



Growth, Biomass and Nickel Accumulation Assessments of *Amaranthus hybridus* and *Celosia argentea* grown in Nickel Contaminated Soil

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ABSTRACT

Agricultural lands used in the cultivation of vegetables are prone to contamination with heavy metals of different degrees, which could impact significantly the physiological performance of the plants, and amassing of these metals. This study was conducted at the botanical garden of the Department of Plant Biology, University of Ilorin, to appraise the effects of nickel contamination on identified growth parameters of *Amaranthus hybridus* and *Celosia argentea*, their biomass and nickel accumulated in the vegetables. The treatment comprised of varying concentrations of nickel (100, 200 and 400 mg/kg) used to pollute soil, while control soil were not contaminated. Growth parameters (stem length and girth, leaf length and breadth, number of leaves; and wet and dry weights) were evaluated. Elemental concentrations of nickel in both plants were determined using Atomic Absorption Spectrophotometer. *Celosia argentea* planted on soil polluted with 100 mg/kg of nickel recorded peak values for leaf length and breadth and number of leaves at 3 weeks after transplanting (WAT) (4.77 cm, 2.68 cm and 11.83) respectively. *Amaranthus hybridus* grown on untreated soil recorded the maximum stem length at 1, 2 and 3 WAT (3.50, 3.80 and 5.15 cm) respectively. *Celosia argentea* and *Amaranthus hybridus* grown on soil polluted with 200 and 100 mg/kg of nickel recorded the highest dry weights of 0.06 and 3.87 g respectively at 1 WAT. The highest values of nickel concentrations in *Celosia argentea* and *Amaranthus hybridus* were recorded in those planted in soil polluted with 200 mg/kg of nickel (3.90 and 3.87 mg/kg respectively). The study revealed that nickel pollution may promote the performance of *Celosia argentea* and *Amaranthus hybridus* when cultivated below the threshold of 200 mg/kg which has been established in this study to also enhance build up of nickel in the tissues of the botanicals.

Keywords: Amaranthus, Celosia, concentration, vegetable, growth, nickel, pollution

Introduction

Vegetables are the fresh and edible portions of herbaceous plants, which can be eaten raw or

cooked (Dhellit *et al.*, 2006). They are valued mainly for their high carbohydrate, vitamin, fibre, protein and mineral contents. Vegetables may be edible roots, stems, leaves, fruits or seed. Asaolu *et*

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al. (2012) and Ononugbu (2002) reported that *Amaranthus hybridus*, *Celosia argentea*, and *Talinum triangulare* are popular edibles vegetable in Nigeria, and their oil content helps to lower blood lipids thereby reducing the occurrence of diseases associated with damage to coronary artery.

Amaranthus hybridus is one of the over 60 species of the genus *Amaranthus* broadly cultivated and consumed in many temperate and tropical regions of the world as a green, annual leafy vegetable. It belongs to the family Amaranthaceae. It's an annual herbaceous plant of 1-6 feet high. *Amaranthus* grows on loose and friable soils with high organic matter content. It grows best in light soil, with a pH of 5.5 and 7.5. Hot sheltered location is one of the major requirements for the crop to do well. Amaranth is promulgated by seed, and planting time range from September to December in Nigeria, depending on soil temperature. Soil temperature should be at least 18 °C at planting; it also requires warm and sunny conditions. *Amaranthus* symbolizes the largest source of nutrients of all the vegetables that can be cultivated in Africa. It has been revealed to contain large amount of squalene, a compound that has both industrial and health benefits (Rao and Newmark, 1998; Smith, 2000; He and Corke, 2003). The cooked leaves are eaten in different way as vegetable, soup or sauce. In Nigeria, *Amaranthus hybridus* leaves are often joined with condiments used in the preparation of soup (Mepha *et al.*, 2007).

