0.08	0.07	0.98	0.08
Potassium (on dry basis)	%				1.09	0.29	1.44	1.14	0.56	1.21
Calcium (on dry basis)	%				0.19	0.15	0.88	0.24	0.49	0.64
Magnesium (on dry basis)	%				0.13	0.18	0.21	0.13	0.36	0.11
Iron (on dry basis)	ppm				304	52.39	291.32	205.06	41.53	196.28
Manganese (on dry basis)	ppm				100	3.33	50.16	57.65	1.26	14.28
Zinc (on dry basis)	ppm				19.4	5.36	40.22	17.66	3.33	28.53
Copper (on dry basis)	ppm				7.73	8.76	38.13	4.02	16.75	39.65
Chlorophyll A	ppm				98.9	101.22	105.33	2519.8	199.42	2422.79
Chlorophyll B	ppm				55.8	60.21	54.22	813.18	54.68	919.33
Total chlorophyll	ppm				155	161.43	159.55	3333	254.09	3342.12

c) Ladies hostel wastewater

Parameters	Unit	*Chrysopogon zizanioides*								
		Root			Stem			Leaf		
		Initial	6 months	12 months	Initial	6 months	12 months	Initial	6 months	12 months
Moisture	%	8.72	74.15	73.87						
Total minerals	%	22.87	44.29	27.25						
Crude fiber	%	29.15	32.46	26.02						
Energy	Kcal/100g	159.5	99.38	191.12						
Crude protein (on dry basis)	%	7.75	13.89	9.76	2.71	7.17	4.73	9.93	11.78	7.69
Crude fat (on dry basis)	%	0.49	1.28	0.84	0.2	0.6	0.21	0.74	0.74	0.55
Carbohydrate on dry basis)	%	31.02	8.08	36.13	14.5	48.71	55.2	44.35	42.66	48.63
Nitrogen (on dry basis)	%				1.22	1.15	0.75	1.59	1.88	1.23
Phosphorus (on dry basis)	%				0.05	1.76	0.1	0.07	2.05	0.06
Potassium (on dry basis)	%				1.09	0.33	0.24	0.14	0.13	0.79
Calcium (on dry basis)	%				0.19	0.39	0.92	0.24	0.59	0.76
Magnesium (on dry basis)	%				0.13	0.07	0.14	0.20	0.28	0.23
Iron (on dry basis)	ppm				304	44.38	276.17	205.06	84.16	166.57
Manganese (on dry basis)	ppm				100	3.27	41.25	57.65	3.1	18.35
Zinc (on dry basis)	ppm				19.4	4.55	42.41	17.66	3.91	30.56
Copper (on dry basis)	ppm				7.73	6.87	47.99	4.02	11.38	41.52
Chlorophyll A	ppm				98.9	3.86	6.16	2519.8	166.9	40.73
Chlorophyll B	ppm				55.8	4.49	15.56	813.18	55.1	128.06
Total chlorophyll	ppm				155	8.34	21.72	3333	222.02	168.79

d) River water

Parameters	Unit	*Chrysopogon zizanioides*								
		Root			Stem			Leaf		
		Initial	6 months	12 months	Initial	6 months	12 months	Initial	6 months	12 months
Moisture	%	8.72	72.53	70.05						
Total minerals	%	22.87	40.21	7.48						
Crude fiber	%	29.15	40.83	49.62						
Energy	Kcal/100g	159.5	154.67	174.75						
Crude protein (on dry basis)	%	7.75	10.42	4.87	2.71	2.62	2.84	9.93	11.62	5.99
Crude fat (on dry basis)	%	0.49	1.1	0.63	0.2	0.32	0.52	1.21	1.19	0.62
Carbohydrate on dry basis)	%	31.02	32.33	37.4	14.5	48.12	50.47	44.35	47.64	42.97
Nitrogen (on dry basis)	%				1.22	0.59	0.45	1.59	1.86	0.96
Phosphorus (on dry basis)	%				0.05	0.09	0.15	0.07	0.85	0.08
Potassium (on dry basis)	%				1.09	0.98	0.62	1.14	0.62	0.47
Calcium (on dry basis)	%				0.19	0.63	1	0.24	0.85	1.1
Magnesium (on dry basis)	%				0.13	0.14	0.15	0.13	0.56	0.23
Iron (on dry basis)	ppm				304	312.1	321.9	205.06	19.2	501.47
Manganese (on dry basis)	ppm				100	136.56	153.01	57.65	1.35	54.45
Zinc (on dry basis)	ppm				19.4	32.21	39.51	17.66	7.99	31.44
Copper (on dry basis)	ppm				7.73	50	55.56	4.02	17.24	38.56
Chlorophyll A	ppm				98.9	84.22	6.64	2519.8	123.24	43.33
Chlorophyll B	ppm				55.8	45.22	16.88	813.18	37.42	152.85
Total chlorophyll	ppm				155	129.44	23	3333	160.65	196.19

