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Research article

The concentration of heavy metals in the potato tubers of the basic seed groups examined by the variation of fertilizers, pesticides and the period of cultivation

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Abstract: The compost, insecticides, and fungicides used by potato farmers in Bali contain heavy metals Fe, Pb, Cd, and Cr. The purpose of this study was to analyze the impact of the seed group potato cultivation system on the concentration of several heavy metals in potato tubers. Cultivation was carried out in the rainy and dry season with: (1) NPK fertilization, (2) NPK fertilization, insecticide and fungicide spraying, (3) NPK fertilization and compost, and (4) NPK fertilization, compost, insecticide and fungicide spray. Each experimental unit was carried out by 5 farmers as a replication. The variables observed were concentrations of Fe, Pb, Cd, and Cr in the soil, plant parts, and potato tubers. Soil, plant, and potato tuber samples were taken randomly with 5 repetitions from the experimental unit. The Concentrations of Fe, Pb, Cd, and Cr metals in potato plants which are cultivated in the rainy season are on average greater in the amount of metal Fe = 1–21 ppm, Pb = 0.05–3.65 ppm, Cd = 0.01–0.15 ppm, and Cr = 0.02–0.18 ppm of concentrations in plants cultivated in the dry season. The metal content in the root zone of the potato seeds plants were Fe = 120.5 ± 3.2 ppm, Pb = 0.82 ± 0.17 ppm, Cd = 0.4 ± 0.1 ppm, and Cr = 0.59 ± 0, 2 ppm. Metal content in potato tubers were Fe = 0.1–0.3 ppm, Pb = 0.07–0.21 ppm, Cd = 0.03–0.06 ppm, and Cr = 0.03–0.07 ppm, these values are still below the food safety threshold according to WHO. The potato tuber which cultivated is still within safe limits for human consumption, but the spraying of insecticides and fungicides and the use of compost must begin to be limited because it causes an increase in Fe, Pb, Cd, and Cr metals in potato plants amounting 3.53–4.36 ppm, 0.41–0.5 ppm, 0.12–0.15 ppm, and 0.22–0.27 ppm, respectively. Fertilization using chicken manure compost at a dose of 10–20 tons ha^{-1} is very effective in supporting potato cultivation with the LEISA system. The ability of microbes in the compost to carry out an in-situ bioremediation process on Fe, Pb, Cd, and Cr metals is 49.61–55.60 ppm, 2.59–5.64 ppm, 35.24–52.44 ppm, and 19.68–54.24 ppm, respectively.

Keywords: potato tuber; heavy metal concentrations; fertilizers; pesticides; cultivation period

1. Introduction

Potato tubers are the fourth foodstuff consumed by mankind because these foods contain carbohydrates [1]. Therefore, these foods must meet the safety standards set by WHO. Food safety standards set by WHO for heavy metal content are Fe < 0.4 ppm, Pb < 0.2 ppm, Cd < 0.1 ppm, Cr < 0.1 ppm and Zn < 0.35 ppm [2,3]. To produce consumption potatoes that meet food safety standards, cultivation must be carried out with: (1) quality seeds, and (2) application of environmentally friendly cultivation technology.

The low external input on sustainable agriculture (LEISA) system uses 10–30 tons ha^{-1} of chicken manure compost fertilizer has been applied by potato farmers for more than 10 years. Low external input on sustainable agriculture (LEISA) developed by Setiyo et al. [4] in potato cultivation with the fertilization method using compost 10–30 tones ha^{-1} were able to improve (1) the quality of soil physical properties [5], (2) the soil fertility [4], and [6] and (3) the in-situ bioremediation of insecticide and fungicide residues in the presence of microbes in the compost [6]. In addition, LEISA is able to reduce the use of insecticides and fungicides in potato cultivation. But on the other hand, the use fungicides, and insecticides in potato cultivation causes the accumulation of Fe, Pb, Cd, Cr, and Zn metals in the soil, especially in the rooting zone. The increased of metal content in the soil has a direct impact on environmental pollution and has an indirect impact on the health of plants, animals, and humans [7,8].

Insecticides and fungicides contain Fe, Pb, Cd, and Cr metals respectively as much as 20–247 ppm, 5.0–7.3 ppm, 2.1–4.1 ppm and 4.5–4.9 ppm. The dosage for use is 2 mL L^{-1} of water. Spraying of 1 ha of potato plants is carried out once a week after the plants are 2 weeks old with a volume of 600 L of insecticide and fungicide solution [4].

Compost contains Fe, Pb, Cd, and Cr with the concentrations of 600 $\pm$15 ppm, 7.3 $\pm$0.6 ppm, 2.4 $\pm$0.3 ppm, and 4.7 $\pm$0.6 ppm, respectively [7]. The addition of 1 ton ha^{-1} of compost fertilization dose caused an increase in the metal content of Fe, Pb, Cd, and Cr in the soil by 9.7 $\pm$1.2 ppm, 0.36 $\pm$ 0.07 ppm, 0.023 $\pm$0.006 ppm, and 0,11 $\pm$0.02 ppm, respectively. In addition, compost has a cation exchange capacity of 65.8 me/100g, C/N of 16.6, pH of 6.8, and microbial population of (3–8) $\times 10^7$ CFU/g. While insecticides and fungicides contain metals Fe, Pb, Cd, and Cr with the concentration of 20–247 ppm, 5.0–7.3 ppm, 2.1–4.1 ppm, and 4.5–4.9 ppm. The active ingredients in insecticides and fungicides used by potato farmers in Bali-Indonesia are mankozeb, propineb, diphenoconazole, dimetomorph, and carbanil [4].

