

Original Research

Phytoremediating Batik Wastewater Using Vetiver *Chrysopogon zizanioides* (L)

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Abstract

Increased wastewater from the batik and textile industries as well as the content of chromium released from the coloring process will negatively affect an aquatic environment. The phytoremediation technique using Vetiver (*Chrysopogon zizanioides* L.) was applied to treat the wastewater. A hydroponic system with batik wastewater concentrations of 0%, 50%, 75%, and 100% was selected. Each treatment contained six pots, and each pot consisted of three clumps. This study aimed to determine the ability of *Chrysopogon zizanioides* L. to decrease chromium concentrations and improve water quality parameters (Ammonia, BOD, and COD) and analyze *Chrysopogon zizanioides* L. growth. On 50% wastewater composition, removal efficiency of chromium was 40%, BOD was 37.95±8.14 mg/L, removal efficiency of BOD was 98.47%, COD was 273.88±24.93 mg/L, and removal efficiency of COD was 89.05%. Relative growth rate (RGR) of plants was 0.002±0.00, and the number of living clumps was nine (50%). The results showed that 50% of batik wastewater can be treated by *Chrysopogon zizanioides* L. in a hydroponic system.

Keywords: chromium, phytoremediation, water quality, *Chrysopogon zizanioides* L.

Introduction

Batik industry in Indonesia is growing rapidly. Based on data from the Ministry of Industry in 2015, the batik industry's production and average export value reached \$178 million USD – an increase of 25.7% from the year before. However, along with its growth, the industry also experienced an increase in wastewater that brings forth environmental consequences. When batik wastewater is directly discharged into waters, it brings highly concentrated toxins into the water. A characteristic of batik wastewater [1] was depicted by its physical

characteristics (color, odor, TSS, and temperature) and its chemical characteristics (organic and inorganic compounds, phenol, sulfur, pH, heavy metals, ammonia, lipid, and oils). The dyes derived from the batik fabric washing process contain heavy metal. Metal originating from the fabric dyeing process is in the form of chromium. The presence of chromium in the water is found in two forms: trivalent chromium (Cr³⁺) and hexavalent chromium (Cr⁶⁺). Cr⁶⁺ is more toxic than Cr³⁺ because its ion is difficult to decompose [2]. Heavy metals contained in the batik waste are Fe, Cu, Cd, and Pb [3]. Therefore, to minimize waste and to reduce the impact of pollution, it is necessary to employ a basic wastewater treatment before the dump. One measure of wastewater treatment is the use of a plant as an agent of phytoremediation. There are

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many advantage of phytoremediation, namely, flexibility of in-situ and ex-situ treatment, easy implementation, low cost, environmental friendliness, and effective contaminant reduction – primarily heavy metals in large quantities. This phytoremediation method may include artificial wetlands or retention ponds using crops due to rapid plant growth and the ability to accumulate toxic substances [4].

In the development, some researchers have applied the treatments of industrial waste, domestic waste, and aquaculture wastewater by using different species of plant such as water hyacinth [5], water cress [6], and *Chrysopogon zizanioides* L. [7-8]. Research on treating batik wastewater containing chromium metal has also been conducted by using *Eichornia crassipes*, *Pistia stratiotes*, and *Hydrilla verticillata* with decreasing percentages of 49.56%, 33.61%, and 10.84%, respectively [9]. Selection of these plants is associated with their abilities to remove heavy metals and other pollutants. Furthermore, the advantages of vegetation over the other method are its high tolerance range to the environment, and that it is generally easy to breed [10]. Plant species criteria suitable for phytoremediation is the high absorption level of organic and inorganic pollutants, growth adaptability in polluted water, controllability of the spread, and a strong ability to reduce contaminants while growing in various rough terrains and conditions [11]. *Chrysopogon zizanioides* L. does not require special growing requirements, grows well in extreme media, and has a massive root system [12]. Several studies on Vetiver (*C.zizanioides* L.) indicate that these plants provide good growth when planted on some types waste such as biogas wastewater and improve waste water quality [13], and can degrade trichloroethylene (TCE) from contaminated land by 98% for two ecotypes [14]. In addition, *Chrysopogon zizanioides* L. is able to absorb soluble nutrients such as N and P as well as cations [15] and heavy metals, and it is also highly tolerant to herbicides and pesticides [16]. Moreover, a color change occurs in the oil palm wastewater treatment [17]. *Chrysopogon zizanioides* L. is also able to reduce chromium levels [18]. The many benefits of *Chrysopogon zizanioides* L. encourage its application in the research of batik wastewater management.

