Aromatic Plants: Phytoremediation of Cadmium Heavy Metal and The Relationship to Essential Oil Production

Yustina Sri Sulastri, Koko Tampubolon

Abstract—This research was aimed to obtain the aromatic plants selected as phytoremediation of cadmium heavy metals (Cd-HM) and their relationship to essential oil production. This research was conducted in the Experiment Land, the Faculty of Agriculture, Universitas Sumatera Utara in March until May 2018. This research was used as a non-factorial Randomized Block Design (RBD) with three replications. Plants treatment: P1 (*Vetiveria zizanioides*), P2 (*Cymbopogon nardus*), P3 (*Curcuma xanthorrhiza*), P4 (*Cymbopogon citratus*), P5 (*Pogostemon cablin*), P6 (*Alpinia galanga*) were treated stress heavy metal of 100 ppm $3CdSO_4.8H_2O$. The parameters include water content, Cd-HM uptake, Cd-HM uptake ratio, essential oil total content, translocation factor, correlation coefficient, and determination. The analysis using the ANOVA and were continued by DMRT at level 5%, and multiple linear regression using the IBM SPSS Statistics 20 software. The results showed that translocation factor value sequentially of P5> P6> P4> P2> P3> P1. The Cd-HM uptake ratio in the root was higher than in the shoot except for P4 plant. There was an increase in the essential oil total content in the P1, P2 and P5 plants of 101.56%; 12.70% and 2.27%, respectively. The increased water content in the plant can decrease the essential oil total content but the Cd-HM uptake can increase the essential oil total content. The water content, Cd-HM uptake in the root and shoot had positive linear correlation, were classified as weak (r = 0.30) and their relationship of 9.10% (slightly) to the essential oil total content.

Index Terms—Aromatic Plants, Cadmium, Heavy Metal, Phytoremediation

1 INTRODUCTION

The heavy metals are high molecular weight metal elements, the density is more than five g/cm^3 [1]. Based on the toxicity, Cd heavy metal (Cd-HM) is second place after Hg and were followed by Ag, Ni, Pb, As, Cr, Sn, Zn heavy metals. The Cd-HM is a metal that is more easily accumulated by plants than other heavy metals [2]. Sources of Cd-HM in agricultural include agrochemicals (fertilizers and pesticides), emissions of motor vehicles, fuel oil, organic fertilizers, household waste, industrial, mining waste and parent materials, such as Cd found in schales sedimentary rocks (0.22 ppm) [3].
Heavy metals can accumulate into the food chain cycle in plant tissues through the roots [4]. Heavy metals will accumulate in the tissues and can cause toxication to humans and plants if they exceed the tolerance threshold. [5] stated that Cd toxication can cause high blood pressure, testicular tissue damage, kidney damage, and erythrocyte damage. The presence of Cd-HM on agricultural must be controlled immediately so as does not dangerous human health. The alternative that can be used to reduce Cd-HM is phytoremediation. [6] stated that phytoremediation is the use of plant parts to decontaminate waste and environmental pollution problems either ex-situ using artificial ponds or reactors and in-situ (directly in the field) on areas that contaminated waste. The plant requirements for phytoremediation, among: fast growing, able to consume a large of water at a short time, able to remediate more than one pollutant, and high tolerance to pollutants.
Previous research of phytoremediation has been reported from several plants. According to [7] stated that vetiver grass plant can accumulate Cd in the roots and shoots of 167-396 mg/kg and 0.13-9.0 mg/kg, respectively. Therefore vetiver grass accumulates of Cd-HM at the root is higher than in the shoot. According to [8] stated that giant milkweed plant has the ability to Cd-HM uptake in the root of 1.26 ppm and in the shoot of 1.01 ppm.
The use of food crops, horticulture or plantations were not recommended as Cd-HM phytoremediation. This is because Cd-HM can disrupt the plant cycle and can accumulate in plant organs that can be consumed such as seeds, leaves, stems, fruits, and other organs. The use of alternative plants such as aromatic plants can be a recommendation as phytoremediation without disturbing the expected output (ex: essential oils production). Therefore research was needed on phytoremediation of Cd-HM in aromatic plants as initial information in reducing the presence of heavy metal in agricultural. The research was aimed to obtain aromatic plants selected as Cd-HM phytoremediation and the relationship to essential oil production.