Metal in dissolved form is more easily absorbed by plants and washed by irrigation water or rainwater [9]. The concentration of hazardous metals in the vegetable part is related to metal concentrations in the root zone of the plants, planting species, plants age, soil type, soil conditions, and microclimate and environment [4]. Therefore, research on the concentration of metals in the tubers of the seeds groups of the base seeds in cultivation in the rainy and dry seasons requires an in-depth study.

The purpose of this study was to analyze the impact of the seed group potato cultivation system on the concentration of several heavy metals in potato tubers.

2. Materials and methods

2.1. Materials

The research materials were: potato tubers, granola seeds (West Java), soil, mixed organic fertilizers (Balitbang West Java), rice husks, chicken manure, Dopos brand organic fertilizers and types of pesticides Antracol, Acrobat, and Dithane M45 (Saba Kimia). Various metal stock solutions were prepared from high purity compound (99.9%) purchased from Sigma-Aldrich (St. Louis, MO, USA). The chemicals used for the analysis of heavy metal content were concentrated HNO_3, concentrated HCl, distilled water, 1000 ppm of Pb, Cd, Cr, and Fe stock solutions (CV Makmur Sejati). All chemical reagents were analytical grade.

2.2. Research design

Experiment design with two factors was used in this study, the use of compost and spraying of insecticides and fungicides was the first factor, while the second factor was cultivation season. The first factor consisted of (1) the cultivation of potatoes fertilized with NPK, (2) the cultivation of potatoes was fertilized with NPK fertilizer and sprayed with insecticides and fungicides, (3) the cultivation of potatoes was fertilized with NPK fertilizer and compost, and (4) the cultivation of potatoes was fertilized with NPK fertilizer and compost and sprayed with insecticides and fungicides. The second factor consisted of dry and rainy season. The number of treatments for the distribution of seedling potato dispersal groups were 8 experimental units, and each experimental unit was repeated 5 times (different farmers), a total of 40 experimental units.

Each unit of the experiment was carried out on open land with an area of 1 acre. Basic seed potato cultivation was fertilized with NPK fertilizer of 250 kg ha^{-1} and compost of 20 tons ha^{-1} as basic fertilizer. Plant cultivation was to control pests and diseases by spraying insecticides and fungicides once every week (dry season cultivation) and twice a week (rainy season cultivation) [4]. Other plant maintenance was by supplementary fertilization and adding nutrients to plants, supplementary fertilization was done twice with NPK fertilizer dose 50 kg ha^{-1} when plants were 1 month and 2 months, while the addition of nutrients was done simultaneously with the process of controlling pests and plant diseases. The nutrition for plants was liquid fertilizer.

Potato cultivation was carried out on the back beds with dimensions of 1 m wide, 10 m long, and 30 cm high. Between beds, drainage canals were made with a width of 40 cm. On each back of the beds were 3 potato grooves with a distance of 40 cm between the grooves and a planting distance of 30 cm in each groove. Each bed was covered with black plastic mulch [4].

Observation of metal content in the soil, plants and potato tubers was done every week from the beginning of planting until the potato tubers were harvested. Samples of soil, plants and potato tubers were randomly taken from each cultivation treatment. Observation of the metal content in the soil, plants, and potato tubers was carried out every week from the beginning of planting until the potato tubers were harvested. Soil, plant, and potato tuber samples were taken randomly from each cultivation treatment. The method of extracting metals from soil, plant parts, and potato tubers was carried out using the following procedure: soil samples, plant parts, and dry potato tubers in the form of powder were taken 5 g and put in a 100 mL beaker. A total of 5 mL of distilled water and 5 mL of concentrated nitric acid (HNO_3) were added to the beaker and then heated for 5 minutes at 100 °C. After the solution cooled, 5 mL of concentrated HNO_3 was added then heated again for 5 minutes. Five milliliters of concentrated hydrochloric acid were added slowly followed by the addition of 10 mL of distilled water then heated at 100 °C. The solution filtered with filter paper into a 50 mL volumetric flask and homogenized. Heavy metal concentrations of Fe, Cd, Pb, and Cd in soil, plants, and potato tubers were observed by atomic absorption spectrophotometry (AAS) [10].

2.3. Data analysis

Data were analyzed by calculating the average value and standard deviation. In addition, the data were made into graph; the relationship between plant age and metal concentrations of Fe, Pb, Cd, and Cr in potato plants by including graph equations, determination values (R^2). The data on the metal content average of Fe, Pb, Cd, and Cr in the soil, plants, and potato tubers cultivated in the dry and rainy season were made tables.

3. Results

3.1. Heavy metal in the soil

The metal content of Fe, Pb, Cd, and Cr in cultivated soils with: (1) NPK fertilization, (2) NPK fertilization and insecticide and fungicide spraying, (3) NPK and compost fertilization, and (4) NPK and compost fertilization and spraying of insecticides and fungicides was carried out as shown in Table 1. Fertilization and insecticide spraying have a significant effect on metal content in the soil [11]. The metal content of Fe, Pb, Cd, and Cr in the soil at the beginning of the experiment were between 191.8–199.4 ppm, 9.73–10.64 ppm, 0.53–0.642 ppm, and 0.96–1.096 ppm, respectively, so that the content of these metals for all experiments has increased. Basically, chicken manure compost, fungicides, and insecticides also contain Fe, Pb, Cd, and Cr. Thus, the results of decomposition of compost, insecticide and fungicide residues by microbes contained in the compost also produce these metals. Therefore, chicken manure compost mixed with husks, fungicides, and insecticides also contains Fe, Pb, Cd, and Cr.

