BIO ACCENT

BAOJ Biotechnology

Rivas Cancino Guadalupe, BAOJ Biotech 2017, 3: 1
3: 028

Research

Aluminum/ Silicon Complex Due Calcium Carbonate Mixed with Silicon Oxide Treatments to Ameliorate Al^{3+} Toxicity in Maize (Zea Mays L) in Juchitlan, Mexico

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Abstract

The formation of aluminum-silicon complex eventually prevents the penetration of Al into the root cortex of mostly crops. The plants that suffer from heavy metal toxicity may be from silicon application through the increased release of compounds that immobilize the heavy metal ions.

The co-deposition of silicon and Al that formed less soluble aluminosilicates or hydroxyaluminosilicates within the root cell wall as responsible for the reduced concentration of free, toxic Al^{3+}ions in plants. A more recent review of the silicon-mediated mechanisms used to alleviate the abiotic stress caused by heavy metal toxicity, salinity, drought and freezing was conducted. The objectives of this research study were to determine silicon and aluminum complex furthermore the evaluation and comparison of the root growth and biomass production due to different dosages of silicon oxide applications in a combination with calcium carbonates in maize and whether effects to induced to ameliorate Aluminum toxicity in soil solution.

KeyWords: Aluminumand Silicon Complex; Silicon; Amelioration of Al Toxicity; Maiz; Calcium Carbonates

Introduction

Its well documentedthe A3+ toxicity in plants and soil solution, soluble aluminium is considered to be one of the more serious potential negativee ffect of acid precipitation in soils [1]. This increase in Al is thought to occur as Al ismobilized from organic and inorganic in soils to ground water and eventually into stream and lake water [2].

Aluminum (Al) toxicity is the most important soil constraint for plant growth and development in acid soils such negatively affects the agriculture production, particularly grain crops.

Al interferes negatively in different cultures, reducing biomass production, interfering more directly in thegrowth of roots [3,4]; thus, affecting the uptake, transport and bioactivity of essential elements (Ca, Mg, P and K) and wáter by plants [5], as well as increased sensitivity to other stresses, especially drought stress [6]. The apoplastic - bound Al hinders, especially at pH 4.00 and 4.50, the phosphate uptake by plants [7].

At present such aluminum – silicon complex have been show in maize crop, due generally coexists with Al in soil solution in the form of monosilicic acid H_4SiO_4 [8].

High accumulation of silicon in the shoots helps some plants to overcome a range of biotic and abiotic stresses. However, plants vary in their ability to take up Si from the soil and load it into the xylem and so the accumulation of silicon varies greatly between plant species, [8]. silicon alleviates many abiotic stresses including chemical stress (metal toxicity,

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Sub Date: December15th, 2017, **Acc Date:** December 28th 2017, **Pub Date:** December 29th 2017.

Citation: Rivas Cancino Guadalupe and Rivas Rodas Ricardo (2017) Aluminum/ Silicon Complex Due Calcium Carbonate Mixed with Silicon Oxide Treatments to Ameliorate Al^{3+} Toxicity in Maize (Zea Mays L) in Juchitlan, Mexico. BAOJ Biotech 3: 028

salt, nutrient imbalance) and physical stress (drought, lodging, radiation, high temperature, freezing, UV) and many others as well [9]. suggested that the ameliorative effect of Si on Al toxicity resulting from decreasing the toxic Al3+ concentration in solution by forming Al – Si complex [10].

Silicon is generally reactive to heavy metals and impairs the translocation inside the plants and eventually reduces the toxic effect to the plant [11-13]. The reduced translocation of absorbed heavy metals in plants was attributed to the buildup of silica deposits in the cell walls that bound the metal ions and prevented the distribution of the ions from the roots to the shoots, in addition to the complex formation of silicon with metal ions that limited the translocation to different parts of the plants [14].

Studies showed that the application of silicon-rich materials effectively reduced the Al toxicity in plants through the reduced uptake of Al [15,16]. The potential mechanisms for this effect include the following: (1) the precipitation of Al caused by the increased soil pH as a result of the elevated concentration of H_4SiO_4; the $H_4SiO_4$was adsorbed on Al hydroxides, which formed a less mobile compound and diminished the activity of the phytotoxic Al in solution [17]; and (3) the mobile Al was strongly adsorbed on the silica surfaces [18]. The soil pH regulates the solubility and the mobility of silicon. The adsorption-desorption processes affect the concentration of H_4SiO_4in the soil solution and are very dependent on the soil pH [19]. The maximum adsorption of H_4SiO_4that occurs at pH of 9–10 and at pH values below or above these levels, the amount of adsorption is reduced.

However, the Fe and Al hydroxides have strong adsorption capacity, which can remove significant amounts of dissolved silicon from the soil solution [20-22].

Some inorganic anions, such as Fluorine F, Silicon Si or sulfate can stable complexes with Al and reduce the harmful effects through organic acid which are able to chelate Al to render it non toxic and are therefore implicated in Al tolerance mechanisms. Silicon has been demonstrated to inhibit Al penetration into the root cortex with Al in the medium/ roots and contributes to the detoxification of Al [23].

Table : (Observe the follow Table 1. $CaCO_3$ Soil amendments treatment in combination with silicon oxide SiO_2).

