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# Accumulation of Aluminium and Zinc in Chinese Convolvulus Planted in Sida Soil Enriched with Mixed Compost and Bottom Ash

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***Abstract*: This research aimed to study aluminium and zinc accumulation, percentage of germination, and growth of chinese convolvulus planted in Sida soil enriched with mixed compost and bottom ash. The ratios of Sida soil enriched with mixed compost and bottom ash were tested with chinese convolvulus. Data analysis was conducted using one way Analysis of Variance, Least Significant Difference tests, and Paired t-test. The result showed that chinese convolvulus planted in soil enriched with mixed compost and bottom ash at the ratio of 0.8:0.2 had the highest germination rate (82.78%). The highest aluminium accumulation was observed in chinese convolvulus root planted in Sida soil (905.09 mg/kg dry weight), and the highest zinc accumulation was found in root that was planted in Sida soil enriched with mixed compost and bottom ash at the ratio of 1:0 (169.40 mg/kg dry weight). In addition, accumulations of aluminium and zinc in plants tested in enriched Sida soil ratios were higher in roots than shoots. The accumulated amounts of zinc in chinese convolvulus shoots did not exceed the consumption criteria of the Food and Drug Administration of Thailand. The results suggest that compost mixed with bottom ash could be used for growing this vegetable.**

***Keywords*: Chinese Convolvulus, Sida Soil, Compost, Bottom Ash, Aluminium Accumulation, Zinc Accumulation.**

## 1. INTRODUCTION

Since, Thailand has been developed to industrialized country, the large amounts of energy especially electricity are highly demanded for many activities. To respond to this need, natural gas, lignite coal, oil and hydropower have been explored to be a source of raw materials. Among these, lignite coal is popular because of its low capital and common in Thailand. For example, Mae Moh, power plant uses lignite coal approximately 40,000 tons per day to generate the electricity. The huge amounts of produced electricity, approximately 10,000 tons per day, which composed of 20 percent or 2,000 tons per day of bottom ash and 80 percent or 8,000 tons per day of fly ash are generated, as well. In theory, if fly ash contacts with water under room temperature, chemical reaction will happen and cause fly ash to cementitious characteristics. Therefore, fly ash is commonly used for construction to decrease capital of concrete, regarding as valuable waste [1]. In contrast to fly ash, bottom ash is not widely used although it is used as fine aggregate replacement in mortar in Thailand [2] and also used as planting media in agriculture [3] but some residue is finally worthless dumped into landfill. Therefore, finding a way to explore more benefits from this waste is interesting because bottom ash can improve soil texture, increase the water holding capacity and air contents. In addition, there are many essential nutrients for plants such as, calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), potassium (K), silicon (Si), and zinc (Zn) [4].

In addition, night soil from human excreta increasing has been resulted, at present, from population increase. In Thailand, the generation rate of human excreta on average is 1 litter each person per day or approximately 0.37 cubic meters each person per year (4% dry solid) or meaning that solid generation is 40 grams each person per day. The generation rate of fecal sludge from treatment system (20% dry solid) is 0.13 cubic meter per 1 cubic meter of night soil [5]. However, after treatment, night soil can be used as the compost in agriculture because the tree vital nutrients for plant growth, nitrogen, phosphorus and organic matter are in night soil. It thus, can be used as soil conditioner [6].

Thailand is agricultural country where people like to crop vegetables for eat and for sell and agriculturist often looks forward to gaining more production. Therefore, increasing nutrients to plants by the use of compost for that soil will be an approach. Because of the benefit of these two materials as mentioned before, this study is designed to mix between compost and bottom ash with soil to grow chinese convolvulus. The optimum ratio for mixing is determined by using the compost Standard of Department of Agriculture, Thailand [7] and Food Contamination Standard of Ministry of Public Health, Thailand [8] together with the chinese convolvulus growth. Besides, the accumulation of heavy metals (Al and Zn) in chinese convolvulus parts (root and shoot) were also thoroughly studied to make sure that they were edible.