3.2. In-situ bioremediation on potato cultivation with LEISA system

LEISA system in potato cultivation with low external input system is land processing technology, use of organic fertilizers, organic insecticides, organic fungicides, seeds technology, simple irrigation, and drainage methods [5]. Experiment of potato plants fertilization with compost of chicken manure, use of seeds from farmers' development, back cover of beds with mulch plastic, irrigation with fertilization and simple drainage through channels between the beds is one of the LEISA systems developed by Setiyo et al. [4].

LEISA which is applied to potato cultivation using chicken manure compost at a dose of 20 tons ha^{-1} has an effect on the microbial population in the soil, especially in the root zone. The microbes in active compost carry out the bioremediation process of insecticide residues, fungicide residues, and metals in the compost. Figure 1 showed that the microbial population increases due to food intake in the form of minerals in compost, minerals in insecticide and fungicide residues and plant litter. Fertilization with compost causes (1) an increase in the microbial population at the beginning of cultivation by 3.4–3.7 $\times 10^4$ CFU/g, (2) the shift in the peak of the microbial population at the age of 6 weeks of potato plants was 1.6–4.1 $\times 10^7$ CFU/g, and (3) the difference in the microbial population when the potato tubers were harvested was 8.2 $\times 10^5$–5.4 $\times 10^6$ CFU/g than the potato cultivation which was only fertilized by NPK.

The microbial population in the soil had a positive correlation with the amount of metal that was bio-remediated in-situ, so that the dynamics of the amount of metal bio-remediated during potato cultivation followed the microbial population. The concentration of Fe, Pb, Cd, and Cr from insecticide and fungicide residues that were bio-remediated by microbes in potato cultivation in the dry season were 8.35 ppm, 0.95 ppm, 0.28 ppm, and 0.50 ppm, respectively. In cultivation in the rainy season these metals are bio-remediated as much as 9.15 ppm, 1.05 ppm, 0.31 ppm, and 0.54 ppm, respectively.

Table 1. The metal contents of Fe, Pb, Cd, and Cr in the soil, plants, and potato tubers.

Kind of metal	Metal concentrations at potato root zone (ppm) at the early cultivation				Metal concentrations at potato root zone (ppm) at the end of cultivation			
	NPK fertilizer	NPK + insecticide and fungicide	NPK + compost	NPK + compost + insecticide and fungicide	NPK fertilizer	NPK + insecticide and fungicide	NPK + compost	NPK + compost + insecticide and fungicide
	Dry climate potato cultivation							
Pb	10.9 ± 1.01	15.5 ± 2.01	41.4 ± 0.01	64.3 ± 2.01	2.6 ± 0.01	3.7 ± 0.01	16.1 ± 1.01	25.9 ± 2.01
Cd	0.67 ± 0.13	0.96 ± 0.11	3.15 ± 0.01	5.16 ± 1.01	0.17 ± 0.11	0.25 ± 0.01	0.59 ± 0.01	1.0 ± 0.11
Cr	1.24 ± 0.12	1.78 ± 0.41	5.62 ± 0.01	7.74 ± 1.21	0.19 ± 0.11	0.28 ± 0.01	0.84 ± 0.11	0.53 ± 0.21
Fe	201 ± 7.2	287 ± 3.2	988 ± 0.01	1575 ± 5.2	21.4 ± 2.01	30.6 ± 0.01	66 ± 3.01	68 ± 2.01
	Wet climate potato cultivation							
Pb	9.9 ± 1.5	14.1 ± 2.01	35.6 ± 2.01	52.1 ± 3.01	2.34 ± 0.11	3.35 ± 0.23	13.86 ± 1.2	20.9 ± 1.01
Cd	0.61 ± 0.11	0.87 ± 0.11	2.71 ± 0.31	4.2 ± 0.21	0.16 ± 0.12	0.23 ± 0.05	0.51 ± 0.11	0.85 ± 0.07
Cr	1.13 ± 0.11	1.62 ± 0.11	4.83 ± 0.21	6.3 ± 0.31	0.18 ± 0.01	0.25 ± 0.08	0.72 ± 0.12	0.43 ± 0.11
Fe	183 ± 3.01	261 ± 6.01	853 ± 7.01	1275 ± 5.0	19.5 ± 1.2	27.8 ± 1.7	56.8 ± 2.4	53.9 ± 3.0

3.3. Heavy metals in potato plant

The metal content in potato plants (roots, stems, and leaves) when the potato plant is 90 days old or when the tuber is harvested is as in Figure 2, Figure 3, Figure 4, and Figure 5. In addition, this concentration is far below the average concentration critical and toxic Fe, Pb, Cd, and Cr in cultivated potato plants [11]. The metal elements Fe, Pb, Cd, and Cr from the decomposition of compost are absorbed by plant roots and accumulated in the stem, roots, and leaves after photosynthesis in the leaves [9]. In addition, there are metal elements from insecticides and fungicides that are sprayed on plants into the plant parts through the stomata during the respiration process.

