Water Spinach (*Ipomoea reptans* Poir) Hydroponic Kratky System at Various Levels of $PbSO_4$ Contamination

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ABSTRACT

Lead (Pb) contamination and types of nutrients in static hydroponic system for growing water spinach are increasingly being studied due to the impact on the food chain. Consequently, the presence of Pb needs to be considered, specifically in fast-growing plant commodities. Alternative nutrient sources that are cheaper and more easily available should be developed and tested for effectiveness in the Kratky hydroponic system. In general, the Kratky hydroponic system runs without electricity and does not use wicks, making it economical and easy to apply in urban agriculture. Therefore, this research aimed to determine the effect of nutrition type and Pb absorption on the growth of water spinach planted in the Kratky hydroponic system. Test plants were planted for 30 days and the research used a 2-factor factorial randomized block design. The Pb concentration was varied at 50 , 100, 150, and 200 mg/L. The plant without Pb was used as control. The nutrition types used were standard hydrophonic (N1) and alternative nutrients containing NPK and Gandasil D (N2). The results showed that nutrition type had a significant effect on plant height, number of leaves, root length, wet and dry weight of shoots and roots, leaf area, shoot root ratio, harvest weight and stem diameter. The ABmix nutrient type (standard hydroponic media) has better performance than alternative nutrient types. There was no growth disturbance due to Pb contamination in the form of $PbSO_4$. Furthermore, the combination of Pb concentration and nutrient-type treatment did not have a significant effect on the plant's growth and production except for the number of leaves. The combination of Pb concentration of 50 mg. L-1 and AB mix nutrition provided the best number of leaves.

Keywords: Hydroponics; Kratky; nutrition; Pb contamination; water spinach

INTRODUCTION

Water spinach is a type of short-lived vegetable, which is easy to cultivate and has relatively wide environmental adaptability. According to previous research, the plant has economic potential when cultivated intensively (Edi, 2014; Shobayar et al., 2018; Kasi et al., 2018). It also has the prospect of being marketed in supermarkets, thereby being suitable for development in urban areas that generally have limited yard space. Caring for water spinach plants is easy and quite suitable for cultivation conditions using hydroponic method. The cleanliness of vegetable products, weeds, pests, and diseases are easily controlled in hydroponic media, but the Kratky system is a static hydroponic system. Therefore, there is no drainage or water

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replacement from planting short-lived vegetables such as water spinach. The potential for Pb (Lead) contaminants in static water media is greater because there is no water washing and changing in static hydroponic system. The Kratky static hydroponic system, with the advantages, can be applied to vegetable cultivation in small urban areas. It ensures production continuity, specifically for household consumption (Wahyuningsih et al., 2016; Suharto, 2016).

The Kratky system is different from Nutrifit Film Technique (NFT) and Deep Flow Technique (DFT), as it runs without electricity and does not use wicks. Meanwhile, NFT and DFT systems use water flow, usually with electrical energy (Pancawati and Yulianto, 2016; Wibowo, 2020). This research was intended to examine the potential for Pb absorption by water spinach grown in the static hydroponic media of the Kratky system.

Water spinach is a hyperaccumulator plant with a translocation factor (TF) value of 1.34, suggesting it has a photo-erectile mechanism (Retno and Rosyidah, 2013). Phyto-erection or Phytoextraction refers to heavy metals absorption by plant roots and accumulation in parts such as roots, stems, and leaves (Caroline and Moa, 2015). Water spinach plants can function as a hyperaccumulator with a phytoextraction mechanism that has the potential to absorb heavy metals such as Cu and Pb, hence, there is a risk of the harvest being transported when planted in polluted conditions. According to Indonesian Food and Drug Authority No 5 of 2018 and Indonesian National Standard of 2009, the safe tolerance limit for fruit and vegetables consumed is 0.2 $mg.Kg^{-1}$ for Cd and 0.5 $mg.Kg^{-1}$ for Pb. The maximum Pb limit in water spinach is 0.5 $mg.L^{-1}$ based on Indonesian National Standard of No 7387: 2009.