## 2. MATERIALS AND METHODS

**Plant used in the study:** Chinese convolvulus *(Ipomoea reptans* Poir.) was used in this experiment. All seeds of chinese convolvulus were bought from Chia Tai Co., Ltd. as showed in Figure 1.


**Figure 1: Chinese convolvulus seed**

**Figure 2: Pots with chinese convolvulus seeds**

**Experimental conditions:** Chinese convolvulus seeds were soaked in water for 1 hour and then grown in plastic pots that contained Sida soil and the mixture ratios of compost mixed with bottom ash in ratios of 1:0, 0.9:0.1, 0.8:0.2, 0.7:0.3, 0.6:0.4 and 0.5:0.5 (weight by weight) and control pot that contained only soil. Each treatment was replicated five times. Pots that contained 36 seeds of chinese convolvulus were arrange for plant at building 2, 4$^{th}$ floor balcony, Department of Environmental Health Sciences, Faculty of Public Health, Mahidol University as showed in Figure 2. Tap water, 250 milliliters which rested for one day to remove chlorine, was used to watering in the morning for each pot. Chinese convolvulus was harvested when they were 20 days old.

**Sample collection:** Bottom ash was obtained from Mae Moh power plant in Lampang province operated by the Electricity Generation Authority of Thailand. Compost was obtained from Nong Kham sewage disposal plant. While, Sida soil was randomly bought from Jatujak market.

**Sample preparation:** Compost and bottom ash were mixed in six ratios as follows:

1:0 (compost 2,500 grams: bottom ash 0 grams), 0.9: 0.1 (compost 2,250 grams: bottom ash 250 grams),0.8: 0.2 (compost 2,000 grams: bottom ash 500 grams), 0.7: 0.3 (compost 1,750 grams: bottom ash 750 grams), 0.6: 0.4 (compost 1,500 grams: bottom ash 1,000 grams), and 0.5: 0.5 (compost 1,250 grams: bottom ash 1,250 grams). Each sample was homogeneously mixed and kept in plastic bag before mixing with Sida soil. After mixing compost with bottom ash in various ratios, then added 1 kilogram of compost mixed with bottom ash to 5 kilograms of Sida soil and then mixed homogeneously. After that, 800 grams of Sida soil (control) and 800 grams Sida soil enriched with mixed compost and bottom ash were filled in plastic pot for planting chinese convolvulus (Figure 3)

**Figure 3: Plastic pot contained 800 grams of planted materials**

**Chinese convolvulus yields**

Chinese convolvulus yields were considered in weight and length of chinese convolvulus after harvesting. The weight of chinese convolvulus was measured in gram of fresh weight of whole chinese convolvulus in each pot after cleaning with tab water and then air dried (Figure 4).


**Figure 4: Size of chinese convolvulus used for weighing**

**Aluminium and zinc accumulation in chinese convolvulus**

Chinese convolvulus's shoot and root part were separated and dried at 65°C in the oven for 48 hours. Dried plants were weighted by three-digit balance, ground by agate mortar, and kept in plastic bags. $HNO_3$:$HClO_4$ (2:1) was used to digest samples. The amounts of heavy metals were measured by using the Atomic Absorption Spectrophotometer.

## 3. RESULTS

The germination of chinese convolvulus was observed after planted for 7 days and then analyzed for germination percentage. The results showed that germination percentage of chinese convolvulus that planted in control (only Sida soil) and planted in soil added with mixed compost and bottom ash at ratios of 1:0, 0.9:0.1, 0.8:0.2, 0.7:0.3, 0.6:0.4 and 0.5:0.5 were 82.22 (9.13), 81.67 (5.76), 61.11 (16.20), 82.78 (4.56), 81.67 (14.38), 73.89 (9.34) and 76.67 (8.91) % respectively (Figure 5). It indicated that the highest germination percentage of chinese convolvulus was found at the ratio of 0.8:0.2 (82.78%) the lowest germination percentage was observed at the ratio of 0.9:0.1 (61.11%).

