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Research Article

Quantitative Determination of Cadmium (Cd) in Soil-Plant System in Potato Cropping (*Solanum tuberosum* var. Huayro)

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One of the main daily consumer products in Peru is potato, but in recent years, the addition of agrochemicals with possible heavy metal content, such as cadmium (Cd) has decreased the quality of the final product resulting in a negative impact on soils. The objective of this study is to determine the concentration of Cd in cultivation areas and in potato plantations. For this purpose, 6 tuber samples, 6 leaf samples, as well as 6 samples of agricultural soil used for cultivation were taken. Subsequently, the concentrations of Cd were evaluated by atomic absorption spectrophotometry, and the results were subjected to variance analysis and mean comparison test (Tukey $p < 0.05$). Soil analysis for Cd shows that 50% of samples are not suitable for agricultural use, with concentrations reaching 3.99 mg kg^{-1} Cd; 83% of tuber samples pose a health risk, exceeding the Maximum Allowable Limits (0.1 mg kg^{-1}) set by the Codex Alimentarius; and in the case of the leaves as a whole they have alarming levels of Cd, exceeding 2 mg kg^{-1}.

1. Introduction

Cadmium (Cd) is a nonessential heavy metal; and it is naturally found in soils, however, their concentrations are low, but what is causing a great concern is that it may be enhanced through anthropogenic activities, such as mining and agriculture in recent years [1–3]. The presence of this metal is appearing at an alarming rate and can have an effect in microorganisms which constitute different types of global ecosystems [4]; since Cd has bioaccumulation capacity, it represents one of the most toxic substances for all human populations who are exposed to cadmium (Cd), mostly from plant-derived food and the intake of contaminated food [5, 6]. A large number of studies have revealed that high levels of Cd (heavy metal) are found in the organs of edible crops, this heavy metal pollution is becoming a great issue for food security [7]; since cadmium is found in foods of plant origin and it puts livelihood of countless families at risk [8]. As far as agriculture is concerned, Cd has long been recognized as a matter of grave concern, thus numerous researches indicate that the efficient soil-to-plant transfer of Cd relative to other toxic metals means that food accounts for about 90% of Cd exposure in the general population. The mounting body of correlative evidence has prompted revisions of risk assessments by the US Agency for Toxic Substances and Disease Registry (ATSDR) and the European Food Safety Authority (EFSA) [6]. Excessive use of fertilizers and pesticides poses and increases serious risks to agriculture [9]. Therefore, applications relatively often may increase potentially hazardous trace elements such as cadmium which has a high toxicity to soils quality and food chain [10]. In light of the above considerations and taking into account that potato is of vital importance to agricultural sector in Amazonas region, in this study we evaluated cadmium accumulations in potato plant organs (*Solanum tuberosum* var. Huayro) grown in potentially contaminated lands. The results may contribute to reveal serious health risks in humans; thus, potato may have toxic effect on humans due to the intake of contaminated tubers due to high levels of Cd accumulation.

2. Materials and Methods

2.1. Study Area. This study was conducted in 6 potato plots of Huayro variety (farms) the 6 plots are roughly the same size

(1 hectare approximately each one), which represent 100% of the potato producers of Huayro Variety, all of them belong to San Juan Bautista Producers Association in Conila village, Conila-Cohechan district, Luya province, Amazonas region—Peru, considered a representative area of potato production. This area is located between the coordinates 6° 9′ 38.6″ south latitude and 78° 8′ 44.1″ west longitude, at an altitude of 2466 meters above sea level.

2.2. Soil Samples. Three composite soil sample were collected by combining 5 subsamples of 1 kg from the same agricultural soil, which were taken to a depth of 30 cm. Finally, as a result a total of 15 subsamples for each potato productive unit or potato plot of Huayro variety were taken. Zig–Zag method was used for the samples collection.

The fifteen sub samples for each potato plot (making a total of 90 subsamples for the 6 plots) were taken to the Soil and Water Laboratory of Instituto de Investigación para el Desarrollo Sustentable de Ceja de Selva (INDES-CES), Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas (UNTRM), in the laboratory we proceeded to mixed the five subsamples in order to obtain a composite sample of 1 kg. After, the samples were dried in an oven at 40°C for five days, then each composite sample was powdered using a wooden mallet and sieved until only materials of >2 mm (no soil or clod) are left on the sieve. The mixed samples were prepared to send all of them to soil laboratory of Universidad Nacional Agraria La Molina. To analyse cadmium in soils they have followed method 3052 EPA [11].

