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The Accumulation Of Cadmium In Corn (*Zea Mays L.*) At Different Levels Of Soil Ph

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ABSTRACT

A pot experiment was carried out in the plastic greenhouse at the Institute of Sustainable Agrotechnology (INSAT), University Malaysia Perlis in Sungai Chuchuh, Perlis, Malaysia. During season of the cultivation of 2014 investigate the impact of soil pH and cadmium on growth of corn plant (Zea mays L.). Twenty five were arranged in factorial experiments according to the Complete Randomized Design (CRD), with three replicates. Five levels of soil pH were, pH4, pH5.2 (i.e., the original value), pH6, pH7 and pH8 and five levels of cadmium (Cd); Cd 1, Cd 2, Cd 3, Cd 4 and Cd 0 where the amounts (2, 4, 6, 8 mg. kg-1 soil and control treatment without add cadmium) are applied as CdCl2. Thus, the total numbers of pots were 75 pots. The results of this investigation revealed that; The decrease of soil pH led to significant effect to increase concentration of cadmium in root, stem, leaves and grain of corn, where the level of pH 5.2 gave highest concentrations of Cd compared with pH 8. the interactions between soil pH and cadmium led to increase of reduced the accumulation of cadmium in the corn, where it gave the interaction between pH 8 and Cd 0 lowest concentration of cadmium in root, stem, leaves and grain.

Keywords:
Accumulation, Cadmium, Corn, Soil pH, Perlis.

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Introduction

Corn (or maize) is one of the oldest human-domesticated plants. Known as the third largest planted crop in the world after wheat and rice. It is mostly used as a primary feed crop – for instance it accounts for 95% of the total feed grain production and its use in the United States. Corn is also important as a food crop in many parts of the world, and in food processing for making starch, sweeteners, oil and beverage. Besides food and feed, nowadays corn has been playing an important role in industrial ethanol production [1] [2].

The Cd is a highly toxic heavy metal for both plants and animals [3]. The presence of Cd in agricultural soils is of great concern regarding its entry into the food chain. Where that the uptake of Cd depends on the ability of plants to counteract its toxicological effects [4]. Cadmium accumulation alters mineral nutrient uptake and inhibits stomatal opening by interacting with the water balance of the plant [5].

The data showed that the concentration of Cd in roots, cotyledons and stems escalated as the exogenous Cd increased up to 50 mM Cd $(NO_3)_2$ [6]. Cd accumulation in root is at a greater extent but its accumulation varies among maize cultivars. Owing to increased peroxidase activity and less transfer of Cd to stem, cultivar 32D99 has better tolerance than 3223 [7]. Also Ahmad [8] indicated that the increased concentration of Cd in the soil led to increase its accumulation in the corn grain. The distribution of Cd in maize cultivated on smelting area. Results reveal that substantial amount of Cd accumulated in stem through root uptake from soil and showed a decrease in biomass yield [9].

Soil-solution pH will influence the diffusion rates greatly because of the strong effect of pH towards Cd solubility in soils [10]. Soil pH is considered a primary factor controlling the availability of Cd in soils, since increasing soil pH favors the adsorption of Cd to metal binding sites and decreases the partition of Cd to soil solution [11] [12]. Also [13] confirm that the pH of the soil is usually the most important factor that controls uptake, with low pH favoring Cd accumulation.

Materials And Methods

Experimental design and treatments

Agricultural experiment is performed inside the plastic greenhouse and arranged by factorial experiments according to the Completely Randomized Design (CRD), with three replicates. This experiment is consisted of five levels of pH value in the soil (pH 4, pH 5.2, pH 6, pH 7 and pH 8) and five levels of cadmium; Cd 1, Cd 2, Cd 3, Cd 4 and Cd 0 where the amounts (2, 4, 6, 8 mg. kg-1 soil and control treatment without add cadmium) are applied as $CdCl_2$. The five of corn plants were planted for each treatment in plastic pots 10 Kg. Where were packed with sandy loam soil, and it were irrigated daily by a drip irrigation system. Where reached the number of treatments for each factor of the study factors (5×5×3).

Management of the experiment

The soil preparation was done before two weeks of cultivation. Soil pH was adjusted to 4.0, 5.2 (i.e., the original value), 6.0, 7.0, and 8.0 by adding a 2 ml solution of 0.15 M HCl, distilled H_2O and 0.06 M, 0.15 M, and 0.6 M NaOH, respectively to 20 g of soil aerobically dried [14]. A complete amount to 10 kg soil was used for each treatment. After that, all the amount of Cd were added to the soil and were mixed together for full homogeneous and then put them in the pots (10 kg). Then, the pots were irrigated with water and incubated for two weeks before transferring corn seedlings for guaranteed uniform distribution of Cd. Ahmed [15] recommends right quantities of NPK fertilizer. A fertilizer rate of 60 N kg.ha-1, 60 P kg.ha-1 and 40 K kg.ha-1 for the maize was followed, MARDI (Malaysia Agriculture Research Development Institute). The fertilizers used were urea (46% N), CIRP (30% P_2O_5) and MOP (60% K_2O). Each seedling was transferred from transplant tray to each pot, which contained 10 kg of soil. All the agronomic practices like weeding; irrigation and plant protection measures were performed as and when necessary. These plants were allowed to grow till they hit the maturity level. All the plants were planted on 10th of June 2014 and were harvested after 110 days.