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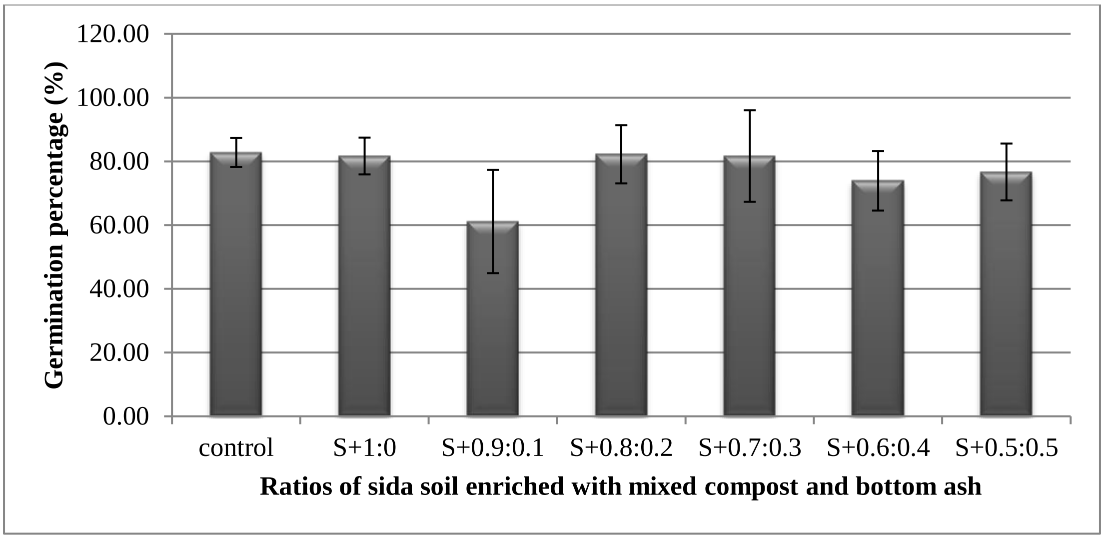


**Figure 5: Germination percentage of chinese convolvulus**

The results of mean comparison between aluminium accumulation in chinese convolvulus roots and shoots planted in control (only Sida soil) and planted in Sida soil enriched with mixed compost and bottom ash at ratios of 1:0, 0.9:0.1, 0.8:0.2, 0.7:0.3, 0.6:0.4 and 0.5:0.5. Results indicated that aluminium accumulation in chinese convolvulus roots and shoots that planted in control and planted in Sida soil enriched with mixed compost and bottom ash at all ratios were significant difference ($p < 0.05$) (Table 1). The highest aluminium accumulation was observed in chinese convolvulus root planted in Sida soil (905.09 mg/kg dry weight). The significant higher amount of aluminium accumulation was also observed in root part than in shoot part.

**Table 1: Mean of aluminium accumulation in chinese convolvulus root and shoot planted in Sida soil and Sida soil enriched with mixed compost and bottom ash at ratios**