2.3. Crops Samples. We identified 15 potato crops in each plot, those crops were taken randomly (adjacent to soil sampling points) in order to analyse them. When potato plants reached physiological maturity, the plants were harvested and leaves and tubers were isolated. Each sample was washed with ultra-pure water, then tubers were grated, finally, they were placed on an oven at 65°C for 12 hours in order to be dried [9]. The dried sample was powdered and weighed to 20 g and then they were prepared to send all of them to Soil and Water Laboratory of the Universidad Nacional Toribio Rodriguez de Mendoza. To analyse cadmium in leaves and tubers of potato crops they have followed method of Microwave Plasma—Atomic Emission Spectroscopy (MP-AES) to which with only 0.20 g of each biological sample were digested using acid digestion reagent combination such as nitric acid and Hydrogen peroxide [12] and the equipment that was used for analysis is Agilent (4100 MP-AES).

2.4. Statistical Analysis. Data collection (18 samples for soil, 18 for leaves and 18 for tubers) was subjected to statistical analysis, therefore analysis of variance (ANOVA) and multiple comparison analysis were used by Tukey method (4) ($p < 0.05$) and Statistix V.8.0. software was used.

3. Results and Discussion

After analyzing the results obtained, data showed that there are not significant differences among Cd level in plot soils

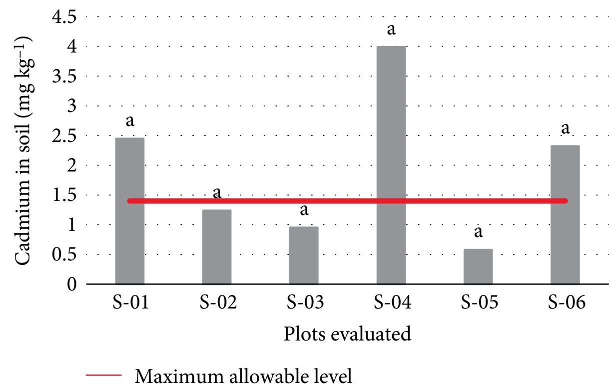


Figure 1: Cd concentrations in cropping soils. Bars with different letters indicate significant differences (Tukey, $p < 0.05$).

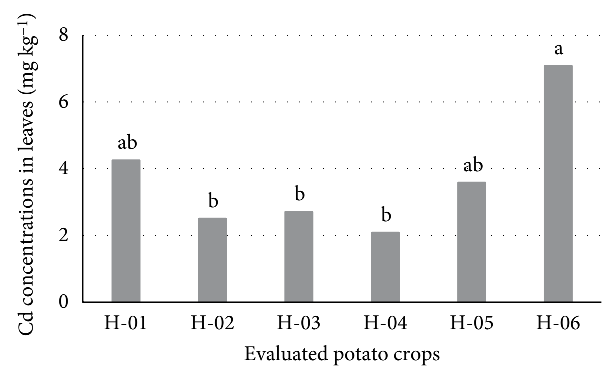


Figure 2: Cadmium concentration in potato leaves. Bars with different letters indicate significant differences (Tukey, $p < 0.05$).

(Figure 1). Nevertheless, 50% of the plots exceeded maximum allowable levels 1.4 mg kg^{-1}, which was adopted by the Ministry of the Environment in Peru [13]. Data indicated that soils of the area assessed are contaminated by Cd, it may be hazard potential for agricultural activities such as potato.

The results of this study confirmed that it may be serious threat to soil quality, taking into account the fact that crop production cycle is highly dependent on fertilizers and other chemical synthesis supplies according to Jiao et al. [10]. It is difficult to put an accurate estimate on the risk of contamination associated with crop fertilization as many farmers do this activity based on their experiences. However, long-term fertilization may increase Cd levels in soils [14]. It would be reasonable to assume that inputs and outputs of toxic metals in soils are variable, given that there is no similarity among CD concentrations in evaluated plots.