Determination of Cd concentration in root, stem, leaves and grains of corn (mg. kg-1)

Root was dried at 70°C to a constant moisture level and the weight recorded for each treatment. A 1.0 g portion of each sample was placed in a conical flask with 12 mL of HNO_3 and $HClO_4$ (3:1 ratio) and kept overnight. Samples were digested on a hot plate until a clear solution was obtained. After digestion, the samples were cooled and diluted to 25 mL with distilled water [16]. The heavy metal concentrations

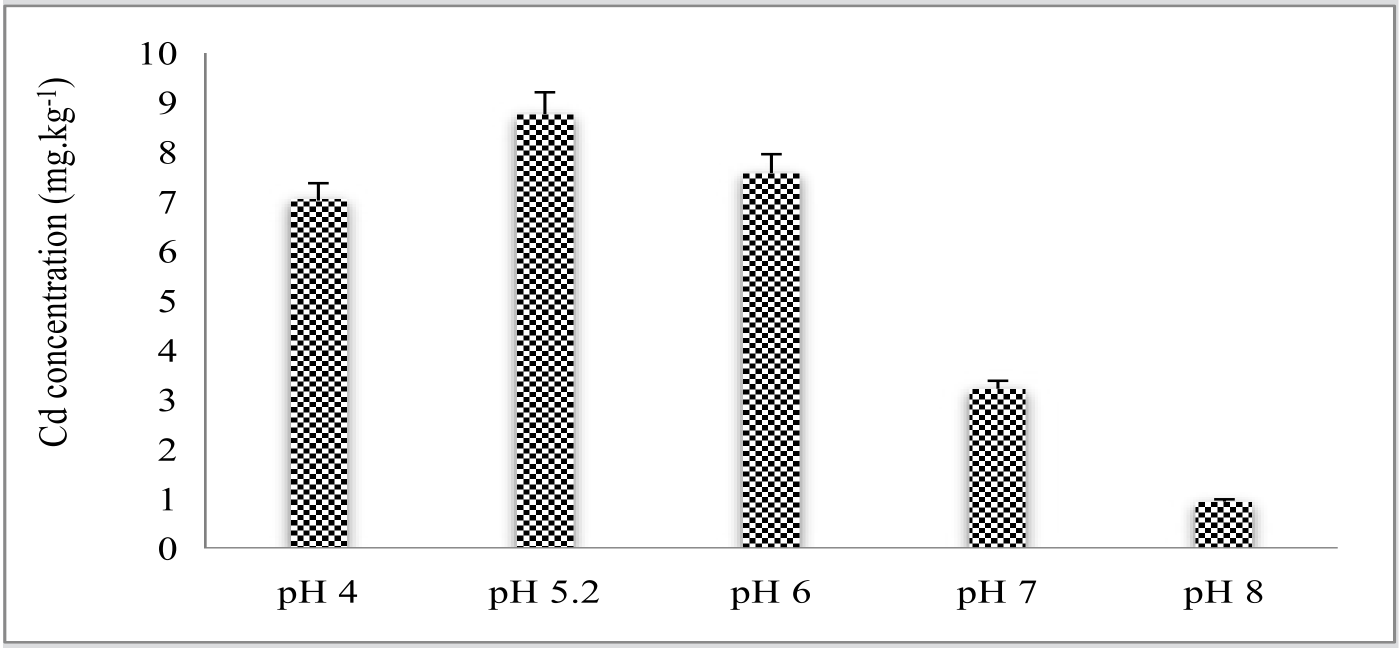

Figure 1: Effect of soil pH levels on Cd concentration in the root (mg.kg-1), n = 3.