Leaves: The initial value of crude fats was recorded as 1.21% in the leaf sample of *C. zizanioides*. However, there was little decrease in the percentage of crude fat in all the phyto-treatment units. Crude fats values were ranging from 0.55% to 1.19%. In literature, crude fats values in grasses are reported in the range of 0.5% to 5%. Crude fats content in *Gonostegia hirta* was observed as 2.57% while analyzing its nutritional composition for utilization as a potential edible plant [12].

7) *Carbohydrates*: The dry matter of plant tissue contains about 75% carbohydrates. Three types of carbohydrates such as soluble carbohydrates, storage carbohydrates and structural carbohydrates are found in plant cells.

Roots: The initial value of carbohydrates in roots was found as 31.02%. In control unit, it increased up to 35.22% and 61% after the sixth and twelfth month of sampling respectively. In domestic wastewater unit, there were no remarkable changes in subsequent observations. Similar observations were obtained in river water unit. On the other hand, after six months of sampling Ladies' hostel unit recorded very low values of carbohydrates i.e., 8.08%. This variation in carbohydrate value might be due to the plant's interaction with the surrounding environment and the balance between processes of photosynthesis and respiration [28].

Stem: In the stem sample initial values of carbohydrates were recorded as 14.5%, which increased in range of 34.8% and 35.5% in control unit. Comparatively domestic wastewater unit recorded highest carbohydrate values i.e., 50.33% and 54.28% respectively in each observation. Though they are low, similar observations were found in Ladies' hostel and river water units.

Leaves: An initial value of 44.35% carbohydrates was observed in leaves of *Chrysopogon zizanioides*. Carbohydrate content remained in the range of 38.2% to 48.63% in all four phyto-treatment units. There was no particular pattern in the content of carbohydrates. Perennial grasses were studied for chemical composition which was linked to methane and biogas production in laboratory conditions [2]. Present study found that water-soluble carbohydrate content was in the range of 5.91% to 20.3% of dry matter. In another study, water-soluble carbohydrates were in the range of 2.50% to 4.20% in stem samples of different grasses and 2.30% to 3.90% in leaf samples [16].

Plants obtain inorganic minerals for nutrition from the surrounding environment, these are nitrogen, phosphorus, potassium, calcium, magnesium and Sulphur, termed as macronutrients. The rest of the essential elements are required in very trace amounts. Micronutrients are boron, copper, iron, manganese, zinc, molybdenum, cobalt etc. The fulfilment of these inorganic minerals is completed through various bio-geo-chemical cycles.

8) *Nitrogen*: Nitrogen is a component of some important biomolecules such as proteins, nucleic acids etc.

Stems: The initial concentration of nitrogen in stem samples was recorded as 1.22%. There was no prominent change in the control unit and it remained in range of 1.3% to 1.34%. However, there was little reduction in nitrogen concentration in stem samples of domestic wastewater unit, Ladies' Hostel wastewater unit and river water unit. It ranged from 0.45% to 1.28%.

Leaves: The initial value of nitrogen in leaf samples was observed as 1.59%. Nitrogen values in all four units were in range of 0.96% to 2.81%. All units recorded an increase in percent nitrogen except the twelfth-month sampling in Ladies' hostel and river water unit where there was little decrease in nitrogen. In earlier studies per cent nitrogen in some grasses was also observed in range of 1.11% to 3.45% [2].