On the other hand, studied plots demonstrated an acidic soil pH with ranges between 4 and 6 according to Arévalo-Gardini, Enrique et al. [15], the European Union indicates that ranges between 5 and 6 in soil pH mean lightly contaminated soil with heavy metals, moreover, pollution increases as pH decreases. This key feature may suggest cadmium potential availability to be taken up by potato crops, since lower-neutral pH values promotes metal mobility and soil-to-plant transfer [16–19]. In view of it, Alloway [20],

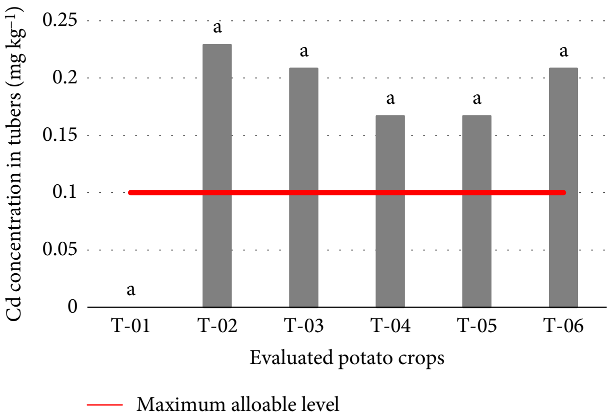


Figure 3: Cadmium concentration in tubers. Bars with different letters indicate significant differences (Tukey, $p < 0.05$).

indicates that heavy metal availability and mobility in soils are closely pH-related. However, Arévalo-Gardini et al. and Bravo Realpe et al. [15, 17], these researchers state that soil texture and organic matter content are determinants for cadmium availability, which was corroborated by Al Mamun et al. [21], who carried out research and confirmed that using compost decreases the concentration of Cd in potato tubers.

Concerning Cd accumulation in potato crop, statistical data suggested significant differences found in potato leaves (Figure 2). Heavy metal concentration varied in relation to sampling area, it was reported that a large range from 2.08 to 7.08 mg kg^{-1}. All of the leaf samples exceeded the limits of Cd; however, these results are lower than those reported by Chen et al. [9], who also found Cd concentrations in leaves have a directly proportional relationship with cadmium content in soils. However, in this study the results found in plot number 4 with reference to concentrations of cadmium in soil would indicate the absence of a direct correlation between cadmium levels found in the leaves and that found in the soil, which could be due to the addition of phosphate products at the time prior to the collection of samples; on the other hand it could also be because of the low level applications of pesticide to this potato plot which has an impact on cadmium levels in leaves.

In Figure 3(6), it is shown cadmium contents found in tubers, levels that go up to 0.23 mg kg^{-1}, and it also presents significant differences among the studied samples for each plot, this result means that cadmium in tubers exceeded a maximum provisional tolerable intake that adopted maximum permissible concentrations for Cd in potato (0.1 ppm) set by International Food Standards Codex Alimentarius [22]. One of the studied samples had no cadmium accumulation, therefore it is not a risk for human health; however, in 5 samples all of them exceeded 0.1 mg kg^{-1}, this has considerable health impact for consumers, given that the frequency of potato consumption. Similar values were reported by McLaughlin et al. and Kabata-pendias & Mukherjee [23, 24] they found concentrations from 0.01 to 0.23 mg kg^{-1} and 0.041 a 1.05 mg kg^{-1} respectively, while Al Mamun et al. [21] found far lower results (0.002–0.008 mg kg^{-1}), those differences may depend on potato variety, nevertheless, McLaughlin et al. [23] conducted

Table 1: Bioconcentration factors from soil to leaves and tubers.

Plots	pH	BCF leaves	BCF tuber
1	5.41	1.73	0.00
2	5.42	2.02	0.19
3	4.44	2.81	0.22
4	5.24	0.52	0.04
5	4.86	6.19	0.29
6	4.82	3.06	0.09

BCF: Bioconcentration factor.

a study and it confirmed that there is slight differences among varieties in the uptake of cadmium from the soil or the results may be different due to the technique used to analyze cadmium in tubers.

Concentration of cadmium in leaves are far higher than concentration in tubers, it may indicate physiological process rather than Cd bioavailability in soils. Therefore cadmium is transported to the tubers almost exclusively in the phloem and cadmium is phloem immobile, on the other hand, cadmium can transport to leaves in xylem [25], that is the reason why cadmium in tubers is lower, since they receive most of their nutrients through the phloem [26].