The nutrient solution in hydroponic cultivation is a crucial factor in determining the yield and quality of plants. Insufficient nutrient solution levels can cause plants to wilt and die, while excessive use may inhibit growth (Wijaya et al., 2020). Hydroponic nutrients available on the market are relatively expensive and are not readily available in certain areas. Water spinach vegetables are easy to cultivate and provide an opportunity to test alternative nutrients with a cheaper raw material. However, it is also necessary to consider the potential for heavy metal absorption in plants grown in environments contaminated with heavy metals such as Pb.

Pb contamination and types of nutrients in static hydroponic system for growing water spinach need to be studied because environmental contamination can be included in the food chain. Consequently, the presence of Pb needs to be considered, specifically in fast-growing plant commodities. It is important to find alternative sources of cheaper and more easily available nutrients and test effectiveness on Kratky static hydroponic. System runs without electricity and does not use wicks, making it economical and easy to apply in urban agriculture. Therefore, this research aimed to determine the effect of nutrition and Pb absorption type on water spinach growth in the Kratky hydroponic system.

METHODS

Planting Conditions

Water spinach was planted with the Kratky system static hydroponic method, using 30 styrofoam boxes with a water capacity of 14 L. A total of 5 holes were drilled in each box to place 5 net pots, and 5 plants. These plants were grown according to the harvest standards for 30 days. The seeds germinated for 2 days using wet tissue media. After germination, 7 water spinach seeds were placed in a net pot, and then 5 uniform plants were selected to continue growth (Figure 1).

Placement in a netpot was made without a wick (Kratky system), using a styrofoam box containing AB

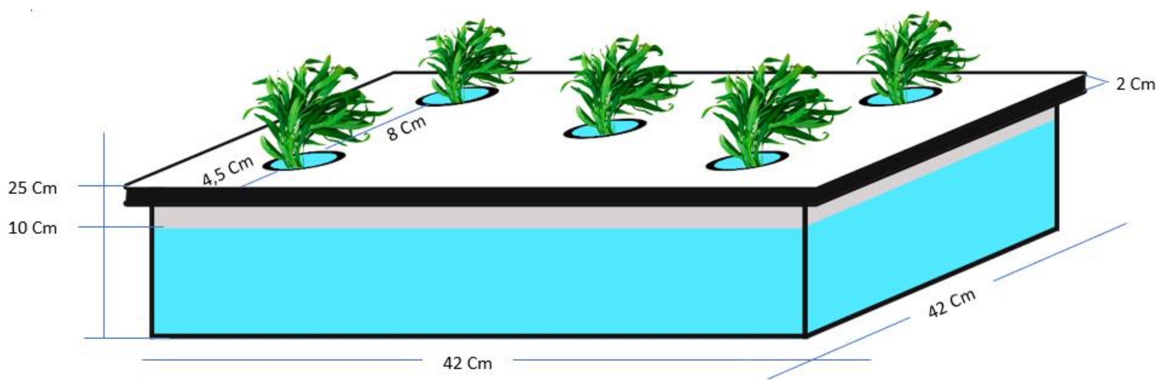


Figure 1 . Sketch and drawing of plant placement

mix nutrient solution and NPK and Gandasil D fertilizer fertilizer, according to the type of nutrient treatment. AB Mix is a hydroponic solution that contains micro and macro nutrients which are used to support plant growth. Pb metal contamination was in the form of $PbSO_4$ dissolved according to the amount of Pb treatment applied. Calculation regarding the amount of Pb and the volume of water placed in the media box required for each treatment is shown in Table 1.

The research used a randomized block factorial design with two factors, specifically, the first factor was level of Pb concentration consisting of five treatment levels including Pb0 = 0 $mg.L^{-1}$, Pb1 = 50 $mg.L^{-1}$ water, Pb2 = 100 $mg.L^{-1}$ water, Pb3 = 150 $mg.L^{-1}$ water, and Pb4 = 200 $mg.L^{-1}$ water. The second factor was nutrient sources consisting of N1= standard hydroponic nutrients (AB mix) and N2= alternative nutrients (sourced from NPK each containing 16% N, P, and K) (Sitorus et al., 2015) and added with Gandasil (N 20%, P 15%, and K 15%). Therefore, 10 combinations were obtained and repeated 3 times. The nutrient amount was calculated based on a standard vegetable crop of 1000 $mg.L^{-1}$ (Furoidah, 2018). Based on the experimental simulations carried out, to achieve 1000 $mg.L^{-1}$ in a volume of 14 L of water, 106 mL of AB mix was added to the treatment media and 16g NPK and Gandasil D (N2). The concentration of nutrient solubility in all media types was regulated in the range of 900-1000 $mg.L^{-1}$ without a change during the 30-day growth period.