Another study was carried out to check impact of sewage sludge on a grass mixture per cent nitrogen was observed [29]. Here percentage of nitrogen was increased from 1.90% to 2.82% as dose of sewage sludge was increased. There was positive correlation among chlorophyll content in leaves and nitrogen concentration in the lettuce plants [31]. In this study chlorophyll content in lettuce grown with wastewater hydroponically was checked.

9) *Phosphorus*: Phosphorus is a macronutrient, essential for seed germination, photosynthesis, protein formation etc. It is a necessary element required in almost all aspects of growth and metabolism in plants.

Stem: The initial concentration of phosphorus in stem sample was 0.05%. It increased in range of 0.06% to 0.15% in all four phyto-treatment units.

Leaves: The initial concentration of phosphorus in leaf sample was observed as 0.07%. It varied between 0.06% to 0.20% in all the units under study.

10) *Potassium*: Potassium is one of macronutrient necessary for formation of biomolecules such as sugars, starches, carbohydrates, protein synthesis and is important in various processes occurring in plants.

Stem: The initial value of potassium in the stem sample was observed as 1.09%. In the control unit, there was little increase in potassium concentration i.e., 1.66% and 1.71% respectively. However, after six months of observation, there was a reduction in potassium concentration in the domestic wastewater unit (0.29%) and the Ladies' Hostel unit (0.33%). Again, there was an increase in twelfth-month observation i.e., 1.44% and 1.24% respectively. The river water unit recorded lower values of potassium than initial values.

Leaves: The initial value of potassium in leaf sample was recorded as 1.14%. In six-month observation, it reduced in control unit (0.54%), domestic wastewater unit (0.56%) and river water (0.62%). It remained low in twelfth month in Ladies' hostel and river water unit. However, in control and domestic wastewater units, potassium concentration was increased.

When grass samples were analyzed at varied doses of sewage sludge which included different seasons and locations, the concentration of phosphorus ranged from 0.22% to 0.27%. Potassium concentrations were observed as 1.13% to 1.82% [29].

Perennial grasses such as *Phalaris arundinacea* and *xFestulolium pabulare* were analyzed for their biomass yield and chemical composition for their possible usage in energy production [20]. After providing a balanced dose of fertilizers concentration of nitrogen (1.11% to 1.48%), phosphorus (0.024% to 0.24%) and potassium (0.24% to 1.99%) was observed.

11) *Calcium*: In stem and leaf samples the initial concentration of calcium was observed as 0.19% and 0.24% respectively. In all the units, in all sampling months, the calcium concentration in stem and leaf remained in the range of 0.15% to 1.16% and 0.49% to 1.99% respectively.

12) *Magnesium*: The initial concentration of magnesium in stem and leaf was recorded as 0.13%. All the phyto-treatment units showed magnesium concentration in stem samples in range of 0.12% to 048% and leaf samples recorded magnesium concentration in the range of 0.09% to 0.79%.

Micronutrients such as iron, manganese, zinc and copper were also evaluated in stem and leaf samples in all four phyto-treatment units.

13) *Iron*: In stem and leaf samples iron had an initial concentration of 303.63ppm and 205.06ppm respectively. In control unit, stem sample showed an increase in iron concentration but in a six-month sampling of domestic and Ladies' hostel units, it dropped drastically and again showed an increase in the twelfth month. As compared to control, river water unit showed normal values. In case of leaf sample, same pattern of iron concentration was observed, but there was a prominent increase in iron concentration in the twelfth month of sampling i.e., from 19.2ppm to 501.47ppm.

14) *Manganese*: Initially manganese concentration in the stem was recorded as 100.23ppm and in leaf it was 57.65ppm. There was a mixed trend in manganese

concentration in stem samples as they were reduced to almost half in the control unit and increased in river water assembly. Both domestic and Ladies' hostel units recorded very low values as compared to control unit in sixth-month sampling. Leaf samples at this time for all the units recorded very low values of manganese as recorded in the control unit.