Pollution put in danger the firmness of the Earth's support systems and threatens the continuing survival of human societies (Damian, 2017). Pollutants can be traced to industrial plants such as smelting complex (Ogunkunle *et al.*, 2013). Soil may turn out to be polluted by the amassing of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine railings, disposal of high metals wastes, pesticides, gasoline and paints, animal manures, land

application of fertilizers, sewage sludge, wastewater irrigation, coal combustion, atmospheric deposition and residents spillage of petrochemicals (Khan *et al.*, 2008; Zhang *et al.*, 2010). Heavy metals constitute an ill-defined group of inorganic chemical hazard, and those most commonly found at contaminated sites are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and Nickel (Ni) (Wuana and Okieimen, 2011). Soils are the major sink for heavy metals released into the environment by anthropogenic activities and unlike organic pollutants which are oxidised to carbon dioxide by microbial action, most metals do not go through microbial or chemicals degradation (Kirpichtchikova *et al.*, 2006), and their concentration in soils continue for a extended time after their introduction. The attendance of toxic metals in soil can rigorously instigate the biodegradation process of organic pollutant (Maslin and Maier, 2000). Heavy metal pollution of soil may create risks and hazard to the ecosystem and humans through; straight intake or contact with polluted soil, the food chain (soil-plant-animal-human or soil-plant-human), ingestion of polluted ground water, decrease in food value through phytotoxicity, cutback in land use capacity for agricultural enterprises consequential to food insecurity, and land tenure problems.

Nickel occurs naturally in the environment, being released through both natural and anthropogenic sources, but seldom in its elemental form (Cempel and Nickel, 2006). Its natural source to the environment includes forest fires and vegetation, volcanic emissions and wind-blown dust, while, the anthropogenic activities resulted in atmospheric accumulation of nickel from combustion of coal, diesel oil and fuel oil, the incineration of waste and sludge as well as, from miscellaneous sources (Wieronska *et al.*, 2019).

Nickel shortage in field-grown crops is uncommon, but in recent years copious fillings have confirmed cases of its deficiency. Only low

degrees of Nickel are known to be beneficial. High level of this element in growing medium may exercise adverse impacts on plants (Molas and Baran, 2004). The absorption of Ni in plants is mainly through roots, both by passive or active transportation and by diffusion (Seregin and Kozhevnikova, 2006). The phyto-availability of nickel has been linked with free nickel ion action in soil solution; thus, plant absorption is also relying on soil organic matter, pH and content and iron – manganese oxide (Rooney *et al.*, 2007). Besides inhibiting plant growth, other symptoms of nickel toxicity include chlorosis, stunted growth and brown interveinal necrosis as (Kabata-Pendias, 2001). Commonly consumed vegetables accumulate heavy metals, and their prolonged consumption may disturb the biological and biochemical processes in the humans (Shobhana *et al.*, 2016). Heavy metals have effect on plant by reducing their dry matter (Ade-Ademilua and Obalola, 2008). The permissible limit for Ni in plant is 10mg/kg (Ogundele *et al.*, 2018). Therefore the aim of this study is to assess the effect of nickel pollution on the physiological performance of *Amaranthus hybridus* and *Celosia argentea*, and the accumulation of nickel.

Materials and Methods

Description of study area

The study was carried out at the Botanical Garden University of Ilorin, Ilorin (N 08° 28'53.3", E 04° 40'28.9"), Kwara State, Nigeria. The study site is situated in the southern guinea savanna belt of Nigeria with a minimum annual rainfall of 800-1300 mm and a maximum temperature of 28°C and 40 °C respectively (Animasaun *et al.*, 2015).

Experimental setup

Seed of *Amaranthus hybridus* and *Celosia argentea* were purchased from a local seed store in Sango, Ilorin. The seeds were raised in the nursery for 2 weeks prior to transplanting into the experimental pots in the screen house. Two sets of

experimental pots were set up for each of the vegetable crops. Each set consists of 1.6kg of loamy soil packed into plastic pots and polluted with different concentrations of nickel. The concentration includes 100 mg/kg soil (T₁), 200 mg/kg soil (T₂), 400 mg/kg soil (T₃), and the control without Nickel pollution. Each treatment was replicated three times. A total of 12 pot setup for collection of data on biomass of *Amaranthus hybridus* and *Celosia argentea* separately. The treatment and replicate were arranged in a complete block design.