Collection of Growth and Yield Data

Water spinach plant height was observed at 7, 14, 21, and 28 days after planting (DAT). Harvesting was carried out when the plants were 30 days old by removing all parts including roots, stems, and leaves. Subsequently, the plant height, number of leaves (strands), root length, wet and dry weight of the shoot and roots, leaf area, shoot root ratio, harvest weight, and stem diameter were measured at the height of 3 cm from the base of the stem. Root length (cm) was observed through measurement from the root collar to the tip. The wet weight was assessed after harvesting, while the dry weight was measured by drying in an oven at 80 °C. Measurement of leaf area (cm2) was calculated using the formula $LA = L \times W \times C$, where LA = leaf area, L = length (cm), W = maximum leaf width (cm), and C = constant. According to previous research, water spinach plant constant is 0.636 (Susilo, 2015). Harvest weight refers to the weight of all plant parts suitable for sale. The roots were separated by cutting 2-3 cm from the base of the stem and yellow or damaged leaves were separated first. Observation of harvest weight was carried out when the plants had been harvested or at the age of 28 days. Furthermore, the root-to-shoot ratio was calculated by comparing the dry weight of the roots and shoot, as follows: shoot dry weight : root dry weight (Yama 2018).

Pb Metal Content Variables

Measurement of Pb metal content was carried out compositely, using 25 plant samples with the same treatment. The observations were made based on level of treatment by measuring the Pb concentration in the media before (mg/L^{-1}) and after planting as well as the concentration in the shoot and root tissue. Pb observations were carried out at the ICBB Bogor Laboratory using the basic determination method. The samples were wet oxidized with HNO_3 and HCO_4, then the extract obtained was used to measure Pb with atomic absorption Spectro (Soil Research Institute, 2005).

Statistic analysis

The statistical tests used were the analysis of variance (ANOVA) and the DMRT (Duncan Multiple Range Test). All observed growth variable data were subjected to ANOVA analysis to determine the effect of nutrient type treatment and level of Pb contamination as well as interactions, using a factorial randomized block design. Subsequently, the treatment with a significant effect was further assessed with a DMRT test (Duncan Multiple Range Test) to determine the differences between treatments.

RESULT AND DISCUSSION

Environmental factors, including water status and nutrient solubility, influence nutrient absorption efficiency. Similarly, plant nutritional status can greatly influence water use efficiency (Dreschell et al., 2020). Nutrient absorption efficiency refers to the ability of plants to absorb nutrients through the roots and use for biomass formation (Tobing et al., 2022). It requires tight regulation of plant systems associated with homeostasis (Dreschell et al., 2020). Cordones This condition was evidenced in the observations of the increase in plant height carried out every 7 (seven) days until harvest, with AB mix completeness, nutrient solubility in AB mix appeared to be more perfect in NPK and Gandasil media. The nutrient solubility in the AB mix tended to be better in water media. In contrast to NPK and Gandasil, there were still nutrients that did not appear to be completely dissolved. The plant height observation resulting from the combination of nutrient types and Pb contamination level is shown in Figure 2.