Materials and Methods

This research was performed in May-July 2016. Wastewater samples were collected from the batik industry in the Cikarang Jababeka industrial area. Analysis of water quality was conducted in the testing and environmental laboratories of Polytechnic AKA Bogor.

Chrysopogon zizanioides L. was used as a phytoremediator plant. The treatments were concentrations of wastewater, namely control PL0 (no waste), PL50 (50% waste + 50% water), PL75 (75% waste + 25% water) and PL100 (100% waste). Each treatment was in triplicate. A hydroponic system was applied when planting *Chrysopogon zizanioides* L. [19]. Water

temperature in the tub and light intensity at each treatment were adjusted homogeneously. The study was carried out in an open space with a roof.

Chrysopogon zizanioides L. selection was based on the same age. Crops were washed with water and stored in a plastic tub containing 25 L of water and an A B mix nutrient solution. Each tub consisted of six pots, each containing three clumps of plant. The plants were acclimatized for three weeks using a floating system where the roots were submerged in water [15].

Preparation of Wastewater

Wastewater was spiked with 2 ppm chromium. The standart usage of chromium based on Regulation of Minister of Environment No.5/2014 on waste of batik and textile industry amounted to 0.5-1 ppm Cr. The 2 ppm spiked concentration is intentionally done above the standard to determine the ability of plants to absorb chromium. A total of 225 L wastewater was added with 0.45 g of potassium dichromate. Calculation of treatment concentration follows the dilution formula: $V_1N_1 = V_2N_2$.

Planting of *Chrysopogon zizanioides* L.

Chrysopogon zizanioides L. which had been acclimatized and had good growth, was adjusted to 10 cm total length, then stored in 40 x 30 x 25 cm of plastic tubs. As many as 14 containers were prepared and filled with 25 l of batik wastewater. Furthermore, six pots were floated in a plastic tub with styrofoam as a holder. Each pot was filled with three clumps of *Chrysopogon zizanioides* L., and the observation lasted 56 days based on the research of [20].

Water Quality Measurement

Water quality observed included temperature, total suspended solids (TSS), pH, total ammonia, BOD, COD, and total chromium. Sampling was performed every week. Samples were analyzed using the APHA method (2012). Metals reduction calculation follows the formula [21]:

$$R = \left(\frac{I-F}{I} \right) \times 100\%$$

...where R is removal efficiency, I is the initial concentration of metals, and F is the final concentration of metal.

Growth of *Chrysopogon zizanioides* L.

Plant height, number of tillers, and the number of living clumps of Vetiver were observed. Relative growth rate (RGR) was calculated by the following equation [22]:

Table 1. Characteristics of inlet of batik wastewater

Parameter	Unit	Batik/ Textiles wastewater	Regulation of the Minister of Environment No 5, 2014
Temperature	°C	30	----
TSS	mg/L	268	50
pH	-	9.8	6.0 – 9.0
Total ammonia	mg/L	1.27	8.0
BOD	mg/L	966.83	60
COD	mg/L	2900.48	150
Total Chrom	mg/L	2.34 (spike)	1.0

$$RGR = \left(\frac{\ln W_t - \ln W_0}{t - t_0} \right)$$

...where W_0 and W_t are the initial wet weight (g) and wet weights at time-t (g), while t_0 and t are the initial observation time (day) and observation at time-t (days).

Data were statistically analyzed using analysis of variance (ANOVA) and the Duncan test ($p < 0.05$). Analyses were performed using the SAS.9.1 program.

Results and Discussion

Water Quality

Batik wastewater quality before treatment is presented in Table 1. Water quality parameters such as temperature, TSS, pH, BOD, COD, total chromium, and total ammonia in each treatment are presented in Table 2. The average temperature in each treatment was relatively not much different and ranged 28.10-29.00°C. Treatments of PL0, PL50, and PL75 had no significant differences ($p < 0.05$),

while PL100 had significant differences compared to PL0, PL50, and PL75 ($p < 0.05$).