Preparation of plant material and determination of nickel concentration

The plant samples were collected and properly washed in running water subsequently rinsed in distilled water. The samples were then first air-dried at room temperature; after which they were oven-dried at 60 °C for 72 hours. The oven-dried samples were ground in an electric grinder and sieve through 2 mm mesh. About 0.5 g each of the prepared *Amaranthus hybridus* and *Celosia argentea* plant materials were weighed into porcelain crucible and ignited at 450 – 500 °C for 6 – 8 hours in muffle furnace, until a greyish-white ashes was obtained. About 5 ml of HNO₃ (2N) was added to each sample, and then filtered with a Whatman filter paper (No.540). The resulting filtrates were transferred into 100 ml graduated flask and made up with distilled water (Fadina, 2017). Analysis of nickel concentration was carried out using Atomic Absorption Spectrophotometer (AAS) (Buck Scientific Model 210 VPG) by adhering to the operational procedure of Association of Chemist (AOAC, 2003).

Collection of data

Data were collected weekly on growth parameters such as stem length, stem girth, number of leaves, leaf length and breadth, after transplanting (WAT). Stem length, leaf length and breadth were measured using measuring tape; stem girth was measured using Vernier calliper; and the numbers

of leaves were counted by visual observation. The growth parameters were taken up to 4 WAT.

Data Analysis

Data collected from the study were analyzed using statistical package for social sciences (SPSS: version 16.0) by subjecting the data to analysis of variance (ANOVA). The mean values of the data were separated using Duncan Multiple Range Test (DMRT) at 5% probability level.

Results

Effects of nickel polluted soil on growth of *Celosia argentea*

Celosia argentea planted in soil treated with 200 mg/kg recorded the significantly ($P<0.05$) highest stem length at 1, 2 and 3 WAT. *Celosia argentea* grown in the control pots that were not treated with nickel recorded the least stem length at 1, 2 and 3 WAT. Highest stem girth at 3 WAT was recorded in *Celosia argentea* planted in soil treated with 100 mg/kg of nickel (2.11 cm), which was significantly different ($P<0.05$) from other treatments and control. Similar results were recorded for leaf length and breadth, and number of leaves, with *Celosia argentea* grown on soil polluted with 100 mg/kg of nickel recording peak values for leaf length and breadth and number of leaves at 3 WAT (4.77 cm, 2.68 cm and 11.83 respectively), as shown in Table 1.

Effects of nickel polluted soil on growth of *Amaranthus hybridus*

Amaranthus hybridus grown on untreated soil recorded the maximum stem length at 1, 2 and 3 WAT (3.50, 3.80 and 5.15 cm) respectively. For

other growth parameters evaluated, *Amaranthus hybridus* planted on soil treated with 100 mg/kg of nickel recorded the peak values at 1, 2 and 3 WAT. However, these high values recorded were closest to the values recorded by those grown in the untreated soil of the control pots; as the result revealed that significant difference ($P<0.05$) were not recorded for stem length and girth, and leaf breadth, at 3 WAT.

Effect of nickel pollution on wet and dry weight of *Celosia argentea* and *Amaranthus hybridus*

Celosia argentea planted in soil treated with 200 mg/kg of nickel recorded the highest wet and dry weight values (2.94 and 0.65 g) respectively; however, they were not significantly different from other treatments ($P<0.05$). *Amaranthus hybridus* grown on soil polluted with 100 mg/kg of nickel recorded the highest wet and dry weights (0.45 and 0.06 g) respectively, which was significantly different ($P<0.05$) from those planted in soil treated with 400 mg/kg of nickel (0.06 and 0.02 g) and 400 mg/kg of nickel (0.08 and 0.02 g) respectively, as shown in Table 3.

Nickel accumulation in *Celosia argentea* and *Amaranthus hybridus*

The highest values of nickel concentrations in *Celosia argentea* and *Amaranthus hybridus* were recorded in those planted in soil polluted with 200 mg/kg of nickel (3.90 and 3.87 mg/kg) respectively. Expectedly, the least value of nickel concentration in the plants were recorded in those grown in the control pots, that were not polluted with nickel, as shown in Table 4.