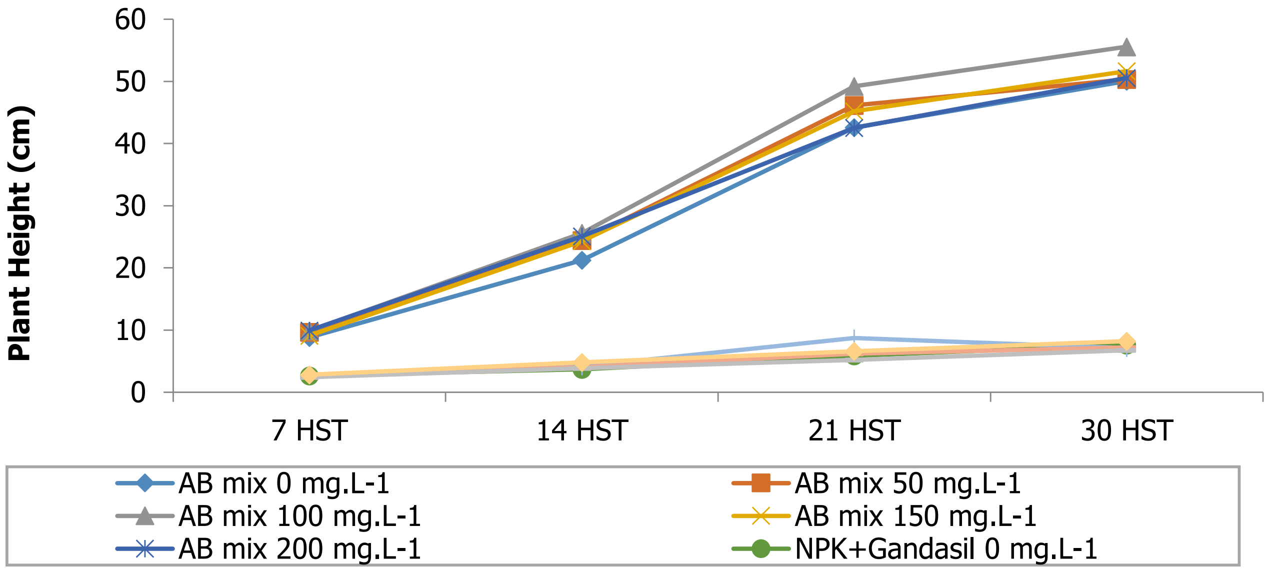


Figure 2. Height of water spinach plants in the Kratky hydroponic system at 7, 14, 21, and 28 DAT, treatment type of nutrition, and Pb contamination level

Table 1 shows that different nutritional treatments (N) significantly affected all water spinach growth and production variables. The administration of lead ($PbSO_4$) at various concentrations had no significant effect on the growth and production variables. Table 1 shows that the type of nutritional treatment has a significant effect on all variables of water spinach growth and production. However, treatment with lead (PbSO4) at various concentrations did not have a real effect on growth and production variables. Providing different nutrients significantly affected the growth and production of water spinach plants in hydroponic system. The solubility of nutrients in hydroponic cultivation is an important factor. Visually, there are still visible deposits in the NPK and Gandasil nutrients, in line with (Kusumawardhani & Widodo, 2003), stating that the crystallization of compounds can interfere with the process of nutrient absorption by the roots. Therefore, growth was not optimally supported in the NPK and Gandasil treatment, as shown in the DMRT test results in Table 2.

Table 1. Traces of various types of nutrition and $PbSO_4$ concentration on water spinach plants using the Kratky static hydroponic system

Parameter	Pr(> F)			KK (%)
	Nutrient (N)	Lead (Pb)	Interaction (N x Pb)	
Plant height	0.00000002*	0.334250tn	0.195054tn	12.71
Number of leaves	0.15323100*	0.873122tn	0.061680tn	7.27
Shoot wet weight	0.77081200*	0.976197tn	0.205836tn	28.40
Shoot dry weight	0.00004700*	0.918411tn	0.285214 tn	30.10
Root wet weight	0.00068000*	0.368738tn	0.333552 tn	14.07
Root dry weight	0.00005800*	0.211599tn	0.108905 tn	9.63
Root length	0.00000014*	0.976858tn	0.283596 tn	15.96
Root volume	0.48294700*	0.007514*	0.0256440*	18.13
Leaf area	0.00000001*	0.725966tn	0.712210tn	12.92
Root Shoot ratio	0.84358300tn	0.266157tn	0.073708tn	6.56

Note = *: Significant effect α 5%, tn: not significant effect, pr>F : probability value, KK : coefficient of variation

Effect of Nutrition Type on the Growth of Kratky System Hydroponic Water Spinach

The DMRT test results showed that the AB mix (N1) treatment was superior (Table 2) compared to NPK and Gandasil D (N2). This condition shows that the inorganic nutritional composition of the AB mix used can meet nutritional needs required during the growth period until harvest compared to NPK+Gandasil. According to (Wulandari et al., 2019), the nutrients N, P, and K are needed for plant growth. Wahyuningsih et al. (2016) stated that the composition of sand with NPK+Gandasil nutrients was able to provide good growth for Pakcoy (Chinese cabbage) plants in hydroponic system compared to other alternative nutrients such as growmore but was not able to match the AB Mix standard.