During the observation period, pH ranged from 8.13 to 9.34. Plants demonstrated better absorption ability at pH 6-9. The more alkaline the pH, the effectiveness of absorption tends to be decreased [23]. TSS ranged 433.79-2,949.08 mg/L, in which the higher the effluent concentration, the higher the turbidity. It can also occur due to the addition of AB mix, which causes turbidity in the waste in containers within the hydroponic system. The levels of total ammonia ranged 0.74-0.78 mg/L and had no significant difference at control PL0. BOD ranged 5.94-52.89 mg/L for each treatment. BOD of PL0 (control) was significantly different from that of PL50, PL75, and PL100. COD was in the range of 44.76 to 559.94 mg/L and differed significantly ($p < 0.05$) in each treatment. Total chromium found in wastewater ranged 0.81-2.34 mg/L. Each treatment of PL0, PL50, PL75, and PL100 was shown to be significantly different ($p < 0.05$). *Chrysopogon zizanioides* L. density was directly proportional to the absorption capability of contaminants. According to [24], the absorption of BOD and COD by 96% and 94% can be achieved by *Chrysopogon zizanioides* L. density by as much as 30 with observation time of four weeks.

Growth of *Chrysopogon zizanioides* L.

The growth of *Chrysopogon zizanioides* L. on various treatments can be seen in Table 3, which shows that the number of living clumps, plant height, and relative growth rate (RGR) on each treatment was not much different. The final wet weights in PL0 and PL50 were not much different and ranged from 16.20 to 16.30 g, while PL75 and PL100 were different, ranging from 14.58 to 15.08 g (Fig. 1). These study results were smaller than other studies in which the average accumulations of biomass were 18.3 g and 18.9 g. According to [25], at 50% tapioca waste, *Chrysopogon zizanioides* L. could live with the dry biomass of 20.51 g/pot, and 15.58 g/pot could grow

Table 2. Average water quality parameter at each treatment

Parameters	Unit	Treatments			
		PL0	PL50	PL75	PL100
Temperature	°C	28.56±0.20 ^b	28.54±0.15 ^b	28.58±0.18 ^b	28.72±0.24 ^a
TSS	mg/L	433.79±91.76 ^d	1424.04±166.62 ^c	2031.29±95.84 ^b	2949.08±117.12 ^a
pH	-	8.13±0.76 ^b	9.21±0.08 ^a	9.28±0.10 ^a	9.34±0.11 ^a
Total ammonia	mg/L	0.07±0.04 ^d	0.74±0.28 ^a	0.89±0.20 ^a	0.78±0.62 ^a
BOD	mg/L	7.05±2.53 ^c	37.95±8.14 ^b	44.02±19.54 ^{ab}	52.89±8.96 ^a
COD	mg/L	44.76±5.65 ^d	273.88±24.93 ^c	427.75±35.93 ^b	559.94±22.56 ^a
Total Chrom	mg/L	0.01±0.02 ^d	0.81±0.06 ^c	1.39±0.15 ^b	2.34±0.07 ^a

Description: PL0 = Vetiver Control (*C. zizanioides*) without waste, PL50 = Vetiver in 50% water + 50% water, PL75 = Vetiver in 75% wastes +25% water, PL100 = Vetiver in 100% waste; Different superscript shows significantly different ($p < 0.05$).

Table 3. The growth of plants in each treatment

Parameter	Unit	Treatment			
		PL0	PL50	PL75	PL100
Initial weight (Wo)	g	14.54±0.07 ^a	14.57±0.19 ^a	14.48±0.03 ^b	14.45±0.11 ^b
Final weight (Wt)	g	16.39 ± 0.51 ^a	16.35± 0.47 ^a	15.08±0.52 ^b	14.51±0.09 ^b
Number of living clumps	clumps	11(61%) ^a	9(50%) ^a	6(35%) ^b	4(20%) ^b
Height growth every week	cm/day	0.032±0.001 ^a	0.03±0.004 ^a	0.022± 0.009 ^b	0.018±0.005 ^b
Relative Growth Rate (RGR)	g/day	0.002±0.00 ^a	0.002±0.001 ^a	0.001±0.00 b	0.0004±0.00 ^b

Description: PL0 = Vetiver (*C. zizanioides*) without waste, PL50 = Vetiver in 50% wastes + 50% water, PL75 = Vetiver in 75% wastes + 25% water, PL100 = Vetiver in 100% waste

at 100% tapioca waste. Research of [26] indicated that growth in PL50 showed RGR values approaching PL0 and was greater than that of PL75 and PL100. This is likely caused by the concentration of Cr in PL0 lower than the concentration of Cr in the PL75 and PL100. Therefore, it can be a cause for the obstruction of plant growth.