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2 MATERIALS AND METHODS

2.1 Media and Plants Preparation

Soil weight of 10 g was prepared for Cd-HM content measurement. The soil was dried air and then put into a polybag measuring of 40 cm x 20 cm with a dry weight of 5 kg. The plants preparation with the criteria used can be seen in Table 1. This research was conducted in the experimental land, the Faculty of Agriculture, Universitas Sumatera Utara. This research was conducted on March until May 2018. This research was used non-factorial Randomized Block Design with the treatment of six plants on the 100 ppm Cd-HM treated conditions and untreated. The treatment was made three replications.

TABLE 1
The Criteria of Aromatic Plants

Aromatic plants	Criteria
P1/Vetiver grass (*Vetiveria zizanioides*)	Taken from the 3-month-old parent plant, with the cutting 20 cm height and 8 cm root length [9].
P2/Citronella grass (*Cymbopogon nardus*)	The leaf are cut approximately 3 until 5 cm from the leaf sheath, and the roots are cut approximately 2.5 cm below the root base [10].
P3/Java turmeric (*Curcuma xanthorrhiza*)	Taken from the rhizome with 20 g weight [11].
P4/Lemongrass (*Cymbopogon citratus*)	The leaf are cut approximately 3 until 5 cm from the leaf sheath, and the roots are cut approximately 2.5 cm below the root base [10].
P5/Patchouli (*Pogostemon cablin*)	Taken from the 4-month-old parent plant with cuttings of 3 segments or 15 cm length and leaving 2 until 4 young leaves [12].
P6/Greater galangal (*Alpinia galanga*)	Taken from the rhizome with 50 g weight containing 2 until 3 buds.

2.2 Cd-HM Application

The $3CdSO_4.8H_2O$ was measured of 100 ppm (0.5 g/kg topsoil) then was immersed in the 3 until 5 cm depth from the ground and 2 cm from the plant main stem. The application was conducted at 6 weeks after planting (WAP).

2.3 Cd-HM Analysis in the Roots and Shoots

Analysis of Cd-HM uptake in the roots and shoots of plants was conducted in the Research Laboratory, the Faculty of Pharmacy, Universitas Sumatera Utara using dry destruction method. The plant material used as sample of cadmium analysis and the essential oil total content is the plant root for P1 (*Vetiveria zizanioides*); P2 (*Cymbopogon nardus*); P4 (*Cymbopogon citratus*); P5 (*Pogostemon cablin*), while the plant rhizoma for P3 (*Curcuma xantorrhiza*) and P6 (*Alpinia galanga*) and the plant shoots respectively. The sample was measured ± 3 g then finely chopped into 50 ml crucible and conducted with the temperature of 0 to 200^oC for ± 30 minutes (reducing water in the material) then the temperature of 200 to 300^oC for ± 60 minutes (the drying process) and finally the temperature of 300 to 600^oC for ± 120 minutes (ash process). The resulting ash is then reconstructed with the concentrated HNO_3 mixture and aquades with the 1: 1 ratio as much as 5 ml, dissolved until homogeneous. The ash solution is then diluted using distilled water up to 25 ml. The solution was filtered with Whatman filter No. 42. Then the solution was analyzed for Cd-HM content using the *Atomic Absorption Spectrophotometer* (AAS).

2.4 Essential Oil Content Analysis

The essential oil total content analysis was conducted in the Research Laboratory, the Faculty of Pharmacy, Universitas Sumatera Utara. The material were used to analyze of essential oil total content was taken from the vetiver grass roots, the leaves of lemongrass, citronella grass, and patchouli, the rhizomes of java turmeric and greater galangal plants. All material were dried in an oven at 40^oC for 3 days. This analysis is through a boiling process for 6 hours that produces water vapor which already contains essential oil.