| Soil Mixture | Plant parts | Mean | SD | n | df | t | P-value |
|---|---|---|---|---|---|---|---|
| **S** | Shoot | 178.43 | 37.69 | 5 | 4 | -11.005 | <0.001 |
| | Root | 905.09 | 120.48 | 5 | | | |
| **S+1:0** | Shoot | 83.25 | 13.01 | 4 | 3 | -11.510 | <0.001 |
| | Root | 897.909 | 153.24 | 4 | | | |
| **S+0.9:0.1** | Shoot | 89.61 | 18.42 | 4 | 3 | -8.636 | 0.003 |
| | Root | 821.20 | 187.19 | 4 | | | |
| **S+0.8:0.2** | Shoot | 122.32 | 23.12 | 5 | 4 | -11.320 | <0.001 |
| | Root | 867.78 | 160.84 | 5 | | | |
| **S+0.7:0.3** | Shoot | 96.14 | 29.02 | 5 | 4 | -11.493 | <0.001 |
| | Root | 702.72 | 102.85 | 5 | | | |
| **S+0.6:0.4** | Shoot | 118.20 | 33.32 | 5 | 4 | -7.075 | 0.002 |
| | Root | 775.76 | 235.00 | 5 | | | |
| **S+0.5:0.5** | Shoot | 122.44 | 45.01 | 5 | 4 | -5.435 | 0.006 |
| | Root | 795.96 | 262.92 | 5 | | | |

**Note:**1. S = Sida soil

2. Significant level was determined at level of α 0.05.

The results of mean comparison between zinc accumulation in chinese convolvulus roots and shoots that planted in control (Sida soil) and in Sida soil enriched with mixed compost and bottom ash at ratios of 1:0, 0.9:0.1, 0.8:0.2, 0.7:0.3, 0.6:0.4 and 0.5:0.5. It indicated that zinc accumulation in chinese convolvulus roots and shoots that planted in Sida soil and in Sida soil enriched with mixed compost and bottom ash in all ratios were significant difference ($p < 0.001$) (Table 2). The highest accumulation was found in root that was planted in root that was planted in Sida soil enriched with mixed compost and bottom ash at the ratio of 1:0 (169.40 mg/kg dry weight). It should note that the significant higher amount of zinc accumulation was observed in root part than in shoot part.

**Table 2: Mean of zinc accumulation in chinese convolvulus shoot and root planted in Sida soil and in Sida soil enriched with mixed compost and bottom ash at ratios**

| Soil Mixture | Plant parts | Mean | SD | n | df | t | P-value |
|---|---|---|---|---|---|---|---|
| S (Control) | Shoot | 57.50 | 2.46 | 5 | 4 | -18.736 | <0.001 |
| | Root | 118.89 | 6.05 | 5 | | | |
| S+1:0 | Shoot | 85.69 | 2.94 | 5 | 4 | -29.067 | <0.001 |
| | Root | 169.40 | 4.98 | 5 | | | |
| S+0.9:0.1 | Shoot | 76.77 | 3.29 | 5 | 4 | -45.382 | <0.001 |
| | Root | 145.01 | 5.16 | 5 | | | |
| S+0.8:0.2 | Shoot | 68.78 | 7.95 | 5 | 4 | -20.495 | <0.001 |
| | Root | 133.66 | 7.53 | 5 | | | |
| S+0.7:0.3 | Shoot | 66.70 | 5.03 | 5 | 4 | -24.543 | <0.001 |
| | Root | 129.85 | 9.49 | 5 | | | |
| S+0.6:0.4 | Shoot | 63.54 | 5.26 | 5 | 4 | -11.915 | <0.001 |
| | Root | 117.56 | 7.87 | 5 | | | |
| S+0.5:0.5 | Shoot | 62.63 | 3.82 | 5 | 4 | -15.312 | <0.001 |
| | Root | 114.15 | 8.09 | 5 | | | |

**Note:**1. S = Sida soil

2. Significant level was determined at level of α 0.05.

## 4. DISCUSSION

From the results, it was found that the highest germination percentage was chinese convolvulus planted in control (Sida soil) (82.78%) and the lowest germination percentage was chinese convolvulus planted in Sida soil enriched with mixed compost and bottom ash at ratio of 0.9:0.1 (61.11%).

In this study, there was significant difference ($p$=0.031) between germination rate of chinese convolvulus planed in Sida soil enriched with mixed compost and bottom ash at ratio of 0.9:0.1 and other ratios except ratio 0.6:0.4 and at ratios of 1:0, 0.8:0.2, 0.7:0.3, 0.6:0.4, 0.5:0.5 and control there were not significant differences in germination percentage.