The number of clumps in PL50 was nine, which is no different from the number of clumps in PL0 (control), yet the values in PL50 and PL0 were greater than that in PL75 and PL100 (six and four clumps), respectively. The number of living clumps is inversely related to the waste concentration level where the greater waste concentration would produce fewer living clumps. Height growth and relative growth (RGR) of PL50 were higher than that of PL75 and PL100 (Fig. 4). These results are consistent with previous research using 50% tapioca waste, and *Chrysopogon zizanioides* L. growth was higher than other levels of tapioca waste (0, 60, 70, 80, 90, and 100%) [26]. The same results were also shown by [27] on coconut husk waste and research of [24] using secondary palm oil waste, as well as automobile waste with a wetlands system [28]. PL50 had average plant height of 0.03±0.004 cm/day and was not much different from the PL0

(control) of 0.032±0.001 cm/day, while PL75 and PL100 had 0.022±0.009 and 0.018±0.005 cm/day, respectively (Fig. 3).

Plant growth is generally influenced by external and internal factors. External factors include air temperature, light, and humidity. Meanwhile, internal factors include heredity and physiology of the individual itself. *Chrysopogon zizanioides* L. is a fast-growing grass with a large and complex root system. It is able to grow in difficult conditions, and it has unique morphological and physiological characteristics, as well as a very high tolerance to heavy metals and adverse conditions [29], and high tolerance toward extreme climatic conditions such as drought, extreme temperatures, and acid and alkaline pH. Factors that control plant uptake were the age of plants, seasonal variations, and climatic conditions [30]. *Chrysopogon zizanioides* L. can accumulate heavy metals in roots, making it suitable for phytostabilization and phytoextraction with the addition of chelating agents [31]. One of the distinctive characteristics of *Chrysopogon zizanioides* L. is its ability to form a thick hedge when planted close together, and it can stand upright at a depth of 0.6 m in water flow, forming a barrier that can impede water runoff and act as a very effective filter for capturing sediment and chemicals [29].

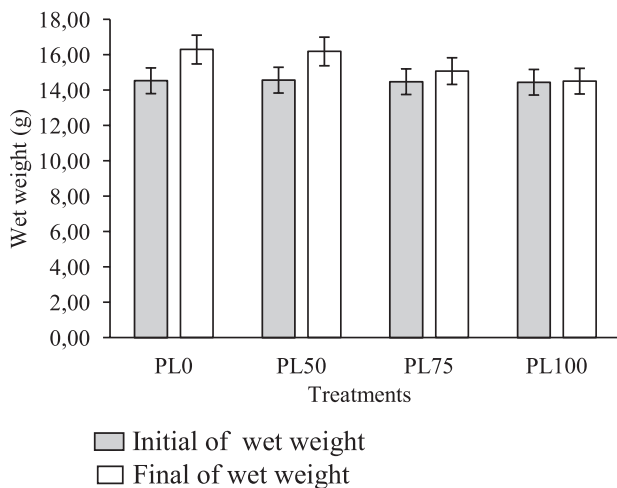


Fig. 1. Weights of *Chrysopogon zizanioides* L.: initial wet weight, final wet weight.

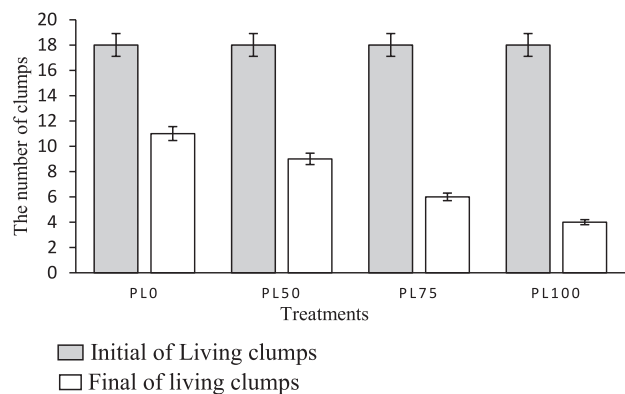


Fig. 2. Number of living clumps: initial living clumps, final living clumps.

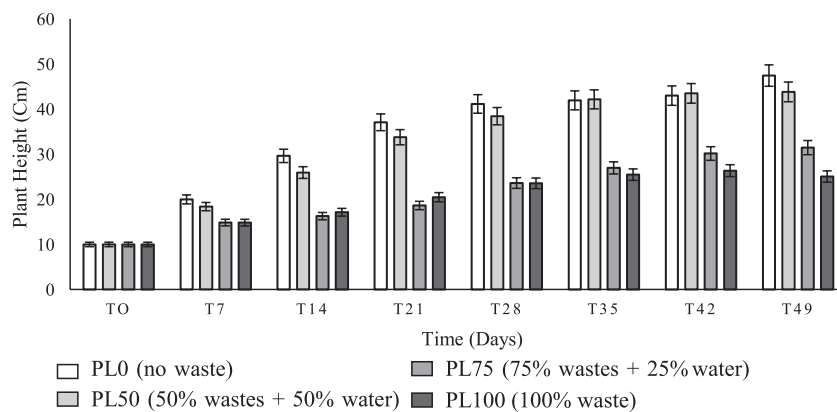


Fig. 3. Plant height growth: PL0 (no waste), PL50 (50% wastes + 50% water), and PL75 (75% wastes + 25% water, PL100 (100% waste).