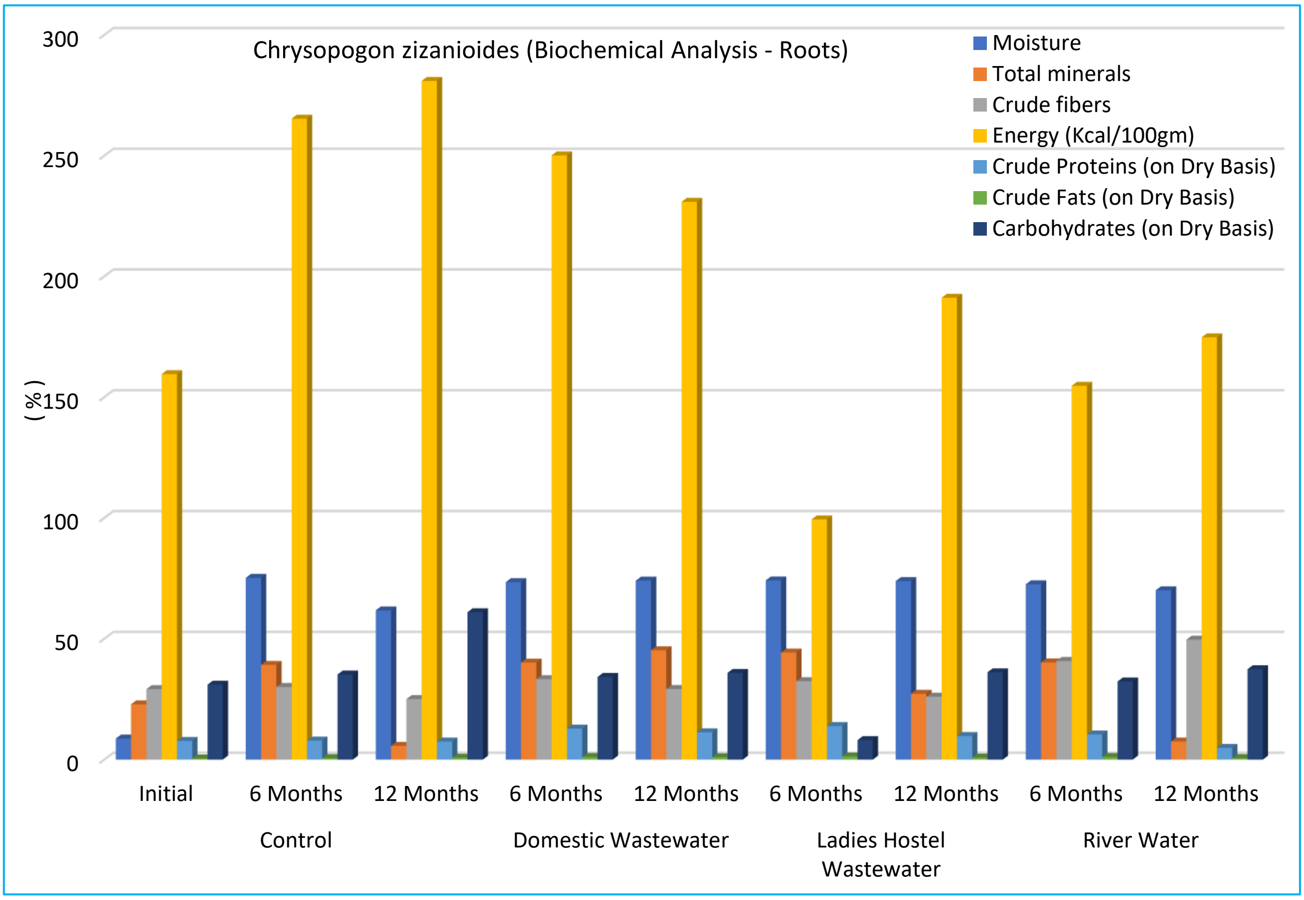

Fig 1 Results of biochemical analysis of roots of *Chrysopogon zizanioides* (*Vetiveria zizanioides*) from phyto-treatment units

15) *Zinc*: Initially zinc concentration in stem sample was found 19.42ppm and in leaf sample it was 17.66ppm. The control unit recorded very high values of zinc as compared to initial value in respective sampling time period. Except for having a lower value in stem samples in sixth month in domestic and Ladies' hostel, it showed a remarkable increase in all units afterwards. In leaf sample values remained normal except in some instances.