2.5 Harvesting and Parameters Analysis

Plants were harvested after 10 WAP. The parameters were observed the water content in the roots and shoots of plants, the Cd-HM uptake in roots and shoots (ppm), the Cd-HM uptake ratio in the roots and shoots, the essential oil total content, and translocation factors. The water content (WaC) in roots and shoots was determined by the fresh weight (FW) and dry weight (DW) of plants, refer to "(1)". Cd-HM uptake (Cd-HMu) in the roots and shoots, refer to "(2)". The Cd-HM uptake ratio in the roots and shoots, refer to "(3)". The translocation factors, refer to "(4)". The essential oil total content, refer to "(5)".

$$\text{WaC in root/shoot} = \frac{FWroot/shoot - DWroot/shoot}{DWroot/shoot} x100\ \% \quad (1)$$

$$\text{Cd-HMu root/shoot} = \frac{\text{Cd Concentration of root/shoot x volume}}{\text{DW of sample}} \quad (2)$$

$$\text{Cd-HMu ratio in root/shoot} = \frac{\text{Cd - HMu root/shoot treated}}{\text{Cd - HMu root/shoot untreated}} \quad (3)$$

$$\text{Translocation factors (TF)} = \frac{\text{Cd Concentration in the shoot}}{\text{Cd Concentration in the root}} \quad (4)$$

$$\text{Essential oil total content} = \frac{\text{Essential oil total content}}{\text{DW of sample}} \quad (5)$$

The data of essential oil total content and the Cd-HM uptake in the roots and shoots were analyzed by ANOVA and were continued by Duncan's Multiple Range Test (DMRT) at level 5%. While the relationship between the water content, Cd-HM uptake in the roots and in the shoots on the essential oil total content were analyzed by the multiple linear regression (Fig. 1). All analyses in this research using the IBM SPSS Statistics 20 software. The multiple linear regression models in this study are as follows:

$$\mathbf{Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \varepsilon}$$

Y: Essential oil total content
a: The constant of the line Y axis
b_1: Coefficient of water content
b_2: Coefficient of Cd-HM uptake in the roots
b_3: Coefficient of Cd-HM uptake in the shoots
X_1: Water content (%)
X_2: Cd-HM uptake in the roots
X_3: Cd-HM uptake in the shoots
ε : Error

This research test include multicollinearity, t-test (partial), correlation coefficient (r), and determination coefficient (R). Multicollinearity testing functions to determine whether there is a linear relationship between independent variables in the regression model. The prerequisite that must be fulfilled in the regression model is the absence of multicollinearity. Multicollinearity test is done by looking at the variant inflation factor (VIF) and tolerance values in the regression model. The good regression model is that multicollinearity does not occur as evidenced by the VIF value < 5 and the tolerance value > 0.1. The t-test functions to determine whether the independent variables (X) partially have a significant effect or not on the dependent variable (Y) with a 95% confidence level. If sig < 0.05 then H_1 hypothesis is accepted and if sig > 0.05 then H_1 hypothesis is rejected.

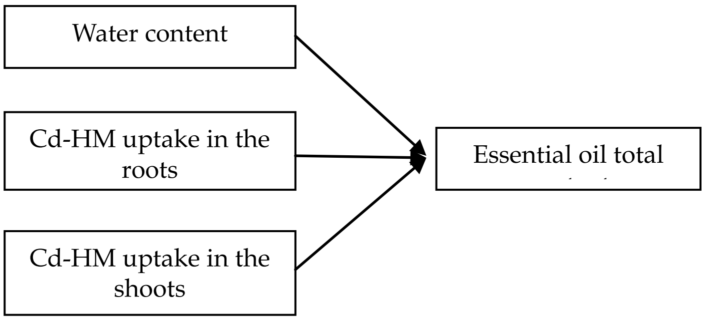

Fig. 1. The relationship between the water content, Cd-HM uptake in the roots and in the shoots on the essential oil total content.

The correlation coefficient (r) was used to determine the strength of the relationship between independent and dependent variables and the relationship between variables. The categories of correlation coefficients include 0.00 until 0.19 (very weak), 0.20 until 0.39 (weak), 0.40 until 0.59 (strong enough), 0.60 until 0.79 (strong) and 0.80 until 1.00 (very strong) [13]. The determination coefficient (R) is used to determine the dimensions of the relationship between the influence of the independent variables to the dependent variable. If the R-value approach to zero, it means that the model is not good or the model variation in explaining is very limited, conversely it is an approach to one, the model is better to explain the influence of independent variables on the dependent variable.