Hidayanti and Kartika (2019) stated that AB mix nutrition consists of concentration A, containing macronutrients, namely C, H, O, N, P, K, Ca, Mg, S, and concentration B consisting of micronutrients, namely Fe, Cu, Mn, Zn, B, Mo, Cl. Previous research (Rizal, 2017) also states that the elements contained in AB Mix nutrition are complete and suitable for plant growth needs. The cost of using AB Mix nutrients is relatively high, hence other alternatives used as hydroponic system nutrients include NPK and Gandasil D.

According to Sumaryani & Ari (2016), NPK is an artificial fertilizer containing the main nutrients such as nitrogen, phosphorus, and potassium. Nugraha & Susila (2015) concluded that NPK fertilizer has an N concentration equivalent to the AB Mix solution. Anam (2017) reported that this material can be used as hydroponic nutrition for water spinach, caisin, and Kalian plants. Furthermore, Gandasil D fertilizer affected the vegetative phase of water spinach plants' growth. With the appropriate fertilizer concentration treatment, the cell walls will enlarge and elongate, but in this research, the effect of NPK+Gandasil was not able to match the nutrient source from the AB mix.

Table 2. DMRT test results on the effect of providing different nutrients and lead ($PbSO_4$) concentration

Variable	Treatment	
	AB Mix (N1)	NPK and Gandasil D (N2)
Plant height	32.25^a	5.16^b
Number of leaves	14.60^a	2.40^b
Shoot wet weight	34.50^a	0.27^b
Shoot dry weight	3.78^a	0.02^b
Root wet weight	11.01^a	0.10^b
Root dry weight	1.21^a	0.003^b
Root length	35.37^a	2.87^b
Root volume	15.27^a	0.15^b
Leaf area	47.31^a	0.93^b
Root Shoot ratio	0.32^a	0.04^b

Note: Numbers followed by the same letter in the same row are not significantly different in the DMRT follow-up test with a confidence level of 95%

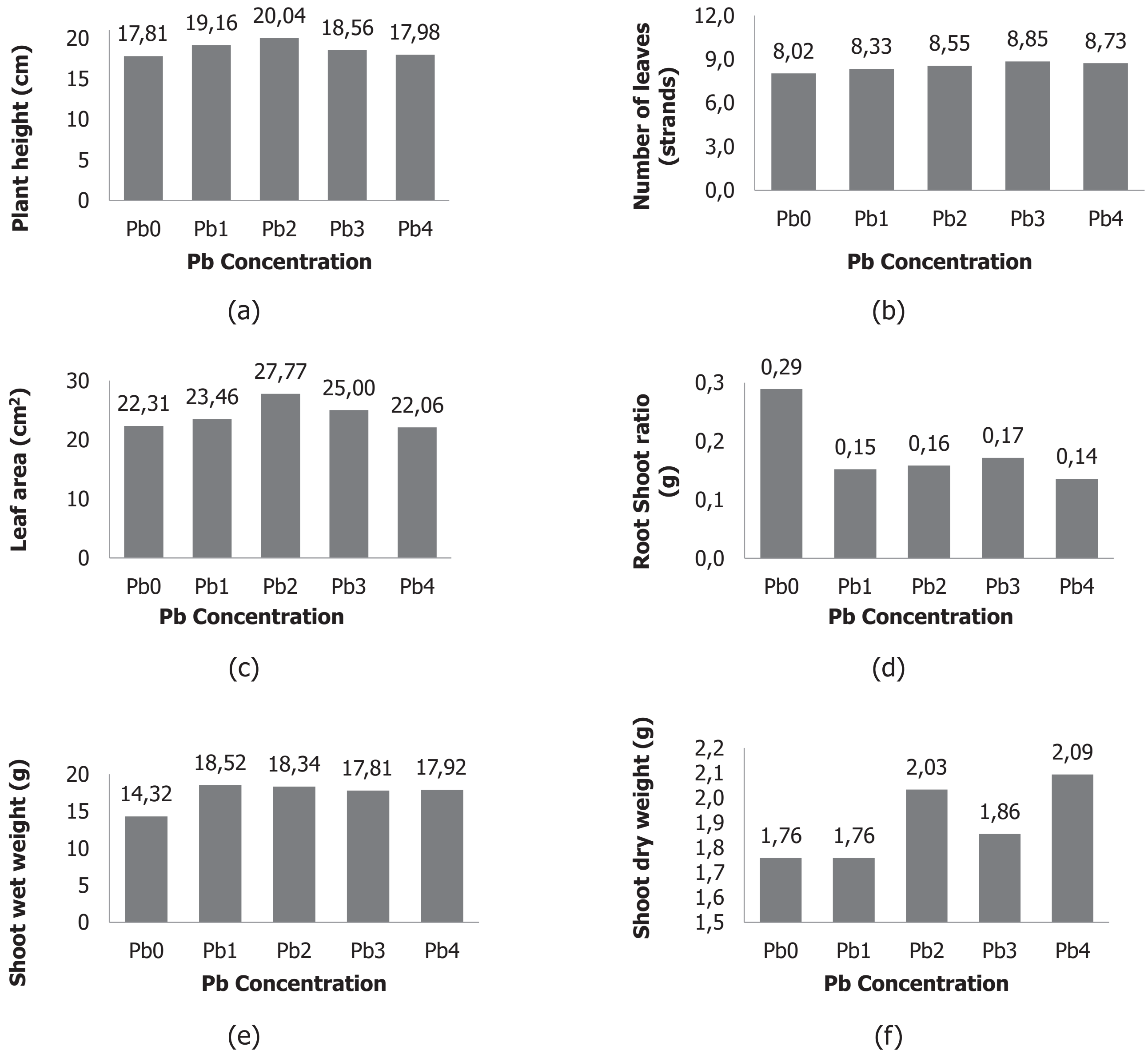
The Pb Contamination Level Effect on the Growth of the Kratky System Hydroponic Water Spinach