Seed germination factors are important such as water, oxygen and temperature and some seeds also need light [11]. Seed dormancy is also important in relation to agricultural and horticultural crops. Its presence cause delayed and sporadic germination, which is undesirable [12]. For this study, the germination of chinese convolvulus in Sida soil enriched with mixed compost and bottom ash at ratio of 0.9:0.1 was clearly low. When considered in pH of planted materials, light and watering that was quite similar done in every pot but seeds dormancy of chinese convolvulus was probably one of the factors that affected the germination of chinese convolvulus seeds. Because seeds that used in experiment was purchased from Chia Tai Co., Ltd. which cannot control the dormancy of seed.

Aluminium accumulation was highest in chinese convolvulus shoots that planted in soil (control) (178.42 mg/kg) and lowest in chinese convolvulus shoot that planted in Sida soil enriched with mixed compost and bottom ash at ratio of 1:0 (83.24 mg/kg). Comparing the mean difference in chinese convolvulus shoot from each ratio, it was found that the accumulation of aluminium in chinese convolvulus planted in only Sida soil (control) was significant difference (P=0.002) in each ratio of Sida soil enriched with mixed compost and bottom ash in all ratios. Aluminium accumulation was highest in chinese convolvulus root planted in Sida soil (control) (905.09 mg/kg) and lowest in chinese convolvulus root planted in Sida soil enriched with mixed compost and bottom ash at ratio of 0.7:0.3 (702.72 mg/kg). No significant difference of aluminium accumulation in chinese convolvulus root in each ratio was observed (p>0.2).

This study indicated that zinc accumulation was highest in chinese convolvulus shoot that planted in Sida soil enriched with mixed compost and bottom ash at ratio of 1:0 (85.69 mg/kg) and lowest in chinese convolvulus shoot planted in soil (the control) (57.50 mg/kg). Zinc accumulation in chinese convolvulus shoot that planted in Sida soil enriched with mixed compost and bottom ash tended to decrease.

The highest of zinc accumulation in chinese convolvulus root was observed when planted in Sida soil enriched with mixed compost and bottom ash at ratio of 1:0 (169.40 mg/kg) and lowest in chinese convolvulus root planted in Sida soil enriched with mixed compost and bottom ash at ratio of 0.5:0.5 (114.15 mg/kg). However, zinc accumulation in chinese convolvulus root planted in Sida soil enriched with mixed compost and bottom ash was decreased.

The previous investigator [13] proposed that there are three types of plant responses to increasing heavy metal contents in soil 1) accumulators, where heavy metals are concentrated in above ground plant parts 2) indicators, where internal concentrations reflect external levels and 3) excluders, where metal concentrations in shoots are low and constant over a wide range of soil concentration up to critical soil level above which unrestricted transport occurs. Most plant species, particularly crop plants, are aluminuim excluders. At neutral or weakly acidic pH, aluminium exists in the form of insoluble aluminosilicate or oxide. When the soil becomes more acid, aluminium is solubilized into a phytotoxic form [14]. $Al(H_2O)_6^{3+}$ which is known as $Al^{3+}$ is dominant in acid soil below pH 5 and is the most toxic form. Aluminium toxicity is the primary growth-limiting factor for plants in acid soils [15] and is most severe in soils with low base saturation, poor in calcium (Ca) and magnesium (Mg) [16]. Aluminium toxicity to plants is difficult to quantify because toxic levels vary with species and even with cultivars within a species [17].

Zinc toxicity symptoms usually become visible at zinc concentration in leaf over 300 mg/kg leaf dry weight although some crops show toxicity symptoms at zinc concentration less than 100 mg/kg dry weight [10],[18] and toxicity thresholds can be highly variable even within the same species. For example, zinc concentration in leaf associated with a 50% yield reduction in radish ranged from 36 to 1,013 mg/kg dry weight [19].