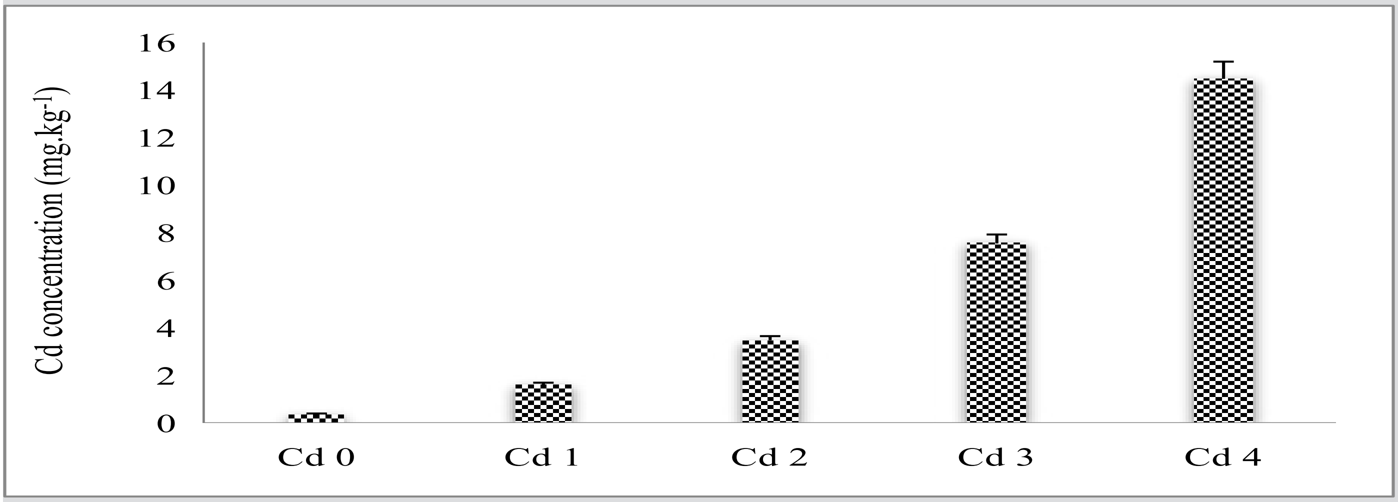

Figure 2: Effect of cadmium levels on Cd concentration in the root (mg.kg-1), n=3.

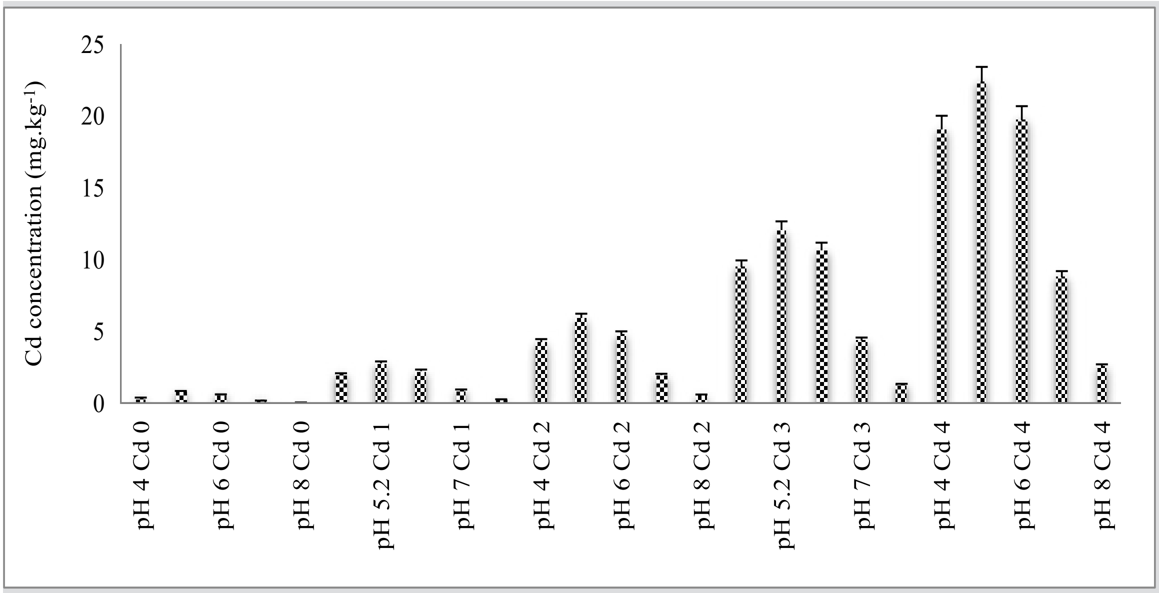

Figure 3: Effect of interaction between soil pH and cadmium levels on Cd concentration in the root (mg.kg-1), n=3.

in root samples were measured using (AAS) atomic absorption spectrometer device (AA-7000) after calibrating the instrument using standard solutions of each metal.

Statistical Analysis

Data were subjected to statistical analysis using the statistical software GenStat [17]. Variety two-way ANOVA was used to analyze the experimental results of dependent variables (treatments). The least significant difference (LSD) was calculated at $P \leq 0.01$.

Results

Cd concentration in the root (mg.kg-1)

Figure (1) showed the effect of soil pH on Cd concentration in the roots, where the increase of soil pH from pH 5.2 to pH 8 led to a significant decrease in Cd concentration in roots. pH 5 resulted in the highest Cd concentration in the roots, reaching 8.77 mg.kg-1, whereas pH 8 resulted in the lowest rate 0.94 mg.kg-1, which agrees with [18]. Many studies indicated that one of the most important control factors in Cd absorption by the plant is soil acidity, so higher pH values resulted in lesser Cd absorption, and vice versa [19] [13]. The same level it was significantly superior on pH 4 level, this might be due to increased readiness of P to uptake by root at pH 5.2, which consequently led to increased the size of the root and absorption of Cd. The increased Cd concentration in the soil led to increased its concentration in the roots, and it is significantly superior to the level of Cd 4 on the rest of the levels, where it gave the highest Cd concentration in the roots, reaching 14.47 mg.kg-1, compared with Cd 0 that resulted in the lowest concentration, reaching 0.39 mg.kg-1, as shown in Figure (2). These results agree with [20] [21], and this increase in the concentration of Cd in the roots is likely due to the activity of the roots, which increase of the melting of Cd in the rhizosphere area, and the huge effect of the quantity of Cd spreading on the root hairs [22].