The Pb analysis results observed in samples with a concentration of 200 mg.L^{-1}(Pb4) are shown in Table 3. Observations in composites were only carried out at the highest contamination concentration of Pb4 (200 mg.L^{-1}). There was lower nutrient absorption in the shoot compared to the roots as described in Table 3, and there was a reduction in the initial Pb concentration of 163 mg.L^{-1} in water. The final detected Pb was 36.5 mg.L^{-1} from the initial concentration of 200 mg.L^{-1}. Absorption in the shoot was detected at 27.26 mg.kg^{-1} and in the roots at 1054 mg.kg^{-1} root. This condition shows the potential for water spinach roots to prevent Pb contamination from being carried to the plant shoot.

The further DMRT tests result on the effect of different nutritional treatments showed that AB Mix nutrition performed better on all growth variables for hydroponic water spinach plants. AB Mix nutrition contains 18.1% more calcium than NPK+Gandasil nutrition and this condition affects root growth. According to Rasyati & Daningsih (2020), root growth parameters, such as root length, determine plant growth. Root length has the highest value in samples given the AB

Table 3. Results of Pb analysis observed in the initial, final media, shoots, and roots of plants at contamination level of Pb 200 mg.L^{-1} and nutrient type AB mix

Observation parameters	Method	Unit	Identification results
Pb initial solution	-	mg.L^{-1}	200
Pb final solution	HCL 25%-AAS	mg.L^{-1}	36.5
Absorbed by plants			
-Shoot	$HClO_4HNO_3$-AAS	mg.Kg^{-1}	27.26
-Root	$HClO_4HNO_3$-AAS	mg.Kg^{-1}	1054.94



Note: Pb0 = 0 mg.L^{-1} , Pb1 = 50 mg.L^{-1} water, Pb2 = 100 mg.L^{-1} water, Pb3 = 150 mg.L^{-1} water, Pb4 = 200 mg.L^{-1}water.

Figure 3. Histogram of shoot growth (a), plant height, (b) number of leaves, (c) leaf area (d) Root Shoot ratio, (e) the shoot wet weight (f) the shoot dry weight of water spinach plants at various levels of $PbSO_4$ contamination in plants given Abmix nutrition

Mix nutrition. This shows that the nutrient content in AB Mix nutrition can meet water spinach needs. Sahetapy & Liworngawan (2013) stated that internal factors and nutrition played a role in plant growth.