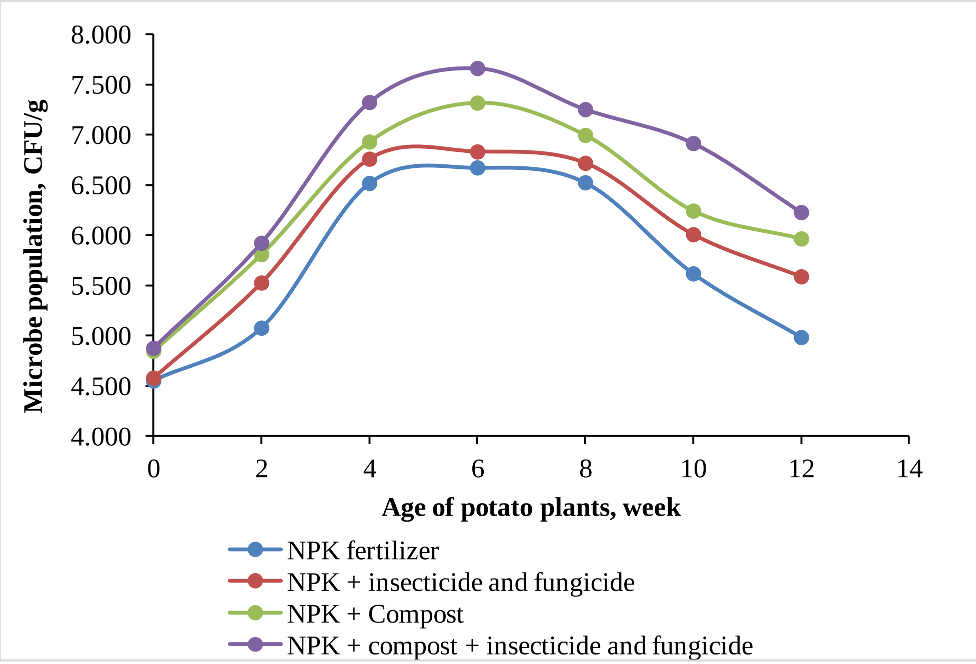

Figure 1. Population of microbe on potato cultivation with LEISA system.

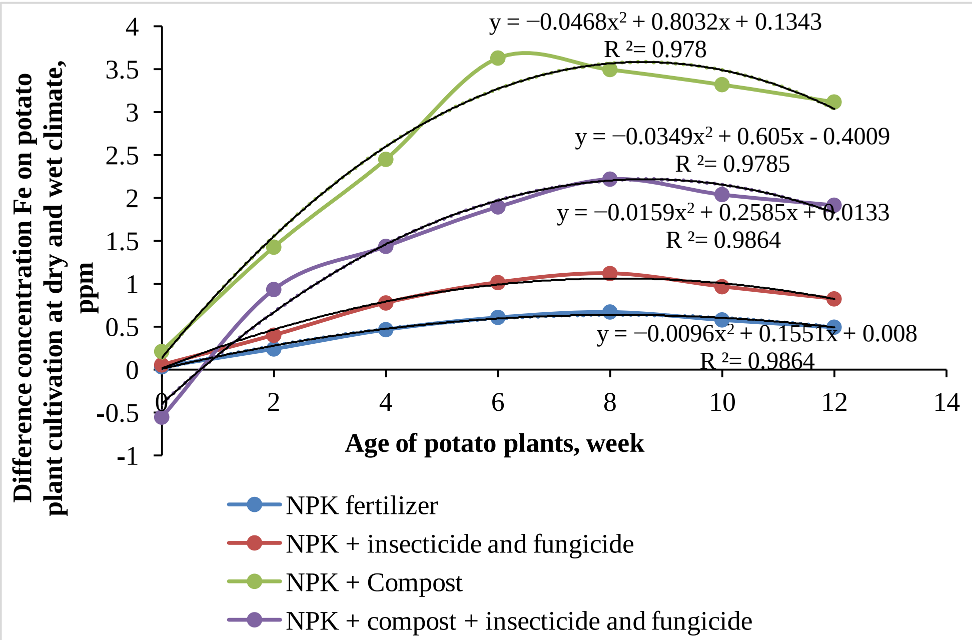

Figure 2. The correlation of potato plants age and Fe metal concentration in the plants.

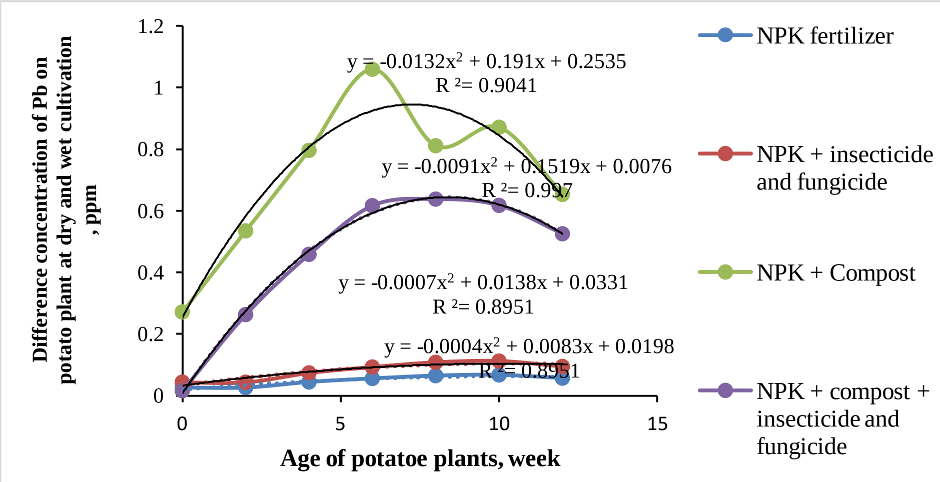

Figure 3. The correlation of potato plants age and Pb metal concentrations in the plants.