Cd can easily access the roots, but its absorption by plant depends on the soil's pH [23]. So, the results in our study, as shown in Figure (3), indicated that the interaction between the pH 5.2 and Cd 4 is significantly superior to the rest of the interactions in increasing Cd concentration in the roots, which leads to the highest concentration, reaching 22.29 mg.kg-1, while the interaction between pH 8 and Cd 0 resulted in the lowest rate of Cd concentration in the roots, reaching 0.05 mg.kg-1. Despite the effect of increased soil pH on the decreased of the absorption of the Cd from the soil, high levels of Cd were accumulated in the roots at high percentages. This might be due to the availability of Cd in the soil and the non-availability of the other nutrients that might be compete with Cd to absorption it by plant [24] and might be because the decreased level of organic matter in the soil [25] [26].

Cd concentration in the stem (mg.kg-1)

The decrease of soil pH led to a significant increase in the concentration of Cd in the root, as shown in Figure (1). This consequently led to the transfer of high concentrations of Cd to the stem, where decreasing the soil's pH to pH 5.2 led to a significant increase in the concentration of Cd in the stem, reaching 12.61 mg.kg-1, and vice versa, leading to the lowest concentration of 1.04 mg.kg-1 at pH 8, as shown in Figure (4). These results agree with [27]. Figure (5) indicated that the presence of a significant increase in the concentration of Cd in the stem when increased the concentration of Cd in the soil , where the level of Cd 4 exceeds on the other levels when it gave the highest Cd concentration in stem, reaching 17.04 mg.kg-1, compared to Cd 0 that resulted in the lowest Cd concentration, reaching 0.52 mg.kg-1. This increase was caused by increased Cd absorption at high levels in the soil by the roots, as shown in Figure (2), transferring them directly to the stem during the first transformation in the plants. These results agree with [13] [16], where they reported that the concentration of Cd in the stem exceeds its concentration in roots, grains, and fruits.

The interaction between the soil's pH levels and the levels of Cd affected its accumulation in the stem, where the interaction between pH 8 and Cd 0 led to a significant decrease in the Cd concentration in the stem, reaching 0.05 mg.kg-1, whereas the interaction between pH 5.2 and Cd 4 resulted in the highest Cd concentration in the stem, reaching 30.44 mg.kg-1, as shown in Figure (6). Despite the inverse relationship between soil pH and Cd concentration in the stem, the high level of Cd in the soil led to its accumulation in the stem based on how much of it was absorbed by the roots.

Cd concentration in the leaves (mg.kg-1)

Figure (7) showed a significant effect of soil pH in

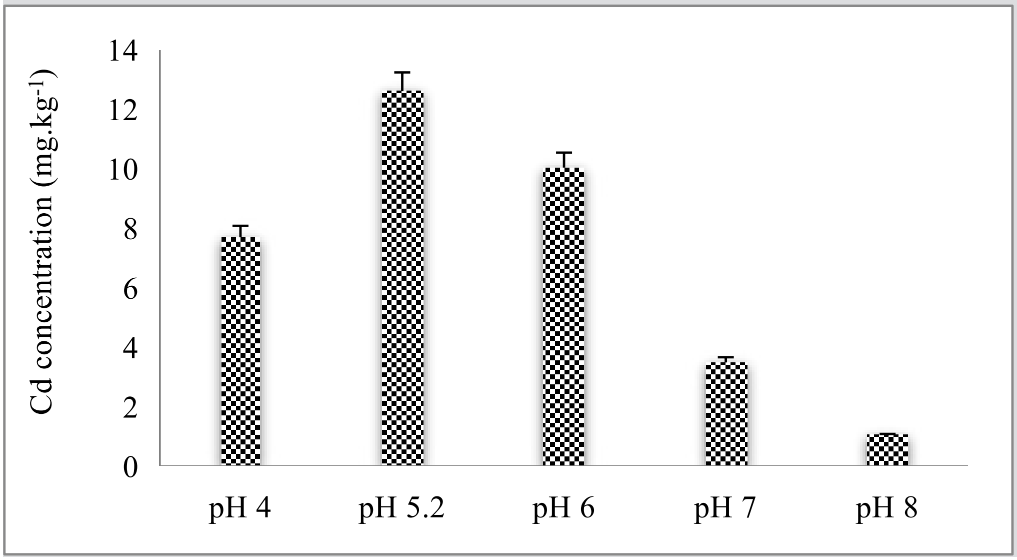

Figure 4: Effect of soil pH levels on Cd concentration in the stem (mg.kg-1), n=3.