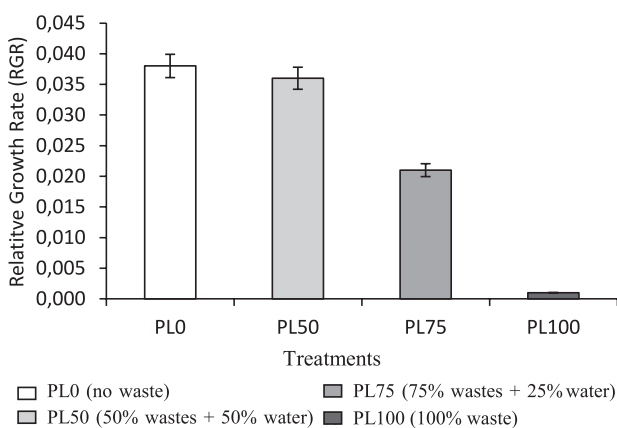


Fig. 4. Relative growth rate (RGR): PL0 (no waste), PL50 (50% wastes + 50% water), and PL75 (75% wastes + 25% water, PL100 (100% waste).

Height growth of Vetiver can reach 134 cm, root length of 24.62 cm, and a survival rate of 95.5% in textile waste [32]. According to [33], although this condition indicates that every plant is conditioned equally in terms of age, height, and weight, each plant has a different ability to adapt

to the new environment. Related to the total accumulated metals in both the roots and in the leaves, *Chrysopogon zizanioides* L. absorb more Cu than Cd. Increasing the age and the biomass of *Chrysopogon zizanioides* L. will enhance root development, and therefore the absorption rate of nutrients and photosynthesis will increase, which means an increase in the potential for waste degradation [25].

Chromium in Wastewater

Cr decline dramatically occurred in PL50 from week 0 to week 1 (Table 4). The treatment of PL50 had significant differences with PL75 and PL100 ($p < 0.05$). Based on the time, week 0 was significantly different from weeks 2, 3, and 5, and also significantly different from weeks 6 and 7 ($p < 0.05$). The concentration in PL50 in the 3rd week until the 5th week had no significant decline. According to [23], *Chrysopogon zizanioides* L. can reduce Cr concentration from 5 mg/L to 1.125 mg/L, and even higher than the results of this study, as well as result of Rodriguez [18], the treatment of contaminated sludge could absorb 30% Cr, which is less than the result of this study of 40.29% (Table 6).

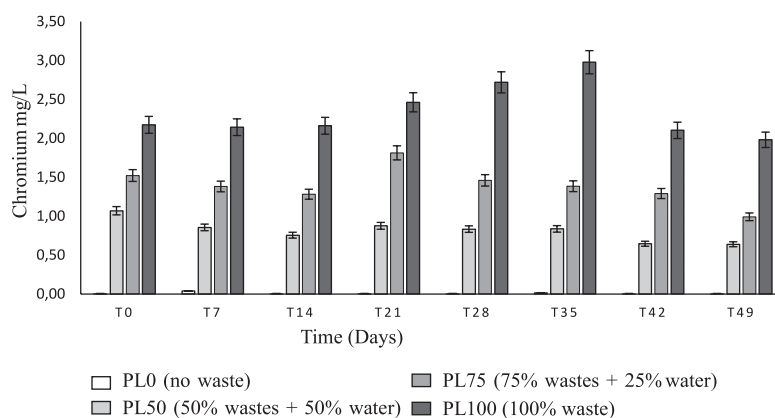


Fig. 5. Chromium concentration fluctuations during the experiment: PL0 (no waste), PL50 (50% wastes + 50% water), PL75 (75% wastes + 25% water, and PL100 (100% waste).

Table 4. Cr concentrations in the water.