Mention must be made of the fact that, cadmium uptake by potato crops depend on the variety, pH, soil characteristics (sampling area), elevation among other factors [27, 28]. In the same way, it is deemed important to take into account that concentrations of cadmium in leaves is not only due to the absorption by the crop but by the frequent application of pesticides (synthetic phosphates) which contain large amounts of heavy metals; in a similar manner accumulations of cadmium in soil is caused by applications of chemical fertilizers (phosphate fertilisers). Having this in mind, this study does not find a relationship between cadmium concentration in soils, leaves, and tubers.

When analyzing the bioconcentration factors from soil to leaves shown in Table 1 it is observed that plot 6 has the maximum value and in plot 4 has the minimum value, whereas in the tubers that are low for all plots, these results coincide with the research carried out by Yuping Zhang et al. [27].

4. Conclusions

Potato is the main crop in cohechan lands, being the most consumed and sold as a result. Nevertheless, it may be really harmful for their health, as this research reveals relatively high levels of cadmium found in tubers, and they also exceed the maximum tolerable intake of Cd set by FAO and WHO. And data also indicate that the researcher area in Conila village which belongs to Conila-Cohechan district have been seriously polluted by cadmium it may be due to the use of agricultural chemicals because there is no other source to cause cadmium pollution in this area. Furthermore, farmers in those lands use agro-chemicals such as pesticides and phosphate fertilizer without knowing how to use it and the consequences that they can cause, for instance negative effect on the environment, decrease soil quality and serious illnesses in humans as this chemical can enter into chain food.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

References

[1] A. P. Puga, C. A. Abreu, L. C. A. Melo, and L. Beesley, "Biochar application to a contaminated soil reduces the availability and plant uptake of zinc, lead and cadmium," *Journal of Environmental Management*, vol. 159, pp. 86–93, 2015.

[2] J. Marrugo-Negrete, J. Pinedo, and S. Díez, "Assessment of heavy metal pollution, spatial distribution and origin in agricultural soils along the Sinú River Basin, Colombia," *Environmental Research*, vol. 154, pp. 380–388, 2017.

[3] H. U. O. Jinxi, D. U. Bing, S. U. N. Sifan et al., "A novel aldo-keto reductase gene, IbAKR, from sweet potato confers higher tolerance to cadmium stress in tobacco," *Frontiers of Agricultural Science and Engineering*, vol. 5, no. 2, pp. 206–213, 2018.

[4] N. Bolan, A. Kunhikrishnan, R. Thangarajan et al., "Remediation of heavy metal(loid)s contaminated soils-to mobilize or to immobilize?" *Journal of Hazardous Materials*, vol. 266, pp. 141–166, 2014.

[5] W. A. Norvell, J. Wu, D. G. Hopkins, and R. M. Welch, "Association of cadmium in durum wheat grain with soil chloride and chelate-extractable soil cadmium," *Soil Science Society of America Journal*, vol. 64, no. 6, pp. 2162–2168, 2000.

[6] S. Clemens, M. G. Aarts, S. Thomine, and N. Verbruggen, "Plant science: the key to preventing slow cadmium poisoning," *Trends in Plant Science*, vol. 18, no. 2, pp. 92–99, 2013.

[7] N. Grytsyuk, G. Arapis, L. Perepelyatnikova, T. Ivanova, and V. Vynogradska, "Heavy metal effects on forage crops yields and estimation of elements accumulation in plants affected by soil," *Science of The Total Environment*, vol. 354, no. 2-3, pp. 224–231, 2006.

[8] L. Insuasty, H. Burbano, and J. C. Menjivar, "Cadmium dynamics in potato cultivated soils in Nariño, Colombia," *Acta Agronómica*, vol. 57, no. 1, pp. 51–54, 2008.

[9] Z. Chen, Y. Zhao, L. Gu, S. Wang, Y. Li, and F. Dong, "Accumulation and localization of cadmium in potato (*Solanum tuberosum*) under different soil Cd levels," *Bulletin of Environmental Contamination and Toxicology*, vol. 92, no. 6, pp. 745–751, 2014.

[10] W. Jiao, W. Chen, A. C. Chang, and A. L. Page, "Environmental risks of trace elements associated with long-term phosphate fertilizers applications: a review," *Environmental Pollution*, vol. 168, pp. 44–53, 2012.