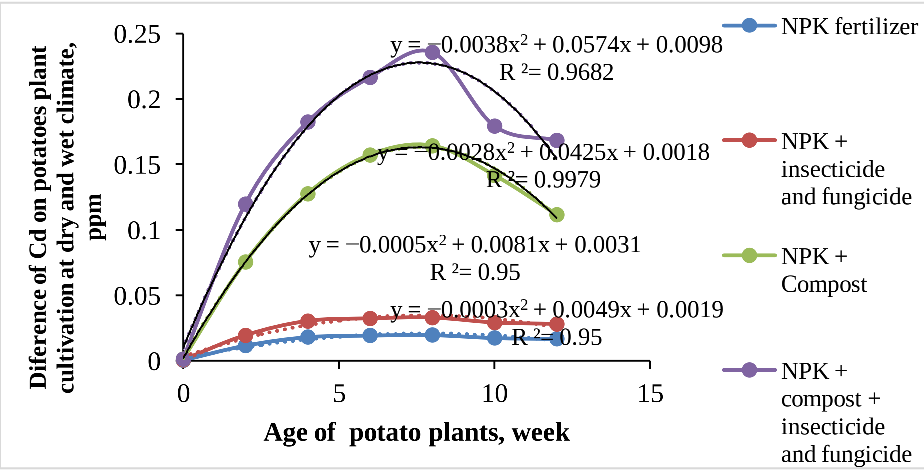

Figure 4. The correlation of potato plants age and Cd metal concentrations in plants.

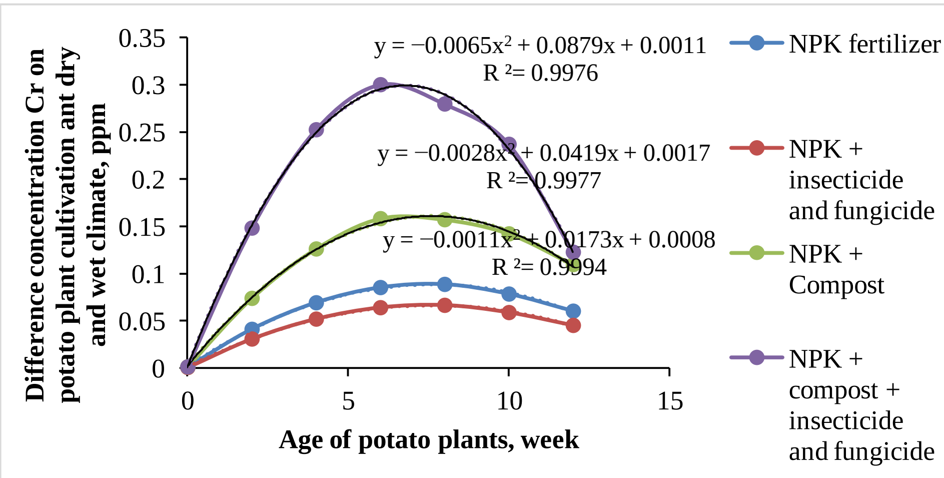

Figure 5. The correlation of potato plants age and Cr metal concentration in plants.

Metal concentrations of Fe, Pb, Cd, and Cr from the soil absorbed by the potato plant base seed groups are respectively Fe = 4.03–6.45%, Pb = 4.5–11.2%, Cd = 35–66% and Cr = 11–70% (cultivation in the dry season), while for the cultivation of these potatoes in the rainy season, the concentration of the metals is Fe = 4.5–7.8%, Pb = 6.8–13.5%, Cd = 54–79%, and Cr = 11–70%, and 16–84.0%.

3.4. Heavy metals in potato tubers

The results of the concentration of Fe, Pb, Cd, and Cr metals in potato tubers are presented in Table 2. The increased of metal content in potato tubers during cultivation in the dry season by 109% (plants were fertilized with NPK), 112% (plants were fertilized with NPK and sprayed with insecticides and fungicides), 248% (plants were fertilized with NPK and chicken manure compost), 240% (plants were fertilized with NPK and sprayed with insecticides and fungicides), 248% (plants were fertilized with NPK and chicken manure compost and sprayed with insecticides and fungicides). The metal content of potato tubers during the rainy season increased by 115% (plants were fertilized with NPK), 125% (plants were fertilized with NPK and sprayed with insecticides and fungicides), 255% (plants were fertilized with NPK and chicken manure compost), 242% (plants were fertilized with NPK and chicken manure compost and sprayed with insecticides and fungicides). Increased content of these metals as a result of accumulation of metals deposited in plant parts [11].

Table 2. Concentrations of Fe, Pb, Cd, and Cr in potatoes

	Metal concentrations in potato tubers (ppm) at early cultivation				Metal concentrations in potato tubers (ppm) at the end of cultivation			
Kind of metal	NPK fertilizer	NPK + insecticide and fungicide	NPK + compost	NPK + compost + insecticide and fungicide	NPK fertilizer	NPK + insecticide and fungicide	NPK + compost	NPK + compost + insecticide and fungicide
	Dry climate potato cultivation							
Pb	0.02 ±0.01	0.03 ±0.01	0.02 ±0.01	0.02 ±0.01	0.07 ±0.02	0.07 ±0.03	0.14 ±0.02	0.11 ±0.03
Cd	0.03 ±0.01	0.04 ±0.02	0.03 ±0.01	0.03 ±0.01	0.032 ±0.01	0.05 ±0.02	0.07 ±0.03	0.04 ±0.02
Cr	0.02 ±0.01	0.03 ±0.01	0.02 ±0.01	0.02 ±0.01	0.032 ±0.01	0.04 ±0.02	0.07 ±0.03	0.05 ±0.02
Fe	0.04 ±0.02	0.06 ±0.03	0.04 ±0.02	0.04 ±0.02	0.1 ±0.03	0.1 ±0.04	0.28 ±0.04	0.8 ±0.02
	Wet climate potato cultivation							
Pb	0.02 ±0.01	0.03 ±0.01	0.02 ±0.01	0.02 ±0.01	0.07 ±0.01	0.07 ±0.01	0.16 ±0.01	0.11 ±0.01
Cd	0.03 ±0.01	0.05 ±0.01	0.03 ±0.01	0.03 ±0.01	0.03 ±0.01	0.03 ±0.01	0.08 ±0.01	0.04 ±0.01
Cr	0.02 ±0.01	0.04 ±0.01	0.02 ±0.01	0.02 ±0.01	0.03 ±0.01	0.03 ±0.01	0.08 ±0.02	0.05 ±0.02
Fe	0.04 ±0.02	0.06 ±0.02	0.04 ±0.01	0.04 ±0.02	0.10 ±0.03	0.10 ±0.04	0.33 ±0.03	0.18 ±0.03