Table 1:Effect of different concentrations of soil nickel pollution on the growth of *Celosia argentea*

Treatment	Stem length (cm)		
	1 WAT	2 WAT	3 WAT
Control	1.73±0.10 ^b	1.73±0.21 ^c	2.45±0.47 ^c
T ₁	2.32±0.24 ^{ab}	2.73±0.31 ^{ab}	3.77±0.36 ^{ab}
T ₂	2.50±0.24 ^a	3.43±0.30 ^a	4.38±0.24 ^a
T ₃	2.35±0.30 ^{ab}	2.65±0.17 ^b	3.03±0.16 ^{bc}
P-value	0.134	0.001	0.003
Stem girth (cm)			
Control	1.28±0.30 ^a	0.60±0.23 ^b	0.81±0.26 ^b
T ₁	0.93±0.23 ^{ab}	2.01±0.28 ^a	2.11±0.30 ^a
T ₂	0.50±0.17 ^{bc}	1.00±0.19 ^b	1.22±0.16 ^b
T ₃	0.07±0.03 ^c	0.47±0.21 ^b	0.56±0.023 ^b
P-value	0.003	0.000	0.001
Leaf length (cm)			
Control	1.23±0.21 ^b	2.38±0.56 ^b	3.08±0.84 ^a
T ₁	2.03±0.14 ^a	3.75±0.18 ^a	4.77±0.19 ^a
T ₂	1.95±0.27 ^a	3.77±0.38 ^a	4.18±0.72 ^a
T ₃	0.75±0.27 ^b	1.90±0.34 ^b	2.90±0.55 ^a
P-value	0.002	0.004	0.140
Leaf breadth (cm)			
Control	0.48±0.11 ^c	1.48±0.18 ^a	1.52±0.53 ^{ab}
T ₁	1.10±0.06 ^a	1.95±0.12 ^a	2.68±0.015 ^a
T ₂	1.00±0.13 ^{ab}	1.78±0.28 ^a	2.67±0.38 ^a
T ₃	0.67±0.13 ^{bc}	0.65±0.24 ^b	1.18±0.36 ^b
P-value	0.003	0.002	0.019
Number of leaves			
Control	3.50±0.43 ^c	5.50±0.62 ^b	8.67±1.96 ^a
T ₁	5.67±0.49 ^a	9.00±0.82 ^a	11.83±1.35 ^a
T ₂	5.00±0.37 ^{ab}	7.67±0.49 ^a	11.67±2.14 ^a
T ₃	3.83±0.40 ^{bc}	4.67±0.76 ^b	7.00±1.39 ^a
P-value	0.006	0.001	0.174

Values (means ± standard error) with the same superscript letter(s) are significantly different at P<0.05.

Table 2: Effect of different concentrations of soil nickel pollution on the growth of *Amaranthus hybridus*

Treatment	Stem length (cm)		
	1 WAT	2 WAT	3 WAT
Control	3.50±0.45 ^a	3.80±0.69 ^a	5.15±0.72 ^a
T ₁	2.77±0.29 ^a	3.70±0.38 ^a	4.73±0.57 ^a
T ₂	1.77±0.17 ^b	2.62±0.72 ^{ab}	2.87±0.73 ^b
T ₃	1.08±0.23 ^b	1.92±0.18 ^b	2.15±0.18 ^b
P-value	0.000	0.065	0.005
Treatment	Stem girth (cm)		
	1 WAT	2 WAT	3 WAT
Control	0.41±0.14 ^a	1.13±0.22 ^a	1.20±0.22 ^a
T ₁	0.18±0.03 ^b	1.41±0.08 ^a	1.52±0.09 ^a
T ₂	0.13±0.04 ^b	0.62±0.17 ^b	0.69±0.17 ^b
T ₃	0.02±0.00 ^b	0.08±0.02 ^c	0.11±0.03 ^c
P-value	0.009	0.000	0.000
Treatment	Leaf length (cm)		
	1 WAT	2 WAT	3 WAT
Control	1.03±0.18 ^a	1.65±0.17 ^a	1.78±0.28 ^b
T ₁	1.18±0.13 ^a	1.65±0.21 ^a	2.43±0.30 ^a
T ₂	0.83±0.07 ^{ab}	1.10±0.14 ^b	1.30±0.14 ^b
T ₃	0.63±0.02 ^b	0.82±0.02 ^b	1.17±0.07 ^b
P-value	0.019	0.002	0.002
Treatment	Leaf breadth (cm)		
	1 WAT	2 WAT	3 WAT
Control	0.53±0.06 ^a	0.97±0.21 ^a	0.95±0.16 ^{ab}
T ₁	0.62±0.60 ^a	1.05±0.19 ^a	1.25±0.17 ^a
T ₂	0.30±0.03 ^b	0.42±0.07 ^b	0.77±0.08 ^{bc}
T ₃	0.23±0.06 ^b	0.28±0.07 ^b	0.48±0.07 ^c
P-value	0.000	0.003	0.003
Treatment	Number of leaves		
	1 WAT	2 WAT	3 WAT
Control	4.50±0.43 ^a	5.33±0.72 ^a	5.17±0.79 ^b
T ₁	4.83±0.40 ^a	6.00±0.45 ^a	7.5±0.62 ^a
T ₂	2.67±0.33 ^b	3.17±0.48 ^b	4.00±0.52 ^b
T ₃	2.50±0.22 ^b	2.67±0.21 ^b	3.67±0.21 ^b
P-value	0.000	0.000	0.001