3 RESULTS AND DISCUSSION

3.1 Water Content in the roots and Shoots

The average data the water content of plants (roots and shoots) Cd-HM treated and untreated for 10 WAP were presented in Fig 2. Based on F-test and DMRT 5% was found that 100 ppm Cd-HM treated can significantly affect the water content in the roots or rhizomes of P2, P4, and P5 plant but not significant in the shoots. Based on Figure 2, was found that the Cd-HM treatment of 100 ppm can decrease the water content in the roots of P3 (*Curcuma xanthorrhiza*), P5 (*Pogostemon cablin*), and P6 (*Alpinia galanga*) of 0.95%; 6.24% and 6.75%, respectively compared to Cd-HM untreated. The giving 100 ppm of Cd-HM can decrease the water content in the shoots of P2 (*Cymbopogon nardus*), P4 (*Cymbopogon citratus*), and P6 (*Alpinia galanga*) of 6.19%; 1.56% and 4.48%, respectively compared to Cd-HM untreated. The decrease of water content in the roots and shoots were caused by decrease the fresh weight and the transpiration level in the presence of Cd-HM stress. This is linear to [14] stated that there is a decrease in the water content in the roots and shoots of pea plants along with the Cd heavy metal increase. The giving 10 and 50 µM of Cd heavy metal can decrease the water content in the pea roots of 1.46% and 4.44%, respectively compared to control. The giving 10 and 50 µM of Cd heavy metal can decrease the water content in the shoots of pea plant of 1.74% and 6.92%, respectively compared to control. According to [15] stated that there was decrease the water content of *Vetiveria zizanioides* from 83.82% to 70.85% when giving stress of Cd heavy metal the dose at 1 until 30 mg/L.

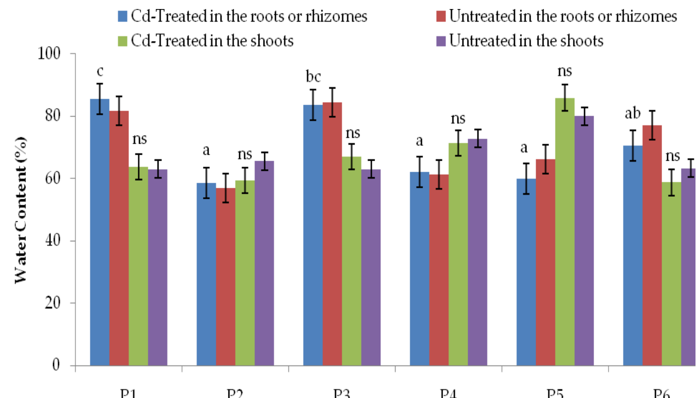

Fig 2. The water content (%) in the roots and shoots Cd-HM treated and untreated for 10 WAP. P1 (*Vetiveria zizanioides*); P2 (*Cymbopogon nardus*); P3 (*Curcuma xanthorrhiza*); P4 (*Cymbopogon citratus*); P5 (*Pogostemon cablin*); P6 (*Alpinia galanga*). Vertical bars indicate ± SE.

3.2 Cd-HM Uptake in the Roots and Shoots

The average data of Cd-HM uptake and ratio in the roots and shoots was treated and untreated for 10 WAP were presented in Table 2. Based on F-test and DMRT 5% was found that the roots and shoots of plants were not significant on the 100 ppm Cd-HM uptake.

TABLE 2
The Cd-HM Uptake and ratio in the roots and shoots of plants on treated and untreated for 10 WAP

Plants	Cd-HM uptake (ppm/fresh weight)					
	In the roots or rhizomes			In the shoots		
	Treated	Untreated	Uptake ratio	Treated	Untreated	Uptake ratio
P1	8.82	0.57	15.47	1.08	0.54	2.00
P2	17.58	0.89	19.75	2.71	0.25	10.84
P3	17.33	1.21	14.32	2.43	0.62	3.92
P4	8.93	2.25	3.97	1.72	0.40	4.30
P5	5.24	0.27	19.41	5.04	4.70	1.07
P6	2.68	0.10	26.80	2.56	0.46	5.57

Note: Numbers followed by the same letters in the same column for each treatment were not significantly different by the DMRT at level 5%. P1 (*Vetiveria zizanioides*); P2 (*Cymbopogon nardus*); P3 (*Curcuma xanthorrhiza*); P4 (*Cymbopogon citratus*); P5 (*Pogostemon cablin*); P6 (*Alpinia galanga*).