4. Discussion

4.1. Heavy metal in the soil

Soil in the root zone of potato plants before the application of the LEISA system has a metal content of Fe = 350 ± 3.2 ppm, Pb = 36 ± 1.1 ppm, Cd = 1.7 ± 0.3 ppm, and Cr = 1.7 ± 0.2 ppm, the concentration of these metals are close to the results of the study [12–15]. In general, basic fertilization in the cultivation of potato dispersal seeds` groups using NPK dosages of 250 kg ha^{-1} and compost doses of 20 tons ha^{-1} and spraying plants using insecticides and fungicides can increase the content of these metals on the ground, plants, and potato tubers [9,16,17]. Fe content in chicken manure compost 852.3 ppm, and Mn in cow manure compost 375.0 ppm, Zn concentration in horse manure compost 94.3 ppm [18]. Standard compost contains heavy metals Pb < 500 ppm, Cu < 800 ppm, Cd < 10 ppm, Cr < 500 ppm, Ni < 100 ppm, Zn < 2500 ppm, and Hg < 5 ppm.

In general, the metal content on potato cultivation in the base seeds groups in the dry season has a greater content than the metal content in the soil in the cultivation in the rainy season, this is because in the cultivation of potatoes in the rainy season some metals will be washed by the surface flow of rain water [9]. The average amount of Fe, Pb, Cd, and Cr metals washed by rainwater are: 8.3 ± 0.27 ppm, 0.53 ± 0.27 ppm, 0.027 ± 0.01 ppm, and 1.09 ± 0,03 ppm (cultivation with NPK fertilizer), 11.88 ± 1.2 ppm, 0.76 ± 0.39 ppm, 0.038 ± 0.022 ppm, and 0.077 ± 0.04 ppm (cultivation with NPK fertilizer and sprayed with insecticide and fungicide), 40.4 ± 4.2 ppm, 2.89 ± 0.3 ppm, 0.18 ± 0.02 ppm, and 0.22 ± 0.03 ppm (cultivation with NPK fertilizer, compost fertilizer), 108.4 ± 3.2 ppm, 9.4 ± 0.5 ppm, 0.38 ± 0.09 ppm, and 0.61 ± 0.02 ppm (cultivation with NPK fertilizer and compost and sprayed with insecticides and fungicides). These metals have chemical bonds which are easily dissolved in water. Metal minerals decomposition from compost, insecticide, and fungicide residues at pH 6.0–6.8 were easily washed away by rainwater [3,18]. Daily rainfall at the test site is between 150 and 360 mm, and the average number of rainy days in the rainy season is 25 days $month^{-1}$. Infiltration speed in agricultural land for potato cultivation experiments is 3.4–4.2 cm $hour^{-1}$, so that rainwater has the potential to leach metals as much as 4.7–32.2 ppm.

The increase in metal content in the soil due to spraying of insecticides and fungicides on plants are Fe = 44.19 ± 0.2 ppm, Pb = 2.75 ± 0.2 ppm, Cd = 0.15 ± 0.02 ppm, and Cr = 0.43 ± 0.05 ppm (dry season cultivation), and Fe = 32.3 ± 0.2 ppm, Pb = 1.98 ± 0.2 ppm, Cd = 0.11 ± 0.07 ppm, and Cr = 0.36 ± 0.03 ppm (rainy season cultivation). The increases in metal content in the soil due to the addition of compost are: Fe = 314 ± 2.1 ppm, Pb = 20.13 ± 1.2 ppm, Cd = 1.43 ± 0.3 ppm, and Cr = 2.04 ± 0, 1 ppm (dry season cultivation), and Fe = 256 ± 2.2 ppm, Pb = 16.5 ± 2.1 ppm, Cd = 1.19 ± 0.4 ppm, and Cr = 1.71 ± 0, 09 ppm (rainy season cultivation). The combination of adding compost and spraying insecticide and fungicide on the addition of metal Fe = 484 ± 3.4 ppm, Pb = 43.75 ± 1.3 ppm, Cd = 1.73 ± 0.4 ppm, and Cr = 4.46 ± 0.4 ppm (dry season cultivation), and Fe = 375.8 ± 3.2 ppm, Pb = 34.33 ± 2.2 ppm, Cd = 1.35 ± 0.08 ppm, and Cr = 3.56 ± 0.2 ppm (rainy season cultivation). This happened also in the study of Atafar et al. [18] conducted in wheat cultivation.

The combination of compost fertilizing on potato plants and spraying insecticides and fungicides regularly every week resulted in an increase in the metal content of Fe, Pb, Cd, and Cr in plants. This occurs due to the absorption of nutrients from the compost by plants through the roots and absorption by plant parts due to spraying of insecticides and fungicides. The concentrations of the addition of Fe, Pb, Cd, and Cr metals absorbed by plants were 41.3 ± 1.2%, 29.05 ± 0.8%, 39.3 ± 2.1%, and 35.71 ± 2.2%, respectively.