Values (means ± standard error) with the same superscript letter(s) are significantly different at P<0.05.

Table 3: Wet and dry weights of *Celosia argentea* and *Amaranthus hybridus* grown on nickel polluted soil at 1 WAT

Treatment	<i>Celosia argentea</i>		<i>Amaranthus hybridus</i>	
	Wet weight	Dry weight	Wet weight	Dry weight
Control	0.29±0.10 ^{ab}	0.05±0.01 ^a	0.17±0.03 ^a	0.20±0.06 ^a
T ₁	0.45±0.09 ^a	0.06±0.01 ^a	0.63±0.09 ^a	0.70±0.12 ^a
T ₂	0.06±0.03 ^b	0.02±0.00 ^b	3.90±3.05 ^a	3.87±3.07 ^a
T ₃	0.08±0.03 ^b	0.02±0.01 ^b	0.47±0.12 ^a	0.60±0.15 ^a
P-value	0.010	0.012	0.336	0.364

Values (means ± standard error) with the same superscript letter(s) are significantly different at P<0.05.

Table 4: Nickel conc. in *Celosia argentea* and *Amaranthus hybridus* grown in nickel polluted soil at 3 WAT

Treatment	Nickel conc. in <i>Celosia argentea</i> (mg/kg)	Nickel conc. in <i>Amaranthus hybridus</i> (mg/kg)
Control	0.17±0.03 ^a	0.20±0.06 ^a
T ₁	0.63±0.09 ^a	0.70±0.12 ^a
T ₂	3.90±3.05 ^a	3.87±3.07 ^a
T ₃	0.47±0.12 ^a	0.60±0.15 ^a
P-value	0.336	0.364

Values (means ± standard error) with the same superscript letter(s) are significantly different at P<0.05.

Discussion

This pattern shows that nickel contamination of the soil enhanced the growth of *Celosia argentea* at 100 and 200 mg/kg. Results from most of the physiological parameters evaluated in this study revealed that *Celosia argentea* performed best at this level of treatments and significantly different (P<0.05) from *Celosia argentea* grown in 400 mg/kg and those in the control pots. This observation implies that the treatment of the soil with nickel at concentrations 200 and 300 mg/kg enhanced the growth of *Celosia argentea*, however was detrimental to the growth of the plant at concentration of 400 mg/kg. This assertion is evident by the higher values exhibited by *Celosia argentea* in its physiological parameters examined during this study. This finding is supported by an earlier submission that elevated levels of nickel contamination in the soil modify plant physiology due to oxidative stress, inhibiting photosynthetic process, and changes in uptake of minerals that could result to inhibition of growth (Nieminen *et al.*, 2007). Lanrewaju *et al.* (2019) who investigated heavy metal residue in *Celosia argentea* reported that the plant shown to have accumulated excessive nickel were observed to have stunted growth, which they attributed to the toxic effect of the heavy metal on the growth of the plant.

The control soil which comprised of untreated soil produced the peak values of stem length during the period of this study.