Pb concentration in shoots fed with Abmix media and Pb contamination

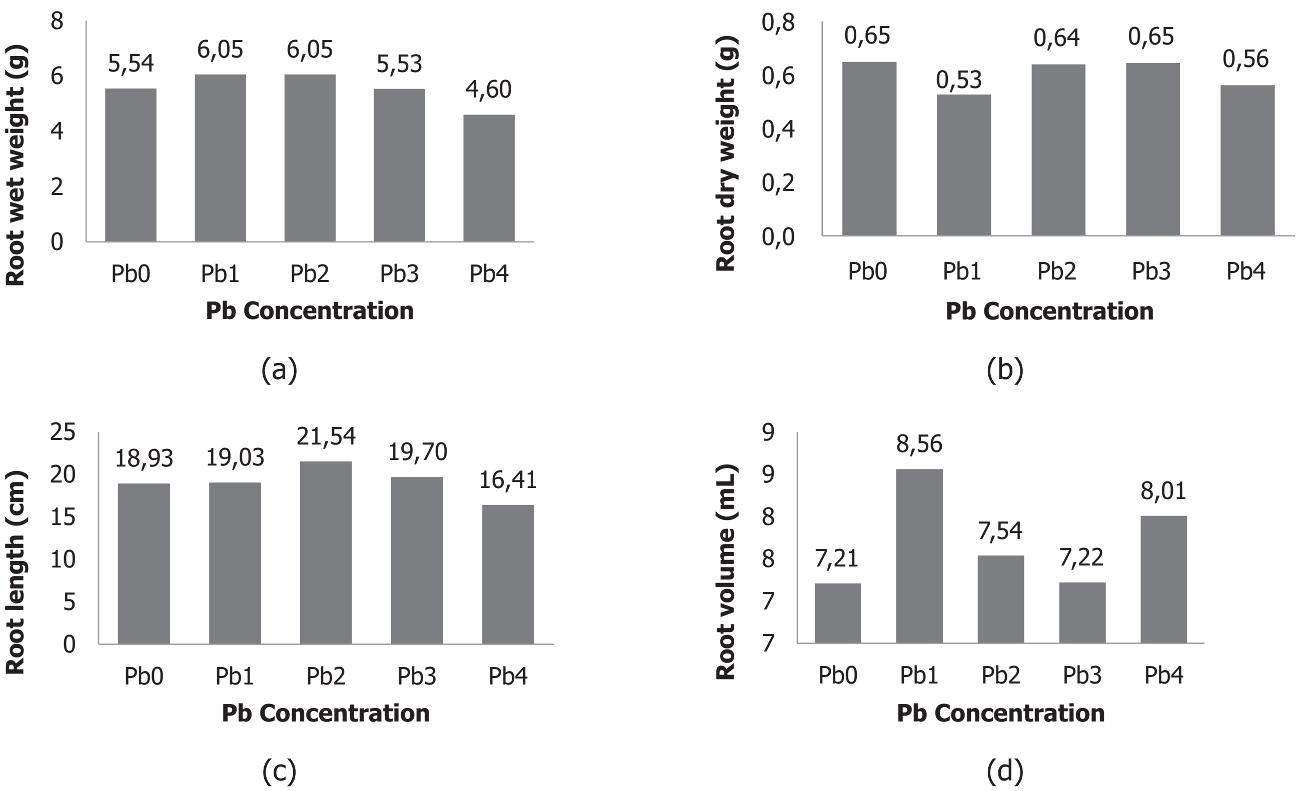
The Pb concentration treatment in the form of PbSO4 did not significantly affect growth as shown in Table 1. This is presumably due to the Pb provision in PbSO4 form, implying that the Pb solubility in water media is relatively low and inconsistent according to the amount of contamination provided. The histogram of the average growth variables for water spinach plants is presented in Figure 3. The administration of Pb given in PbSO4 form did not show a significant difference and tended to be inconsistent with the amount of contamination. Plant mechanisms and nutrient solubility, root absorption, and flow to the shoot all influence Pb absorption. Root absorption data, as well as shoots, also show that no significant effect was obtained (Table 1).