Based on Table 2, was found that the Cd-HM uptake ratio in the roots was higher than in the shoots of the plant except for *Cymbopogon citratus* (P4). The Cd-HM uptake ratio highest in the roots was found in *Alpinia galanga* (P6), were followed by *Cymbopogon nardus* (P2) and *Pogostemon cablin* (P5) of 26.80; 19.75; 19.41-fold respectively compared to Cd-HM untreated.

This shows that the P6, P2, and P5 plants can accumulate dominant Cd-HM in the roots. The Cd-HM uptake ratio on highest in the shoots was found in *Cymbopogon nardus* (P2) and were followed by *Alpinia galanga* (P6) and *Cymbopogon citratus* (P4) plants of 10.84; 5.57; and 4.30-fold respectively compared to Cd-HM untreated. This is shown that the P2, P6, and P4 plants can accumulate dominant Cd-HM in the shoots. According to [7] stated that *Vetiveria zizanioides* can accumulate Cd in the roots (167-396 mg/kg) is higher than in the shoots (0.13-9.0 mg/kg). According to [16] stated that the Cd-HM uptake in the roots of aromatic plants such as *Matricaria recutita* (48.6 ppm) and *Salvia officinalis* (51.7 ppm) is higher than in the shoots of plants of 27.1 ppm and 2.31 ppm, respectively. According to [17] also stated that Cd-HM uptake in the roots of *Pogostemon* is higher (0.07-0.09 mg/kg) than in the shoots (0.02-0.05 mg/kg).

3.3 Translocation Factor (TF)

The data of the translocation factor on Cd-HM treated plants for 10 WAP were presented in Fig 3. The result was showed that the translocation factor (TF) sequence of six plants as follows P5 > P6 > P4 > P2 > P3 > P1. Based on Fig 3, was found that the P5 (*Pogostemon cablin*) and P6 (*Alpinia galanga*) plants showed that the efficiency of Cd-HM removal from the roots to shoots with TF value of 0.963 and 0.956, respectively is higher than other plants. The P1 (*Vetiveria zizanioides*), P2 (*Cymbopogon nardus*), P3 (*Curcuma xanthorrhiza*) and P4 (*Cymbopogon citratus*) plant is more dominant in accumulating Cd-HM in the roots or rhizomes.

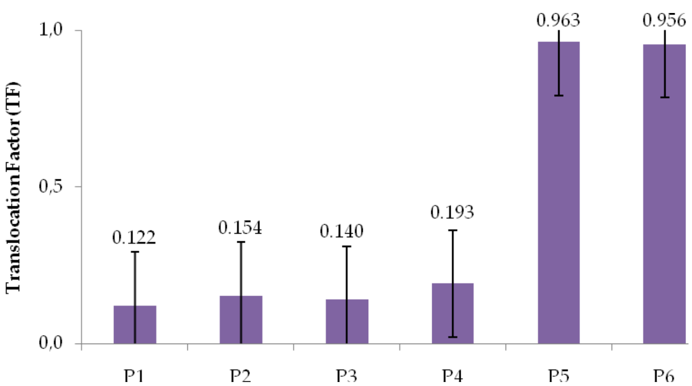

Fig 3. The translocation factors on Cd-HM treated plants for 10 WAP. P1 (*Vetiveria zizanioides*); P2 (*Cymbopogon nardus*); P3 (*Curcuma xanthorrhiza*); P4 (*Cymbopogon citratus*); P5 (*Pogostemon cablin*); P6 (*Alpinia galanga*). Vertical bars indicate ± SE.

The results showed that indicate there are no plants that have TF > 1 so that all plants nothing can be as Cd-HM accumulator or phytoextraction. According to [18] stated that if TF value > 1 showed that plants can be as phytoextraction, where FT describes the efficiency of plants internal removal in heavy metal distributing from the roots to the shoots. [7] stated that *Vetiveria zizanioides* had the translocation factor value of Cd heavy metal accumulation of 0.026. [16] stated that the translocation factors value from the Cd heavy metal accumulation in aromatic plants (*Matricaria recutita* dan *Salvia officinalis*) of 0.56 and 0.04, respectively. In addition, [17] stated that the translocation factor value of Cd heavy metal accumulation in the *Pogostemon* plant of 1.09.