Treatment	Calcium Carbonate $CaCO_3$ in combination with silicon oxide SiO_2				Control
	10 Liters/ 2kg	15 Liters/ 2kg	20 Liters/ 2 kg	25 Liters/ 2kg	
Days after germination	pH	pH	pH	pH	pH
5	4.2	4	4.1	4	4
10	4.2	4.2	4.3	4.3	4
15	4.4	4.3	4.3	4.3	4.1
20	4.4	4.4	4.5	4.5	4.1
25	4.5	4.4	4.6	4.6	4
30	4.5	4.5	4.6	4.9	4
35	4.6	4.5	4.7	4.9	4
40	4.7	4.6	5	5.1	4.1
45	4.7	4.8	5.2	5.5	4
50	4.8	4.8	5.3	5.6	4
60	4.9	5	5.3	5.5	4
65	5	5.2	5.3	5.7	4
70	5	5.2	5.2	5.7	4
75	5.1	5.4	5.4	5.6	4
80	5.1	5.5	5.7	5.7	4.1
85	5.2	5.6	5.7	5.8	4
90	5.2	5.6	5.8	5.8	4
95	5.3	5.5	5.8	5.8	4
100	5.3	5.6	5.8	5.8	4
140	5.7	5.7	5.9	6	4

Methods

The present study was conducted in a maize plot located in Juchitlan, Mexico (20°4´59´´N, 105°52´59´´W). Randomized trial was used, four treatments were established under field conditions, which were consisted of the absence and presence of silicon + Calcium carbonates applications. (Observe the follow Table 1. $CaCO_3$ Soil amendments treatment in combination with silicon oxide SiO_2).

The application of soil amendments treatments:

1. Calcium carbonatein a different concentration with a combination of silicon dioxide in 2kg Ha^{-1}concentration:

A) $CaCO_3$10Lt Ha^{-1} + SiO_2 Kg Ha^{-1}

B) $CaCO_3$ 15Lt Ha^{-1} + SiO_2 Kg Ha^{-1}

C) **$CaCO_3$ 20Lt Ha^{-1} + SiO_2 Kg Ha^{-1}**

D) $CaCO_3$25Lt Ha^{-1} + SiO_2Kg Ha^{-1}

E) Control Treatment

Those were designed and applied to evaluate the effect of silicon oxide in an Al complex in soil solution.

The main of the study was evaluation and comparison of the root and foliar growth and its amelioration due to silicon applications.

The application treatments days are described below, such was started at day **5th** after seed germination and it had continued every five days until 100thday, the final application was until 140th day.

Calcium carbonate addition is for the improving fertility and increase pH levels in soil solution.

Initial and final soil pH was registered gradually increased according the follow table. Soil pH levels were observed not significant changes (**Treatment E**).

- **Treatment C.** ($CaCO_3$ 15Lt Ha^{-1} + SiO_2Kg Ha^{-1})

From**60th**until **140th** Days after germination showed higher elongation root and biomass growth thus enhance crop yield.

*There was a significant increase of Biomass.

-From 65thuntil 100th DAG the root growth remained stable.

Treatment **C, D** had shown the same plant response, due to the fact that the beneficial effect of Si to anatomical variations produced by the deposition of silica on the walls of epidemical cells, which keep the leaves upright and improve light interception, stimulating photosynthesis and thereby promoting higher accumulation of biomass [19,24], Therefore, Si improves mineral absorption of plants, increasing the availability of some nutrients [25].

Image 1. Maize Root growth under treatment C, Silicon applications promoted an increase in the volume of root;

Image 2. Differences among Control and Treatment C. Treatment E (Control). In presence of Al^{3+} decrease of root elongation was observed; C. ($CaCO_3$ 20Lt Ha^{-1} + SiO_2 Kg Ha^{-1}) was showed increase of root growth.

-Treatments **A, B,** Not significant difference among treatments were observed.

-Treatment **E** (Control) Reduction of root and shoot growth was observed which is a visible symptom of Al toxicity.

Results

Under the experimental conditions used in this research, Al decreased the elongations of roots and according with the plant response, under **treatment E**, root was stubby and brittle, root tips as well lateral roots became thick and turn slightly brown.

- **Treatment C** ($CaCO_3$ 15Lt Ha^{-1} + SiO_2 Kg Ha^{-1}), from **60th** until**140th,** DAG was showed higher elongation root and expand of biomass growth. *There was a significant expand of biomass.
- The accumulation of **Al** in roots can cause root growth inhibition, directly ori ndirectly affecting the growth, metabolism and productivity of the entire plant. Furthermore, [26]. Si deposition on the plant may have reduced binding sites for Al, resulting in lower metal translocation from roots to shoot. The important role of silicon in the maintenance of crop productivity. According to [27].
- **Al / Si** complexes are formed ameliorating the toxic Aluminum effects increaseda higher silicic acid concentration.
- **Calcium carbonate**was used as an amendment in acid soil, but in combination with **silicon oxide** showed a strongly response to increase of root and biomass growth as well, thus enhance crop yield.
- **Silicon** applications ameliorate the toxic effects of Al^{3+}.
- Silicon application reduced stalk lodging and increased the lignification of stem.
- The addition of **silicon oxide** to treatments ameliorate the Aluminum toxicity, enhance yield crop.
- **Treatment E** was observed root stunting, is a consequence of Al induced inhibition of root elongation.

Conclusion

It was shown there is a beneficial effect of Si is not only due to the fact that influence on AL specification in the external solution, but also to Al / Si interactions principally in the root [28].

Silicon oxide addition increased root elongation and biomass growth.

Additionally, an increased concentration of silicic acid ions in the soil solution leads to the formation of complexes with heavy metals in the soil and to competition with other ions for adsorption sites [29]. Silicon shows great influence on the development of plant roots, thus allowing better root resistance in addition reduce stalk lodging stem, mitigation of both biotic and abiotic stresses.

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