Pb concentration in roots fed with Abmix media and Pb contamination

Treatment concentrations of Pb1 (50 mg.L^{-1}) and Pb2 (100 mg.L^{-1}) showed the highest value at a root wet weight of 6.05 g (Figure 3a). The lowest average value of fresh root weight at 4.60 g was found in the treatment with a Pb4 concentration of 200 mg.L^{-1}. Treatment concentrations of Pb0 (0 mg.L^{-1}) and Pb3 (150 mg.L^{-1}) produced the highest value at a root dry weight of 0.65 g. The lowest average root dry weight value was found in the treatment with a Pb1 of 0.53 g. Furthermore, Pb3 showed the highest value at a root length of 21.54 cm. The lowest average root length value was found in Pb4, at 16.41 cm. Pb1 also showed the highest value at a root volume of 8.56 mL and the lowest average root volume value was found in the treatment with a Pb0 of 7.21 mL (Figure 4).

The presence of heavy metal absorption, such as lead (Pb), in plants, is influenced by solubility and the species. The Pb used is in the form of $PbSO_4$, which does not dissolve easily in water, showing limited absorption. Based on the results, Pb concentration of 0 m/L produced the lowest value for water spinach plants' growth and yield variables. These results differ from (Jamil, 2015) stating that the higher the Pb content in the planting medium, the lower the plant growth rate. The disparity can be attributed to differences in the solubility level of Pb used. According to (Katipana, 2015), the metal Pb content in the roots can be absorbed by water spinach and influence the photosynthesis process in the leaves, affecting growth.

The analysis result carried out showed that the Pb content in plant tissue was 27 mg.L^{-1} in water spinach shoot, 200 mg.L^{-1} in contamination treatment of $PbSO_4$ in AB mix media, and 1054 mg.L^{-1} in water spinach roots. The roots had a very large Pb content because this research used the Kratky hydroponic system, where the roots are directly dipped into a nutrient solution given Pb, leading to increased absorption. Pb absorption occurs not only in the roots but also in the stems and through the passive absorption process of the leaves (Yusuf et al., 2016). Metal absorption can be prevented by detoxification or localization, for example,



Note: Pb0 = 0 mg.L^{-1} , Pb1 = 50 mg.L^{-1} water, Pb2 = 100 mg.L^{-1} water, Pb3 = 150 mg.L^{-1} water, Pb4 = 200 mg.L^{-1} water.

Figure 4. Histogram of root growth (a) root wet weight, (b) root dry weight, (c) root length, and (d) root volume of water spinach plants at various levels of $PbSO_4$ contamination in plants given Abmix nutrition

Table 4. Average observations of the number of leaves and DMRT test results for treatment of a nutrient type and Pb contamination level in hydroponic water spinach plants in the Kratky system.

Pb Concentration ($mg.L^{-1}$)	Nutrient type		Pb Average
	AB Mix	NPK+Gandasil D	
0	13.45 c	2.59 d	8.02
50	14.42 b	2.25	8.33
100	14.40 b	2.70 d	8.55
150	15.57 a	2.14d	8.85
200	15.15 ab	2.30d	8.73
Nutrition Average	14.60a	2.40b	8.496

Note: Numbers followed by the same letter in the same row and column are not significantly different at the 5% test level.

by depositing metal into certain organs such as the trunk (Jamil, 2015).

Combination Between Nutrient Treatment and Pb Concentration

Treatment combinations between different nutritional treatments and Pb concentrations changed the number of leaves (Table 4). The best number of leaves was obtained in the Pb3 concentration treatment (150 $mg.L^{-1}$) in the AB Mix Nutrition (Pb3N1), which was not significantly different from Pb4 (200 $mg.L^{-1}$) in the AB Mix Nutrition (Pb4N1).

The results showed that nutritional composition and concentration provided did not synergic effect to support the growth of water spinach plants. Based on the average for each variable in the treatment combination, all Pb concentrations with AB mix nutrients produced the highest results. The heavy metal Pb in hydroponic system was absorbed through the roots in water medium. The greater the volume of water absorbed, the higher the amount of Pb in water spinach. $PbSO_4$ did not show any significant disturbance because it is suspected that the accumulation and distribution are dependent on environmental factors, type of plant, specific metal, pH, DO, temperature, and secretion by roots (Fahlevi et al., 2018).

CONCLUSION

In conclusion, the AB mix type of nutrition provided the best water spinach growth. The PbSO4 has low solubility in the Kratky system's hydroponic water medium Therefore, the Pb contamination did not cause any significant disturbance to the growth of water spinach plant. The interaction of nutrient treatment and the amount of $PbSO_4$ contamination only affected the growth of the root volume.

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CONFLICT OF INTEREST

The author declares that this research has no conflict of interest from various parties.

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