The accumulation of aluminium and zinc in chinese convolvulus root was higher than in shoot. This was similar to study of earlier investigator [9] who found that copper and zinc was accumulated in lettuce root higher than in shoot. Heavy metals are largely transported apoplastically in plant tissue. During their transport through the plant, metals get bound largely on cell wall, which explains why most of metals taken up is commonly found in the roots (75-90%) and smaller amounts are distributed in the shoots. Similarly, Carranza-Alvarez C. *et al.* [20] suggested that roots revealed greater metal concentrations than stems and leaves. In the case of emergent macrophytes, higher accumulation of heavy metals in root might be explained because this is the tissue most exposed to the existing heavy metals. Moreover, macrophytes have a well-developed root-rhizome system.

When compared value of zinc accumulation in chinese convolvulus shoot (edible part) with food contaminate standard of Ministry of Public Health, Thailand [8]. It was found that the value of zinc accumulation in chinese convolvulus shoot that planted in Sida soil enriched with mixed compost and bottom ash in every ratio did not exceed 100 mg/kg. Therefore, chinese convolvulus shoot that planted in compost mixed with bottom ash was safe from zinc.

Although, no standard for aluminium accumulation in food in Thailand was available, the Food Standard Agency [21] has set the limit the unprocessed foods between 0.1 to 20 milligrams of aluminium per kilogram of food. Moreover, Joint FAO/WHO Expert Committee on Food Additives (JECFA) [22] evaluated the safety of aluminium from all sources, including food additives, and established a Provisional Tolerable Weekly Intake (PTWI) at 1 mg/kg body weight.

## 5. CONCLUSION

The compost mixed with bottom ash affect to chinese convolvulus growth because of nutrients in both materials. From the experiment, it was found that chinese convolvulus yields that planted in Sida soil enriched with mixed compost and bottom ash was higher than planted in soil.

Aluminium and zinc accumulations in chinese convolvulus roots were higher than in shoots and there was significant difference ($P<0.05$) between aluminium and zinc accumulation in root and shoot of chinese convolvulus.

Compost mixed with bottom ash in ratio of 0.8:0.2 was the most suitable for plant growth because the germination percentage and yields of chinese convolvulus was higher than other ratios.

When compared zinc accumulation in chinese convolvulus shoot with food contaminate standard of Ministry of Public Health, Thailand. It indicated that zinc accumulation in chinese convolvulus shoot planted in Sida soil enriched with mixed compost and bottom ash in all ratios did not exceed the standard limit.

## 6. RECOMMENDATION

Compost mixed with bottom ash from this experiment can be used to plant chinese convolvulus because chinese convolvulus weight that planted in compost mixed with bottom ash in every ratio were higher than chinese convolvulus planted in Sida soil. Chinese convolvulus shoot is edible due to the zinc accumulation did not exceed food contaminate standard of Ministry of Public Health, Thailand.

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## REFERENCES

[1] Success stories about pollution management. Available from: http://www.pcd.go.th/info_serv/en _ pol_suc ash.html#top. Cited on 12 Jan 2023.

[2] Suwanvitaya, P.A., and Suwanvitaya, P.R. (2006). Utilization of Mae Moh bottom ash as fine aggregate replacement in mortar. International Conference on Pozzolan, Concrete and Geopolymer; 24-25 May 2006; Khon Kaen, Thailand. 2006 p. 127-132.

[3] Singkanipa, J. (2007). Preparation of unfired planting media from bottom ash and FGD-Gypsum from the Mae Moh electric power plant. The 1st Graduate Studies Academic Conference. Presentation of research results for developing country.2007 p.544-547. Available: http://www.graduate.su.ac.th/proceeding/data/31.pdf. Cited on 12 Feb 2023.