3.4 Essential Oil Total Content

The data of essential oil total content on Cd-HM treated and untreated plants for 10 WAP were presented in Table 3. Based on the F-test and DMRT 5%, was found that the 100 ppm Cd-HM treatment can significantly increase the essential oil total content on plants.

TABLE 3
The Essential Oil Total Content on Cd-HM treated and untreated for 10 WAP

Aromatic plants	Essential oil total content (10^{-2} ml/g)			
	Treated	Untreated	%	Treated/ untreated ratio
P1	1.29 ab	0.64	101.56	2.01
P2	2.13 a	1.89	12.70	1.13
P3	0.82 bc	1.42	-42.25	0.57
P4	1.83 a	1.93	-5.18	0.95
P5	0.90 b	0.88	2.27	1.02
P6	0.01 c	0.22	-95.45	0.02

Note: Numbers followed by the same letters in the same column for each treatment were not significantly different from the DMRT at level 5%. P1 (*Vetiveria zizanioides*); P2 (*Cymbopogon nardus*); P3 (*Curcuma xanthorrhiza*); P4 (*Cymbopogon citratus*); P5 (*Pogostemon cablin*); P6 (*Alpinia galanga*).

Based on Table 3, was found that the 100 ppm Cd-HM treatment can increase the essential oil total content in P1 (*Vetiveria zizanioides*), P2 (*Cymbopogon nardus*), and P5 (*Pogostemon cablin*) plants of 101.56%; 12.70% and 2.27%, respectively compared to Cd-HM untreated or had treated/untreated ratio of 2.01; 1.13; and 1.02-fold, respectively. Plants can respond to stress will result in an increase in secondary metabolites. The Cd-HM stress will cause plants to release some of the secondary metabolites (ex: essential oil, etc.). [19] stated that *Vetiveria zizanioides* can produce secondary metabolites such as essential oil. [20] stated that the *Cymbopogon nardus* on Cd exposed had ability to accumulate the highest of total Cd heavy metals of 20.29 ppm compared to Cd unexposed. [21] stated that the 50 ppm Cd-HM treatment can increase the essential oil content in *Vetiveria zizanioides* of 33.33% compared to control. [17] stated that the phenolic content of the stems and leaves of *Pogostemon* plant had decreased with increase of Cd heavy metal treatment amount of 0.03-0.06 mg/mL (40-70%) and 0.08-0.11 mg/mL (38.89-55.56%), respectively compared to control. [16] stated that Cd heavy metals have few effects on the essential oil production in the *Matricaria recutita* (aromatic) plant, increasing the E-β-ocimene, camphene compounds and decreasing the artemisyl acetate, E-β-farnesene compounds. The Cd heavy metal also has an effect on the essential oil of *Salvia officinalis* (aromatic), which increases the 1.8-cineole compound and can decrease β-thujone compound in several concentrations of Cd heavy metal.

3.5 Multiple Linear Regression Analysis

The distribution pattern of water content, Cd-HM uptake in the roots and shoots, and essential oil total content in this research can be seen in Fig. 4.

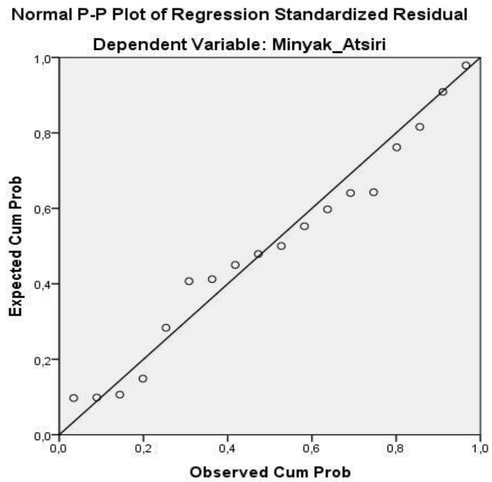

Fig 4. The distribution pattern of water content, Cd-HM uptake in the roots and shoots, and essential oil total content.

The analysis results showed that the resulting points approach the diagonal axis, meaning the regression model obtained of the essential oil total content with three independent variables (water content, Cd-HM uptake in the roots and shoots) on normally distributed. The results of multicollinearity, t-test (partial), regression coefficient, correlation coefficient and determination coefficient of the water content, Cd-HM uptake in the roots, and in the shoots to essential oil total content can be seen in Table 4.