Period (Weeks)	Concentrations mg/L		
	PL50 ^c	PL75 ^b	PL100 ^a
T0 ^{ab}	1.07±0.059	1.52±0.057	2.17±0.053
T1 ^{bc}	0.85±0.037	1.38±0.017	2.14±0.011
T2 ^c	0.75±0.033	1.28±0.171	2.16±0.085
T3 ^a	0.88±0.031	1.81±0.615	2.46±0.014
T4 ^a	0.83±0.099	1.46±0.082	2.72±0.063
T5 ^a	0.84±0.019	1.38±0.009	2.98±0.130
T6 ^c	0.64±0.138	1.29±0.118	2.10±0.120
T7 ^d	0.64±0.099	0.99±0.104	1.98±0.069

Description: Different *superscript* shows significantly different effect among treatments ($p < 0.05$).

Table 5. Accumulation of Cr (mg kg⁻¹) in *Chrysopogon zizanioides* L.

Parameter	Concentration (mg L ⁻¹)			
	PL0	PL50	PL75	PL100
Root	0.45	18.28	27.17	33.52
Leaf	0.88	1.27	0.96	0.86
Total accumulation	1.33	19.56	28.12	34.37

Description: PL0 = Vetiver Control (*C. zizanioides*) without waste, PL50 = Vetiver in 50% wastes + 50% water, PL75 = Vetiver in 75% wastes + 25% water, PL100 = Vetiver in 100% waste

Table 6. Removal efficiency of chromium in wastewater.

Treatment	Initial Concentration mg/L	Concentration mg/L		Efficiency (%)
		Final	Decreasing	
PL50	1.069	0.638	0.431	40.29
PL75	1.521	0.991	0.530	34.87
PL100	2.172	1.980	0.192	8.85

Description: PL50 = Vetiver in 50% wastes + 50% water, PL75 = Vetiver in 75% wastes + 25% water, PL100 = Vetiver in 100% waste

Table 7. Removal Efficiency of BOD and COD

Parameter	Unit	PL50		Efficiency %	PL75		Efficiency %	PL100		Efficiency %
		Initial	Final		Initial	Final		Initial	Final	
BOD	mg/L	117.28	1.80	98.47	134.77	4.42	96.72	164.21	3.68	97.76
COD	mg/L	773.50	84.72	89.05	806.00	60.89	60.89	788.64	95.18	88.65

Chromium Accumulation in Plants

Chrysopogon zizanioides L. can accumulate Cr in large quantities. The Cr toxicity threshold for *Chrysopogon zizanioides* L. ranged from 5-18 mg/kg [30]. Concentrations of Cr in roots ranged 18.28-33.52 mg/kg, and in leaves ranged 0.86-1.27 mg/kg (Table 6). Accumulation of Cr in the roots was higher than that in the leaves because the root has a high cation exchange capacity to absorb the Cr in the wastewater, which is then transmitted to the leaves [34]. *Chrysopogon zizanioides* L. can absorb metals such as Mn, Fe, Cu, Zn, and Pb from industrial waste [35] and TNT organic waste [36]. *Chrysopogon zizanioides* L. can be grown on waste containing cadmium at concentrations of 1-7.5 ppm, and it does not produce toxicity [37]. *Chrysopogon zizanioides* L. absorption of Cu was greater than that of Cd [33].

An increase in the number of *Chrysopogon zizanioides* L./pot totally increases the absorption of Cr, yet the absorption continuously decreases with the lower number of *Chrysopogon zizanioides* L. or clumps [38]. The height growth of plants was not much different between the control and PL50, whereas the growth of PL75 and PL100 were different from PL0 and PL50. The increase in number of *Chrysopogon zizanioides* L./pots increases the absorption of Cr for any number of plants per clump. The absorption rate of 37.01% was observed in three clumps of *Chrysopogon zizanioides* L./pot [38]. This suggests that *Chrysopogon zizanioides* L. has the ability to absorb Cr. This result was lower than the results obtained in this study (40.29%). [24] found that Cr absorption efficiency reached 77-78%. *Chrysopogon zizanioides* L. is also able to reduce the levels of Cr up to 30% in sludge containing chromium of 21,000 mg/kg to be 13,529 mg/kg [38]. The *Chrysopogon zizanioides* L. can also grow well in fish cultivation media by absorbing and using nutrients in water for its growth process [39].

Conclusion

The growth of *Chrysopogon zizanioides* L. in PL50 (50% wastewater treatment) was more optimal than that of in PL75 and PL100. Absorption of Cr reached 40.29%. It is suggested to conduct further research using a much higher number of clumps in order to make more optimal metal absorption.

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