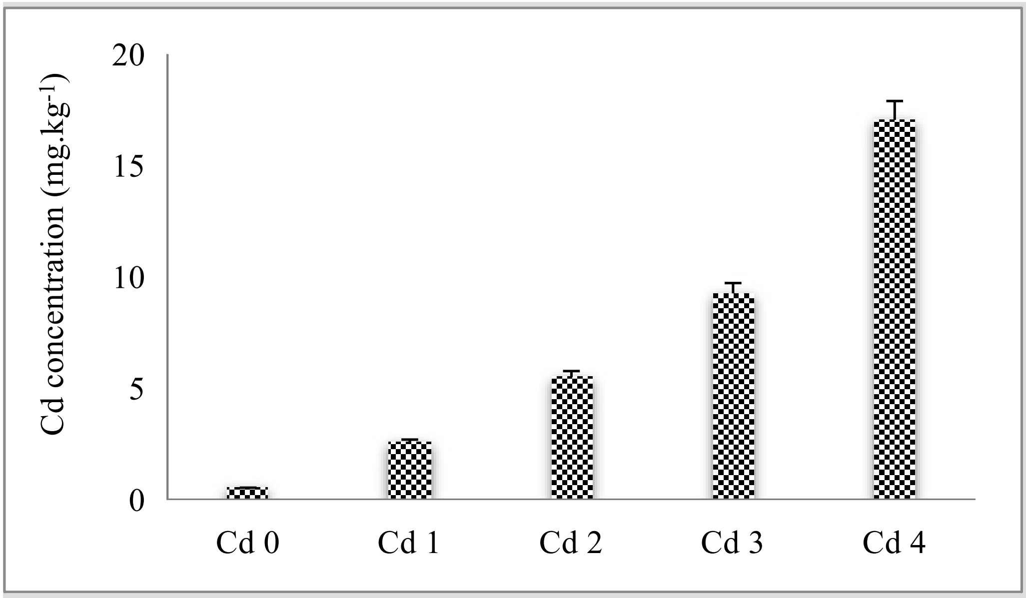

Figure 5: Effect of cadmium levels on Cd concentration in the stem (mg.kg-1), n=3.

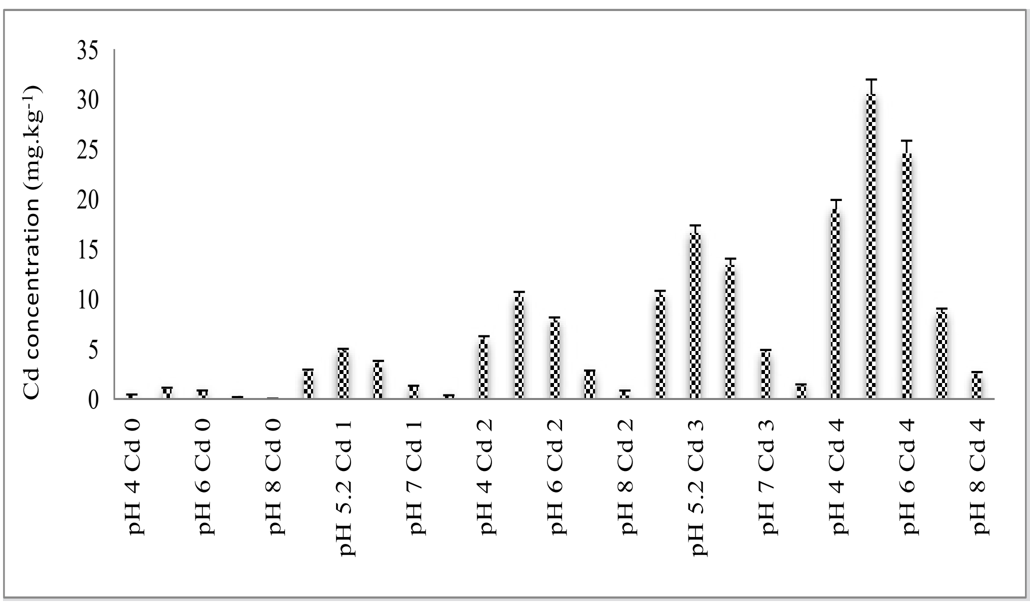

Figure 6: Effect of interaction between soil pH and cadmium levels on Cd concentration in the stem (mg.kg-1), n=3.

the fluctuation of the concentration of Cd in the leaves. Where the soil pH 5.2 gave the highest rate of the Cd concentration in the leaves, reaching 6.75 mg.kg-1, while a pH 8 resulted in the lowest rate at 0.52 mg.kg-1. These results agree with [28]. This high concentration in the acid soil most likely to be caused by the effect of the high acidity of soil with the presence of high concentration from Cd, leading to its absorption and distribution throughout the plants.

The increase in the concentration of Cd led to a significant increase in its concentration in the leaves of the corn, where the Cd 4 resulted in the highest rate of Cd concentration in the leaves reaching 8.86 mg.kg-1, which is significantly superior to other levels, especially Cd 0, where the concentration reaches 0.28 mg.kg-1, as shown in Figure (8). These results agree with [21] [29], who indicated that the accumulation of Cd was high in the cells surrounding the main veins of corn leaves. This increase in Cd in the leaves is most likely the result of increased absorption and accumulation of the Cd in the roots and the stem of corn, leading to increased of accumulation in the leaves, but less concentration from root and stem [30].

Figure (9) indicated that the interaction between factors of the study significantly affected in the decreasing of the Cd levels in the leaves at the interaction between the pH 8 and Cd 0, where it resulted in the lowest concentration of Cd, reaching 0.03 mg.kg-1, compared to other interactions, where its concentration increased in the interactions whenever the soil's pH decreased, which in turn increased the levels of Cd in the soil until it reaches the interaction to pH 5.2 and Cd 4, resulting in the highest Cd concentration in the leaves at 15.59 mg.kg-1, as reported by [31].