The role of compost is higher than the role of insecticides and fungicides in the addition of metal content in the soil. Only a small proportion of insecticides and fungicides are sprayed on the plants that fall to the ground due to the use of plastic mulch cover on the surface of the potato cultivated soil. The difference in absorption of these metals by potato plants and fertilization with compost and spraying with insecticides and fungicides are 11.96 ± 0.4 ppm, 0.83 ± 0.02 ppm, 0.44 ± 0.02 ppm, and 0,20 ± 0.01 ppm, respectively. The effectiveness of nutrient absorption in the experimental land is quite high because the physical, biological, and chemical properties of the soil support the bioremediation process and nutrient absorption by plants [19].

The remaining metals that are not absorbed by the potato plants are partly bio-remediated by microbes in the compost and partly washed away by rainwater. Fertilization with compost increase the amount of these metals bio-remediated. Bio-remediated of Fe, Pb, Cd, and Cr metals were increased when the potato plants are fertilized using compost at a dose of 10–30 tons ha^{-1} are 34.9–39.7%, 36.4–37.5%, 15.1–16,1%, and 28.6–36.1%, respectively. In addition, the available moisture content in rainy season also increased the amount of metal that is bio-remediated by microbes in the compost. The land that is fertilized with chicken manure compost, the soil microbial population increases by an average of 4.4 ± 0.5 times compared to the land which is not fertilized with compost, as shown in Figure 1. It shows that the bio-remediation activity of microbial in the compost is very high in supporting the LEISA system. The *Pseudomonas luteola* bacterium present in compost at neutral pH have the ability to degrade the residues of organophosphate fungicides and insecticides with a degradation rate of 85.44% [4].

Only a small proportion of the insecticides and fungicides that are sprayed on the potato crop fall to the ground due to the use of plastic mulch cover on the soil surface. However, fungicides and insecticides are sprayed on plants was able to increase the Pb content = 0.199 ppm, Cd = 0.086 ppm, Cu = 0.544 ppm, and Zn = 5.11 ppm [11].

4.2. Heavy metals in potato plant

The nature of metals that are soluble in water and soil water content in the root zone caused the amount of metals absorbed by the plant to be greater in cultivation in the rainy season than in cultivation in the dry season [1]. The soil water content in the root zone of potato plants during cultivation in the dry and rainy season are 24.3–32.4% (wet basis) and 30–50% (wet basis), respectively. In addition to soil water content, metal absorption by the roots of potato plants is also influenced by the organic substance content in soil, pH, metal concentrations and dissolved organic carbon [20]. The experimental field contained more than 5% organic matter, a pH of 6.5–6.8, and a porosity of 24.2%. The differences in the metal content of Fe, Pb, Cd, and Cr in the potato plant parts of the two potato cultivation seasons are 0.49 ± 0.02 ppm, 0.06 ± 0.02 ppm, 0.02 ± 0.01 ppm, and 0.06 ± 0.02 ppm (plants fertilized by NPK), 0.82 ± 0.2 ppm, 0.09 ± 0.03 ppm, 0.03 ± 0.01 ppm and 0.05 ± 0.012 ppm (plants fertilized by NPK and sprayed with insecticides and fungicides), 3.12 ± 0.4 ppm, 0.26 ± 0.04 ppm, 0.11 ± 0.01 ppm, and 0.11 ± 0.012 ppm (plants fertilized by NPK and compost), 1.92 ± 0.06 ppm, 0.53 ± 0.04 ppm, 0.17 ± 0.05 ppm, and 0.12 ± 0.012 ppm (plants fertilized by NPK with compost and sprayed with insecticides and fungicide).

The results of research on the metal content of Cd, Pb, and Zn in potato plants by Janette et al. [21] are 0.058 ppm Cd, 0.020–0.630 ppm Pb, and 1.836–3457 ppm Zn. The research results from Cheraghi et al. [6], the heavy metal contents in leaves is higher than in stems and tubers, with the lowest heavy metal content in tubers. The content of metals in the leaves, stems, roots and tubers of the potato results of this study were 25.07 ± 2.1%, 33.1 ± 3.2%, 27.1 ± 1.7%, 14.7 ± 2.2%, respectively. The relationship between plant age and the metal content of Fe, Pb, Cd, and Cr in potato plants during cultivation is quadratic patterned. The general equation of relationship between plant age (x) and the metal content of Fe, Pb, Cd, and Cr in the root zone is $y = ax^2 \pm bx \pm c$, the constant value of a = −0.046 – (−)0.0003, the constant value of b = 0.0081–0.08, the value of c = 0.0008–0.25 and the value of r^2 = 0.94–0.98. The increase and decrease of metals in plant parts in the cultivation of potato dispersal seed groups that are fertilized by NPK and compost and sprayed with insecticides and fungicides are most quickly seen from the constant values a, b, and c. This proves that the metals in compost, insecticides and fungicides are easily absorbed by plants so that the metal content in plant parts increases. The increase in metal content is in accordance with the growth pattern of potato plants with the equation $y = -13.9x^2 + 273.8x - 874.63$. The total biomass of potato plants reached a peak at 528 ± 23 g, in the vegetative phase the total biomass of potato plants increased by 528 ± 23 g and in the generative phase the total biomass of potato plants decreased by 259 ± 12 g.