TABLE 4
The Multicollinearity, t-test, Regression Coefficient, Correlation Coefficients and Determination Coefficient of The Water Content, Cd-HM Uptake in the Roots, and in the Shoots to Essential Oil Total Content.

Variable X	Collinearity Statistics		t-test (sig)	regression coefficient	r	R (r^2)
	Tolerance	VIF				
Constant	-	-	-	1.4037		
X_1	0.91	1.09	0.65^{ns}	-0.0074	0.30 (weak)	9.10%
X_2	0.79	1.26	0.31^{ns}	0.0261		
X_3	0.82	1.21	1.00^{ns}	0.0003		

Note : X_1 (water content); X_2 (Cd-HM uptake in the roots); X_3 (Cd-HM uptake in the shoots). t-test (sig) > sig 5% then not significant (ns).

Based on Table 4, showed that the tolerance value in the water content, Cd-HM uptake in the roots and shoots > 0.1 and VIF value < 5, then there is no multicollinearity, its mean that there was a linear relationship between the water content, Cd-HM uptake in the roots and shoots to the essential oil total content in regression model. Then the linear regression model of this research eligible good regression. The t-test value or sig of the water content (0.65), the Cd-HM uptake in the roots (0.31) and the Cd-HM uptake in the shoots (1.00) is higher than the probability value (Sig> 0.05) then the water content, the Cd-HM uptake in the roots and in the shoots partially did not significantly affect to the essential oil total content. The multiple linear regression equation models of this research:

$$\mathbf{Y = 1.4037 - 0.0074\, X_1 + 0.0261\, X_2 + 0.0003\, X_3}$$

The results of multiple linear regression equations in this research was indicated that each increase of 1% water content will decrease the essential oil total content of 0.0074 x 10^{-2} ml/g. Each increase of one ppm Cd-HM uptake in the roots and in the shoots of plants will increase the essential oil total content of 0.0261 and 0.0003 x 10^{-2} ml/g, respectively. This is indicates that the presence of Cd-HM both in the roots and in the shoots can affect the increase in the essential oil total content. The correlation coefficient (r) of 0.30. This is shown that the water content, the Cd-HM uptake in the roots and in the shoots had positively linearly correlated, in line and were classified as weak to the essential oil total content. The determination coefficient (R) of this research of 9.10%. This is shown that the effect of the water content, the Cd-HM uptake in the roots and in the shoots to the essential oil total content of 9.10% (slightly) and the residual of 90.90% were influenced by other factors such as plant age, plant material size, soil pH, C-organic content, soil cation exchange capacity, soil moisture, and rainfall. According to [22] stated that the essential oil quality of Citronella (*Cymbopogon winterianus* Jowitt.) was obtained at 80-90 days after the first harvest (3 months). [23] stated that the Cd uptake from the soil by plants were influenced by Cd input total in the soil, soil pH, Zn content, types of plants and cultivars. The Cd uptake will be high at low pH and decrease at high pH. [24] stated that weather conditions and harvest frequency cause a quantitative change in the essential oil components of *Marrubium vulgare* plant.

4 CONCLUSIONS

The highest sequence of translocation factor value was found in P5 (*Pogostemon cablin*) > P6 (*Alpinia galanga*) > P4 (*Cymbopogon) citratus*) > P2 (*Cymbopogon nardus*) > P3 (*Curcuma xantorrhiza*) > P1 (*Vetiveria zizanioides*). The Cd-HM uptake ratio in the roots is higher than in the shoots except for P4 plant. The 100 ppm Cd-HM treatment can decrease the water content in the roots of P3, P5 and P6 plants of 0.95%; 6.24% and 6.75%, respectively but can increase the essential oil total content of P1, P2 and P5 plants of 101.56%; 12.70% and 2.27%, respectively. Each 1% water content increase will decrease the essential oil total content of 0.0074 x 10^{-2} ml/g but each 1 ppm Cd-HM uptake increase in the roots and in the shoots will increase the essential oil total content of 0.0261 and 0.0003 x 10^{-2} ml/g, respectively. The water content, Cd-HM uptake in the roots and in the shoots had positive linear correlations, were classified as weak (r = 0.30) and the relationship of 9.10% (slightly) to the essential oil total content.

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