Cd concentration in the grains (mg.kg-1)

The soil pH has a huge influence on the accumulation of Cd in grains, where pH 8 led to a significant decrease in the concentration of Cd in the grains reaching 0.048 mg.kg-1, which is significantly superior to other soil pH levels in decreasing the accumulation of Cd in grains. Despite its accumulation at a high concentration in grains when the soil have high concentration of it, decreasing the soil's pH to 5.2 resulted in the highest concentration of Cd, reaching 2.391 mg.kg-1, as shown in figure (10). These results agree with [32] [33], who pointed out that the soil acidity was significantly affected upon the accumulation of Cd in grains. The increase in Cd levels in the soil led to a significant increase in its concentration in the grains (figure 11), since Cd 4 resulted in the highest level for the Cd in the grains, reaching 2.444 mg.kg-1, and showed superiority over other Cd levels, while its concentration decreased in the grains whenever reaches Cd 0, at 0.088 mg.kg-1. These results agreed with [16] [32], both pointing out that the increase in the concentration of Cd in the soil increases the transfer of Cd from the stem to the grains.

Figure (12) explains the presence of a significant effect at pH 8 and Cd 0 interaction, resulting in a significant decrease in the accumulation of Cd in grains, where the lowest concentration reached 0.003 mg.kg-1, which was superior to all other interactions, while the interaction between pH 5.2 and Cd 4 resulted in the highest concentration of Cd, reaching 4.882 mg.kg-1. The results agree with [31], who assured that the concentration of Cd and the soil's acidity is important factors that influence the accumulation of Cd in the grains. The increase in the concentration of Cd at a pH 5.2 might be caused by the soil acid effect in increasing Cd melting and the availability of P, which led to increased size of the roots, consequently transferring Cd and accumulating it in different parts of the plants and grains after absorbing it in large amounts via the roots.

Discussion

Cadmium contamination is one of the increasing concerns worldwide thereby various scientists proposed different strategies to overcome this environmental problem. The present study was conducted to reduce the accumulation of cadmium in the maize plant. To achieve this, experiment were conducted at the Institute of Sustainable Agrotechnology (INSAT), University Malaysia Perlis in Sungai Chuchuh, Perlis, Malaysia, to determine the levels of soil acidity that increases and the levels that reduce the accumulation of cadmium in the plant. Where the decrease of soil pH led to significant effect to increase concentration of cadmium in root, stem, leaves and grain of corn, where the level of pH 5.2 gave highest concentrations of Cd compared with pH 8. the interactions between soil pH and cadmium led to increase of reduced the accumulation of cadmium in the corn, where it gave the interaction between pH 8 and Cd 0 lowest concentration of cadmium in root, stem, leaves and grain.

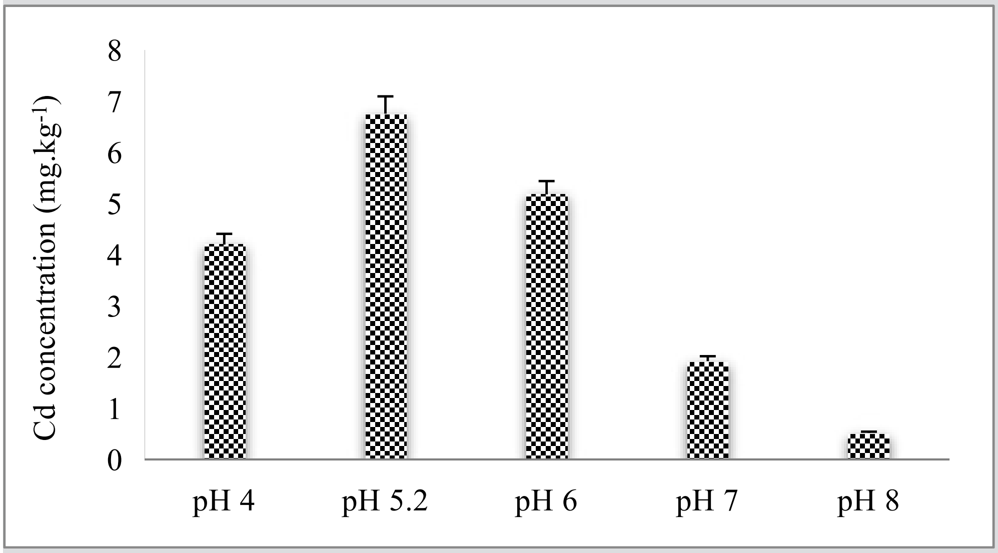

Figure 7: Effect of soil pH levels on Cd concentration in the leaves (mg.kg-1), n=3.