Potato plants dispersal seeds groups which is given chicken manure compost give greater impact in increasing metal content of Fe, Pb, Cd, and Cr in the roots, stems and leaves of plants compared to the plants which sprayed by insecticides and fungicides. This is as a result of fertilizing doses with compost and metal concentrations in insecticides and sprayed fungicides. In addition, farmers often use insecticide and fungicide doses inappropriately or in excess [11]. Fungicides and insecticides are preferred for pest control and potato crop diseases. This has an impact on the order of the concentration of Fe, Pb, Cd, and Cr metals in potato plants from highest to lowest according to Figure 1 to Figure 4, respectively: (1) fertilization with NPK and compost and plants sprayed with insecticides and fungicides, (2) plants fertilized by NPK and compost, (3) plants fertilized by NPK and sprayed with insecticides and fungicides, and (4) plants fertilized by NPK.

Plants in vegetative phase need these metals for the preparation of plant tissue (roots, stems, and leaves), while in generative phase the formation of plant tissues roots, stems and leaves slows down. In the generative growth phase, the potato plants store up food reserves in the tubers and produce flowers and fruit. In the generative growth phase, the potato plants absorb metals from the soil as well as from the air, metals are absorbed through the leaf stomata by spraying insecticides and fungicides.

4.3. Heavy metals in potato tubers

The concentrations of Pb and Cd in potato tubers were lower than the results of the study by [6,10]. Islam et al. [10] reported that the concentrations of Pb and Cd (mg/kg fresh weight) in the potato tuber are 0.57 ± 0.06 and 0.45 ± 0.03 mg kg^{-1}, respectively. Concentrations of these metals are below the threshold value of food safety standards set by Indonesian National Standard (SNI) and WHO. According to WHO the threshold of food safety standards is Fe < 0.4 ppm, Pb < 0.25 ppm, Cd < 0.1 ppm, and Cr < 0.1 ppm. The effectiveness of the in-situ bio-remediation process by microbes present in compost has a direct impact on the amount of metals absorbed by plants and accumulated in the tubers. In addition, controlling the soil water content in the root zone of potato plants due to the application of plastic mulch technology as well as the fertigation and drainage system can control the process of nutrient absorption by plant roots.

Fertilization with compost, spraying plants using insecticides and fungicides and the combination of treatments is very significant in increasing the metal content of Fe, Pb, Cd, and Cr in potato tubers [16]. Fertilization with chicken manure compost increased the metal content of Fe = 0.08 ppm, Pb = 0.04 ppm, Cd = 0.01 ppm, and Cr = 0.01 ppm. Spraying plants using insecticides and fungicides increased the metal concentration of Fe = 0.1 ppm, Pb = 0.03 ppm, Cd = 0.02 ppm, and Cr = 0.02 ppm. Whereas fertilizer treatment with compost and spraying plants using insecticides and fungicides increased metal concentrations in potato tubers as much as Fe = 0.21 ppm, Pb = 0.14 ppm, Cd = 0.03 ppm, and Cr = 0.04 ppm. The research result conducted by Janette et al. [21] the metal content of Cd = 0.039–0.106 ppm, Pb = 0.03–0.318 ppm in potato tubers. Metal concentrations in potato tubers were found in the range of 48.87–72.64 ppm for Fe, 3.07–5.43 ppm for Cu, 13.80–18.89 ppm for Zn, 6.93–13.06 ppm for Mn, 0.51–0.77 ppm for Pb, 2.02–3.55 ppm for Ni and 0.08–0.32 ppm for Cd [22]. The metal content in plants tubers are Zn = 3.7 ppm, Cu = 2.7 ppm, and Cd = 0.04 ppm [23], while the concentration of Mg is 420–438 ppm, Cr is 176–254 ppm, Fe is 27.3–90.4 ppm, and Pb is 2.00–17.4 ppm [24].

5. Conclusions

The compost fertilizer increased the metal content of Fe = 0.08 ppm, Pb = 0.04 ppm, Cd = 0.01 ppm, and Cr = 0.01 ppm in potato tubers, sprayed plants using insecticides and fungicides increased the metal concentrations of Fe = 0.1 ppm, Pb = 0.03 ppm, Cd = 0.02 ppm, and Cr = 0.02 ppm in potato tubers, but the content of these metals is still below the food safety standards set by WHO. The Concentrations of Fe, Pb, Cd, and Cr metals in potato plants which are cultivated in the rainy season on average are greater in the amount of metal Fe = 1–21 ppm, Pb = 0.05–3.65 ppm, Cd = 0.01–0.15 ppm, and Cr = 0.02–0.18 ppm of concentrations than in plants cultivated in the dry season. The increased of Fe, Pb, Cd, and Cr metals concentration in potato tubers due to spraying with insecticides and fungicides was 24.8 $\pm$0.9%, 22.25 $\pm$0.5%, 26.4 $\pm$0.6% and 21.0 $\pm$0.7% from the initial value which contained in potato tuber. The initial concentratian of metals in the potato tubers were 0.1 $\pm$0.02 ppm for Fe, 0.68 $\pm$0.01 ppm for Pb, 0.032 $\pm$0.02 ppm for Cd and 0.032 $\pm$0.04 ppm for Cr. Fertilization using chicken manure compost at a dose of 10–20 tons ha^{-1} is very effective in supporting potato cultivation with the LEISA system. The ability of microbes in the compost to carry out an in-situ bioremediation process on Fe, Pb, Cd, and Cr metals are 49.61–55.60 ppm, 2.59–5.64 ppm, 35.24–52.44 ppm, and 19.68–54.24 ppm. In addition, controlling the ground water content in the root zone. This is very important to support the application of the LEISA system, so that the in-situ bio-remediation process is able to keep Fe, Pb, Cd, and Cr metals in low concentrations. Thus the potato tuber is safe for human consumption and its quality is in accordance with WHO standards.

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Conflict of Interest

The authors declare no conflict of interest in this paper.

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