[11] USEPA, United States Environmental Protection Agency, "SW-846 test method 3052: microwave assisted acid digestion of siliceous and organically based matrices," 1996, https://www.epa.gov/hw-sw846/sw-846-test-method-3052-microwave-assisted-acid-digestion-siliceous-and-organically-based.

[12] D. Xu, Z. Chen, K. Sun, D. Yan, M. Kang, and Y. Zhao, "Effect of cadmium on the physiological parameters and the subcellular cadmium localization in the potato (*Solanum tuberosum* L.)," *Ecotoxicology and Environmental Safety*, vol. 97, pp. 147–153, 2013.

[13] MINAM, "Environmental Quality Standards (EQS) for Soils Approved," Ministry of the environment, Supreme Decree N° 011–2017-MINAM, Lima, Peru, 2017.

[14] D. McGrath and H. Tunney, "Accumulation of cadmium, fluorine, magnesium, and zinc in soil after application of phosphate fertilizer for 31 years in a grazing trial," *Journal of Plant Nutrition and Soil Science*, vol. 173, no. 4, pp. 548–553, 2010.

[15] E. Arévalo-Gardini, M. E. Obando-Cerpa, L. B. Zúñiga-Cernades, C. O. Arévalo-Hernández, V. Baligar, and Z. He, "Heavy metals in soil of cocoa plantations (*Theobroma cacao* L.) in three regions of Peru," *Ecología Aplicada*, vol. 15, no. 2, pp. 81–89, 2016.

[16] M. W. Evangelou, H. Daghan, and A Schaeffer, "The influence of humic acids on the phytoextraction of cadmium from soil," *Chemosphere*, vol. 57, no. 3, pp. 207–213, 2004.

[17] I. Bravo Realpe, C. Arboleda Pardo, and F. Martín Peinado, "Effect of organic matter quality associated with soil use and management on cadmium retention in high andean systems in Colombia," *Acta Agronómica*, vol. 63, no. 2, pp. 1–14, 2014.

[18] A. Gebrekidan, Y. Weldegebriel, A. Hadera, and B. Van der Bruggen, "Toxicological assessment of heavy metals accumulated in vegetables and fruits grown in Ginfel river near Sheba Tannery, Tigray, Northern Ethiopia," *Ecotoxicology and Environmental Safety*, vol. 95, pp. 171–178, 2013.

[19] S. Wang, D. Y. Huang, Q. H. Zhu et al., "Speciation and phytoavailability of cadmium in soil treated with cadmium-contaminated rice straw," *Environmental Science and Pollution Research*, vol. 22, no. 4, pp. 2679–2686, 2015.

[20] B. J. Alloway, *Heavy Metals in Soils: Trace Metals and Metalloids in Soils and Their Bioavailability*, Springer, 3rd edition, 2013.

[21] S. Al Mamun, N. J. Lehto, J. Cavanagh et al., "Effects of lime and organic amendments derived from varied source materials on cadmium uptake by potato," *Journal of Environment Quality*, vol. 46, no. 4, pp. 836–844, 2017.

[22] FAO, *Programa Conjunto FAO/OMS sobre Normas Alimentarias Comisión del Codex Alimentarius 37*, Período de sesiones 14–18 de julio de 2014, Ginebra (Suiza), 2014.

[23] M. J. McLaughlin, K. G. Tiller, T. A. Beech, and M. K. Smart, "Soil salinity causes elevated cadmium concentrations in field-grown potato tubers," *Journal of Environment Quality*, vol. 34, pp. 1013–1018, 1994.