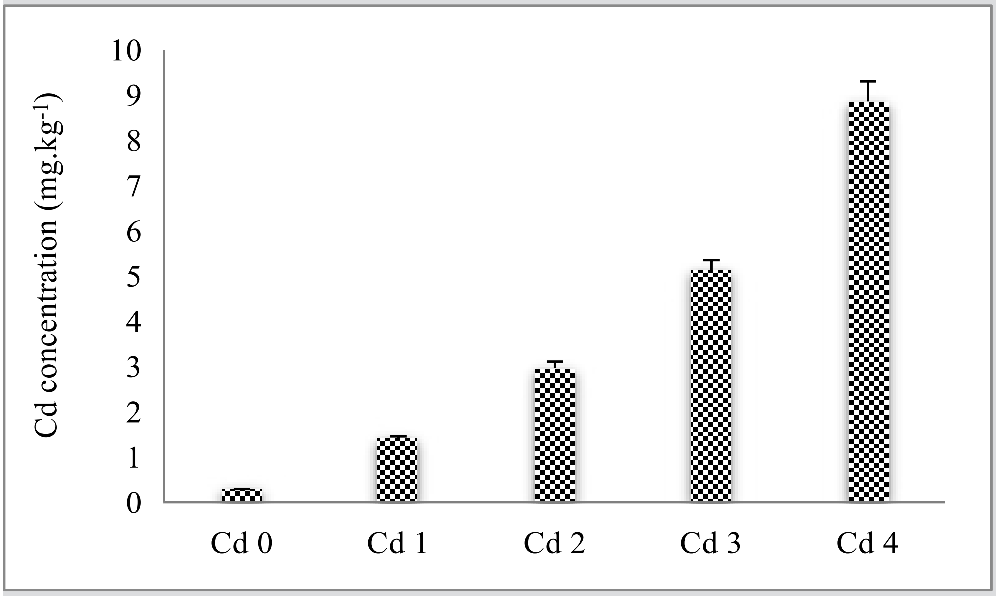

Figure 8: Effect of cadmium levels on Cd concentration in the leaves (mg.kg-1), n=3.

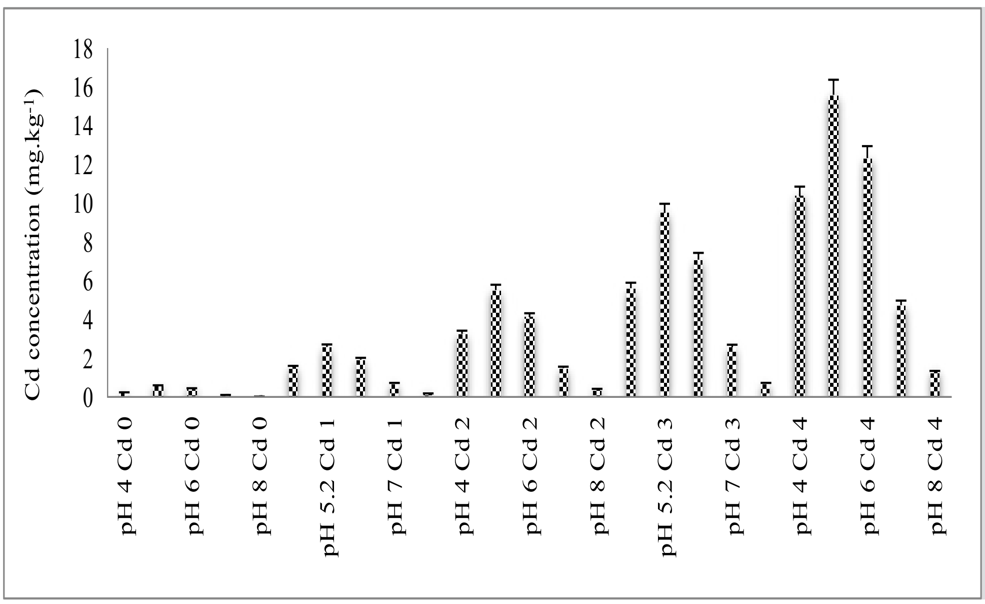

Figure 9: Effect of interaction between soil pH and cadmium levels on Cd concentration in the leaves (mg.kg-1), n=3.

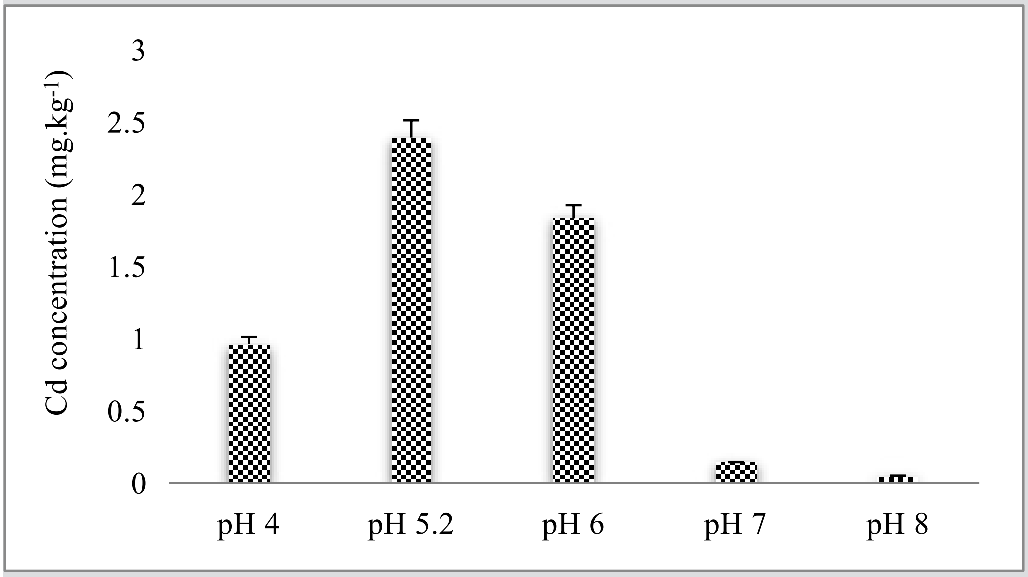

Figure 10: Effect of soil pH levels on Cd concentration in the grains (mg.kg-1), n=3.