This observation could be as a result of negative impact of the nickel contamination on the stem length of the plant. This finding agrees with the report of Joseph *et al.* (2018) who probed the implication of nickel uptake on identified growth parameters in *Amaranthus viridis*. They concluded that treatment of *Amaranthus* could bring about oxidative stress by impacting the physiological functions of the plant negatively. On the contrary, evaluation of the other growth parameters in this study revealed that *Amaranthus hybridus* planted on soil treated with 100 mg/kg of nickel gave the best performance. This pattern suggests that nickel pollution would not promote the growth of *Amaranthus hybridus* when the concentration is greater than 100 mg/kg. In other words, this finding revealed that treatment of soil with nickel at concentration of 100 mg/kg may assist growers to achieve better result from cultivating *Amaranthus hybridus*, as evident by the results recorded in growth parameters examined. This finding is corroborated by an earlier similar submission by Fabrizio *et al.* (2013), that *Amaranthus* can tolerate nickel amended soil up to 50 µm of NiCl₂ without negatively affecting the physiological functions of the plant. Osu and Isaac (2014), who worked on the impact of nickel

concentration on *Amaranthus* uptake of nutrient, reported similar observation that high nickel concentration resulted in progressive decline in nutrient uptake in the plant which could in turn result in poor growth of the *Amaranthus*.

Celosia argentea recorded its peak values of wet and dry weights for the plants grown on soil treated with 200 mg/kg of nickel, while these peak values were recorded in plant grown on 100 mg/kg of nickel in *Amaranthus hybridus*. This observation recorded in *Amaranthus hybridus* could be ascribed to deleterious impact of the higher concentrations of nickel on the growth and development of the plant thereby resulting in reduced biomass as the concentration of the nickel in the soil increased. This is in harmony with a report that biomass of the plant reduced with increase in nickel supply. This submission was made by Joseph *et al.* (2018) who studied the effect of nickel uptake on growth of *Amaranthus*. Similarly, an earlier report by Valentina *et al.* (2013) reported dose dependent reduction in root, stem and leaf biomass in *Amaranthus* grown in hydroponic culture.

Celosia argentea and *Amaranthus hybridus* were observed to accumulate nickel most in the plants grown in soil treated with 200 mg/kg which is an indication that both plants exhibit high rate of accumulation of nickel at a concentration of 200 mg/kg. The peak accumulation of nickel at 200 mg/kg observed in this study could be attributed to the threshold of nickel concentration in the soil which could optimally enhance the absorption and bioaccumulation of nickel in the tissues of the plants. This finding is in harmony with an earlier report by Kacholi and Sahu (2018), who carried out heavy metal assessment in soil water and vegetable, and reported that *Amaranthus* species are capable in accumulating high heavy metals from soil where they are grown. This report was also further corroborated by the submissions of Sharma *et al.* (2006) and Sahu and Kacholi (2016), who worked on heavy metal contamination in

vegetables grown in wastewater irrigated area and heavy metal levels in *Amaranthus* species, respectively. Heavy metal contamination of soil can restrict plant growth. *Celosia argentea* is a tolerant plant to heavy metals. *Celosia argentea* is a hyperaccumulator of Cadmium, and could be utilized in the bioremediation effort of cadmium contaminated soil.

Plants have been reported to absorb heavy metals from soil and store them in leaves and in edible parts (Fadina *et al.*, 2017). Metal accumulation in vegetables taken from different soils in Nigeria varies significantly (Olufunmilayo *et al.*, 2014). In addition, this observation is supported by the earlier report of Abdul-Qadir *et al.* (2015) that improved pollution of soil by heavy metal could result in an increased accumulation of nickel by *Celosia argentea*. Abdul-Qadir *et al.* (2015) worked on the assessment of heavy metal bioaccumulation potential of selected vegetables. However, Fadina *et al.* (2017) reported that nickel accumulation rate was lowest among other heavy metals evaluated during their study of heavy metals accumulation in *Celosia argentea*.

Conclusion

This study concluded that *Celosia argentea* growth was significantly enhanced when planted on soil contaminated with 100 mg/kg of Nickel, as revealed by the peak values recorded in stem length, number of leaves, and leaf length and breadth. Growth parameters were negatively affected when the concentration of nickel in the soil exceeded 200 mg/kg. Similar effects were recorded for growth parameters of *Amaranthus hybridus* grown on soil contaminated with 100 mg/kg of nickel, however, this study revealed that the improvement in these parameters were not significantly different from the unpolluted soil of the control. The findings of this study shows that nickel may be deployed to improve the growth of *Celosia argentea* when applied at 100 mg/kg of cultivation soil.

Conflicts of Interest

The authors declare that there are no conflicts of interest among authors on the publication of this article.

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