[4] Juntaramitree, J.(1999). The feasibility of removing heavy metals from sewage sludge for agricultural applications using fly ash and bottom ash. Thesis. School of Environment, Resources and Development. Asian Institute of Technology.

[5] Department of Pollution Control. (2003). Guideline for wastewater sludge management from wastewater treatment.

[6] Department of Health. (2002).Health and environment. 7th Issue 1. Available from http://www.environnet.in.th/ index.php?option=com_content&view=article&id=467&catid=18&Itemid=16. Cited on 15 Jan 2023.

[7] Department of Agriculture. (2005). Announcement of the Department of Agriculture on Organic Fertilizer Standards B.E. 2548. Available from http://www.ratchakitcha.soc.go.th/DATA/PDF/2548/00172707.PDF. Cited on 10 Feb 2023.

[8] Ministry of Public Health (1986). Announcement of the Ministry of Public Health No. 98 (B.E. 2529). Standards for contaminated food. Available from http://www.fda.moph.go.th/fda-net/html/ product/food/ntfmoph/ntf098.htm. Cited on 22 Dec 2022.

[9] Intrarasaksit, P., 2008. Accumulated copper and Zinc in Lettuce plantation in soil amended with different bottom ash ratios. Thesis. Environmental Sanitation. Faculty of Graduate studies, Mahidol University.

[10] Kumharn, S. (2003). Seed germination.Thesis. Ubon Ratchathani University.

[11] Bewley, J.D. (2011). Seed germination and dormancy. Available from:http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html. Cited on 14 Jan 2023.

[12] Andrivon, D. (1995). Inhibition by aluminum of mycelial growth and of sporangial production and germination in Phytophthora infestans. European Journal of Plant Pathology, 101, 527-533.

[13] Baker, A. J. (1981). Accumulators and excluders-strategies in the response of plants to heavy metals. Journal of plant nutrition, 3(1-4), 643-654.

[14] Matsumoto, H.(2000). Cell biology of aluminium toxicity and tolerance in higher plants. International Review of Cytology, 200,1-47.

[15] Foy, C.D. (1992). Soil chemical factors limiting plant root growth. In: Advances in Soil Sciences: Limitations to Plant Root Growth. Hatfield JL and Stewart BA (Eds), Springer Verlag, New York,19,97-149.

[16] Vitorello, V.A, Capaldi, F.R.C and Stefanuto, V.A. (2005). Recent advances in aluminium toxicity ans resistance in higher plants. Brazilian Journal of Plant Physiology,17,129-143.

[17] Foy, C.D. (1989). Plant adaptation to acid, aluminium-toxic soils. Communications in Soil Science and Plant Analysis,19,959-987.

[18] Hai, T.V, Nga, T.T, and Laudelout, H.(1989). Effect of aluminium on the mineral nutrition of rice. Plant Soil,114,173-185.

[19] Davies, B.E. (1993). Radish as an indicator plant for derelict land-uptake of zinc at toxic concentrations. Communications in Soil Science and Plant Analysis,24,1883-1895.

[20] Carranza-Alvarez, C, Alonso-Castro, A.J., Alfaro-De La Torre, M.C., and Garcia-De La Cruz, R.F.(2008). Accumulation and Distribution of Heavy Metals in *Scirpus americanus* and *Typha latifolia* from an Artificial Lagoon in San Luis Potosi, Mexico. Water Air Soil Pollutions,188,297-309.

[21] Food Standard Agency. Aluminium.(2023). Available from http://www.food.gov.uk/ foodlabelling/packagingbranch/ aluminium_qanda/#. Cited on 12 Feb 2023.

[22] Aguilar, F., Autrup, H., Barlow, S., Castle, L., Crebelli, R., Dekant, W., & Toldrá, F. (2008). Safety of aluminium from dietary intake scientific opinion of the panel on food additives, flavourings, processing aids and food contact materials (AFC). European Food Safety Authority Journal, 754, 1-34.