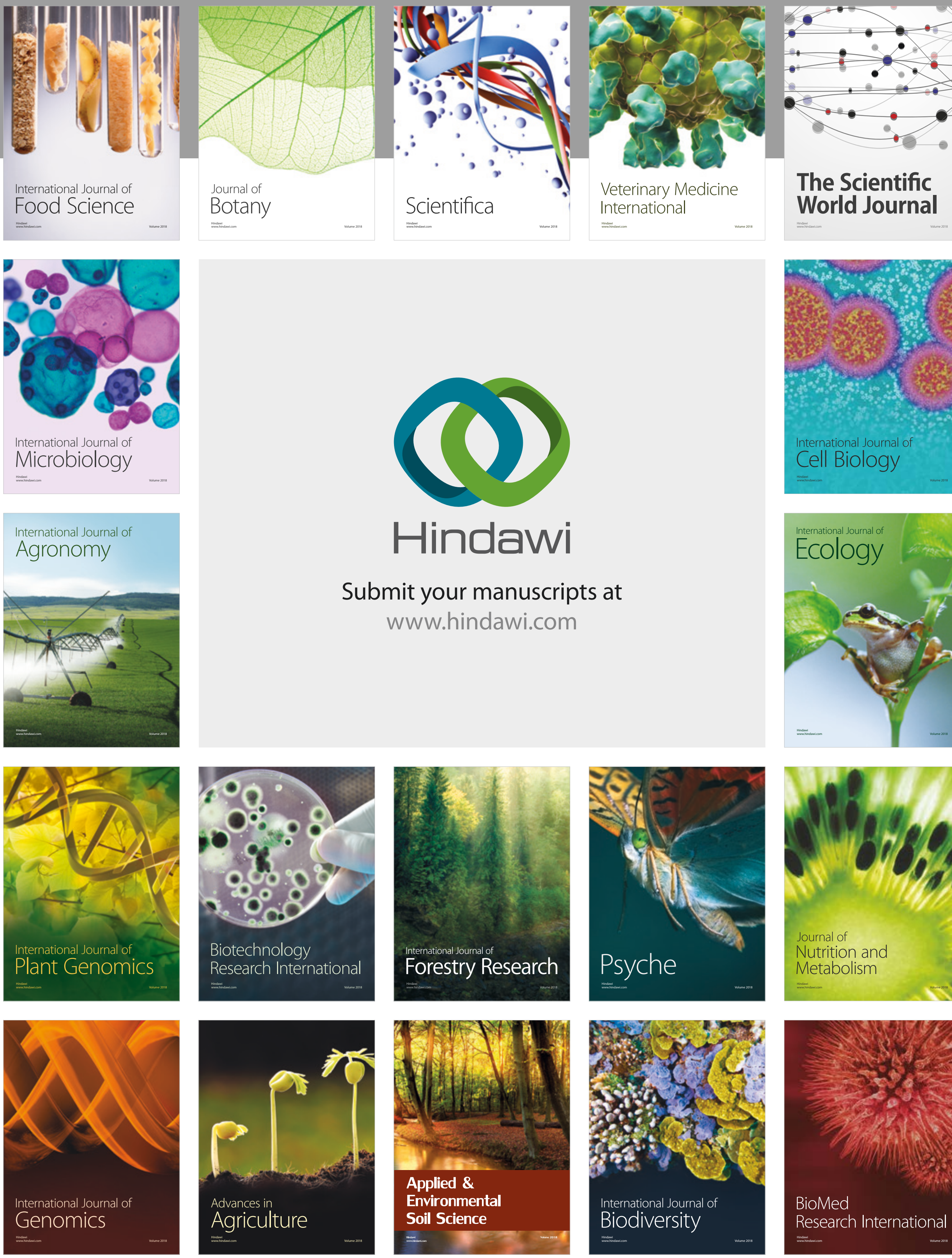
[24] A. Kabata-pendias and A. B. Mukherjee, *Trace Elements from Soil to Human*, Springer, New York, 2007.

[25] S. Uraguchi, S. Mori, M. Kuramata, A. Kawasaki, T. Arao, and S. Ishikawa, "Root-to-shoot Cd translocation via the xylem is the major process determining shoot and grain cadmium accumulation in rice," *Journal of Experimental Botany*, vol. 60, no. 9, pp. 2677–2688, 2009.

[26] K. R. Dunbar, M. J. Mc Lauglin, and R. J. Reid, "The uptake and partitioning of cadmium in two cultivars of potato (*Solanum tuberosum* L.)," *Journal of Experimental Botany*, vol. 54, no. 381, pp. 349–354, 2003.

[27] Y. Zhang, Y. Wu, A. Yang, J. Wang, K. Zhang, and D. Hu, "Assessment of cadmium content of potato grown in Weining Country, Guizhou Province, China," *Environmental Monitoring and Assessment*, vol. 189, p. 226, 2017.

[28] Horticulture Australia, *Managing Cadmium in Vegetables*, ARRIS Pty Ltd, 2003.



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