16) *Copper*: The copper values in stem (7.73ppm) and leaf (4.02ppm) were increased by many folds in control unit and in stem remained in range of 8.76ppm to 55.56ppm in remaining three phyto-treatment units. Leaf samples recorded an increase in initial concentration of copper in range of 11.38ppm to 60.73ppm.

A study of the chemical composition of 15 native and cultivated grasses was done to quantify nutritive value in different seasons. The mean values of phosphorus (0.3%), potassium (0.6%), calcium (0.45%), magnesium (0.1%), iron (50ppm), manganese (20ppm), zinc(30ppm) and copper (10ppm) were observed [19].

Lycopersicum solanum (tomato) was grown on partially treated domestic wastewater by using hydroponic system where concentration of macro and micro nutrients were recorded as nitrogen (2.88%), phosphorus (0.43%), potassium (0.91%), Magnesium (0.93%), calcium (2.48%), iron (216%), zinc (44%), copper (945.5%) and manganese (217%) [13]. Mineral composition in different varieties of lettuce grown in wastewater by hydroponic system was observed [30]. Concentration of Nitrogen was found in the range of 4.2 – 5%, phosphorus (0.41 – 0.55%), potassium (5.49 – 7.25%), calcium (1.21-1.31%), magnesium (0.49 – 0.70%), zinc (6.3 – 15%), copper (1 – 3.3%), iron (35.1 47.7%) and manganese (35 – 38.7%).

Grass species from ungrazed forests in northern Bulgaria were assessed for their chemical composition where concentrations of phosphorus (0.28% to 3.22%), potassium (2.80 to 3.22%), calcium (2.87% to 3.11%) and magnesium (0.26% to 0.28%) was observed [26].

Vetiveria zizanioides was assessed for its nutrient potential for feeding small ruminants with reference to clover hay. In vetiver grass phosphorus (0.26%), potassium (1.36%) and calcium (0.52%) were observed [24].

In another study, vetiver grass samples were analysed to find out the dynamic nature of nutrients with respect to seasons, soil conditions, growth stages and mowing times [32]. The concentration of iron (90.07 to 782.29ppm), manganese (45.72 to 465.04ppm), zinc (27.61 to 87.38ppm) and copper (2.14 to 61.27ppm).

17) *Chlorophyll*: The initial content of chlorophyll 'A' in stem sample was recorded as 98.87 ppm and in the leaf sample it was recorded as 2519.82 ppm. In some phyto-treatment units, it reduced drastically and, in some units, it remained within the same range. Initially, Chlorophyll 'B' was observed in stem samples up to level of 55.79ppm and in leaf samples it was found at 813.18ppm. The concentration of Chlorophyll 'B' in the stem sample remained in range of 4.49ppm to 60.2ppm and

in leaf sample 51.71ppm to 919.33ppm. In some instances, there was a slightly higher value of Chlorophyll 'B'. The light intensity and climatic conditions might be responsible for variation in the content of Chlorophyll 'A' and Chlorophyll 'B' in respective sampling periods and seasons [1], [4], [21].

Thus, domestic wastewater is enriched with multi-nutrients along with micronutrients and when it was supplied after secondary treatment to tomato plants, had positive impact on chlorophyll content [13]. In Saudi Arabia, where there is water scarcity, green fodder production consumes 67.27% of total water used in agricultural sector [7]. So, they suggested treated wastewater can be used for fodder production.

CONCLUSION

The present study focused on assessing impact of phyto-treatment of domestic wastewater on biochemical content of *Chrysopogon zizanioides*. It was found that values obtained for all the biochemical parameters remained within normal range as compared to grasses used as conventional feed for livestock. Thus, *Chrysopogon zizanioides* utilized in phyto-treatment to the domestic wastewater from various sources serves dual function of decentralized domestic wastewater treatment and promising source of fodder for livestock to address India's green fodder shortage.

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