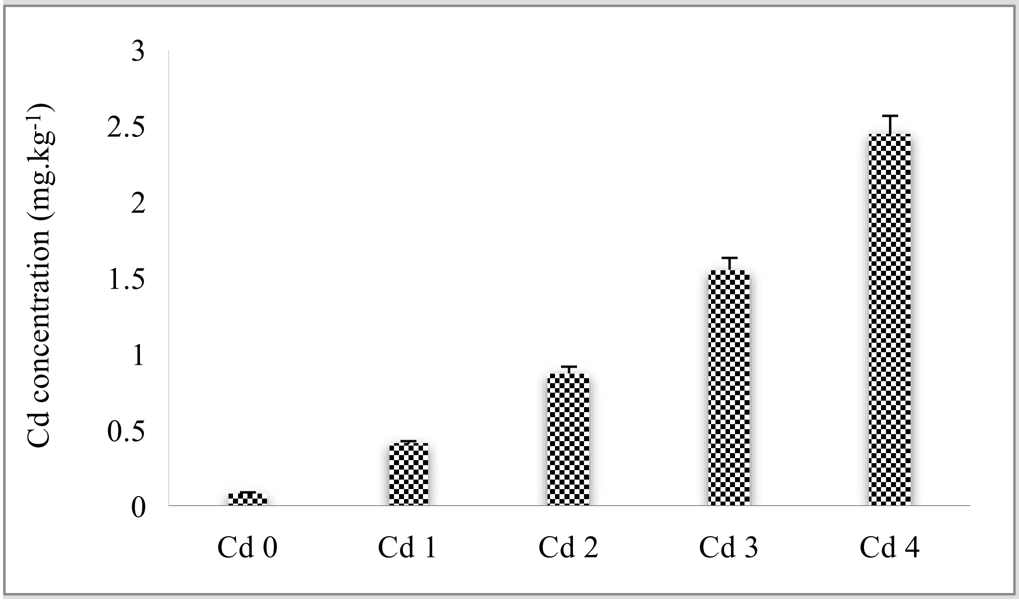

Figure 11: Effect of cadmium levels on Cd concentration in the grains (mg.kg-1) , n=3.

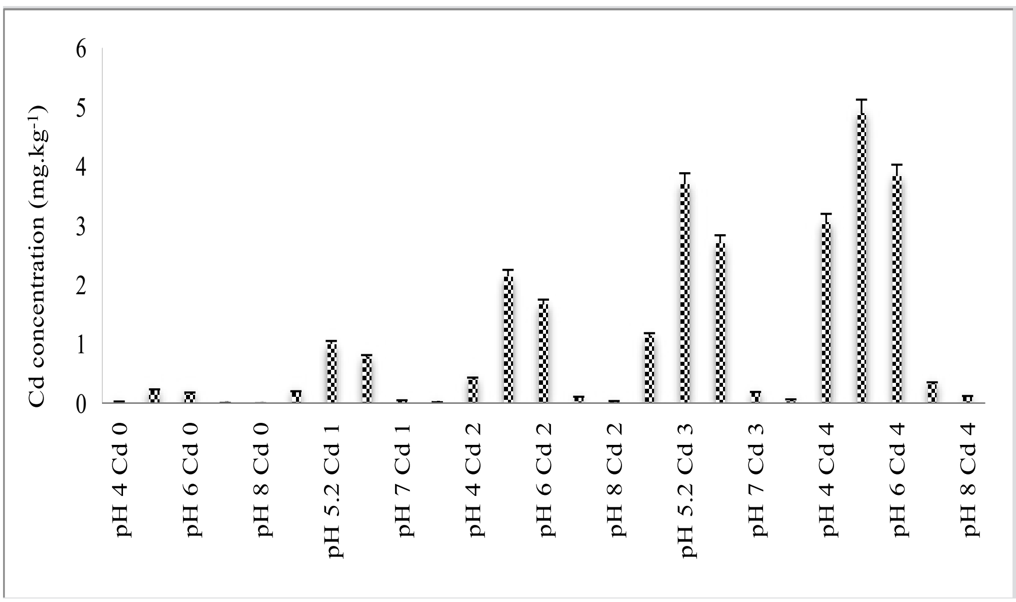

Figure 12: Effect of interaction between soil pH and cadmium levels on Cd concentration in the grains (mg. kg-1), n=3.

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Table: 1 Initial physical and chemical properties for soil of study.

Bulk Density (g/cm3)	pH	CEC (cmol. kg^{-1})	EC (dS. m^{-1})	Cd (mg. kg^{-1})	N (%)	P (mg. kg^{-1})	K (mg. kg^{-1})	Ca (mg. kg^{-1})	O. M (%)
2.3	5.20	2.03	0.24	0.92	1.24	37	95.7	6.4	0.21