Vol 4 Issue 11 Dec 2014

ISSN No : 2230-7850

International Multidisciplinary Research Journal

Indian Streams Research Journal

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RNI MAHMUL/2011/38595 **ISSN No.2230-7850**

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Indian Streams Research Journal
ISSN 2230-7850
Impact Factor : 2.1506(UIF)
Volume-4 | Issue-11 | Dec-2014
Available online at www.isrj.org

ALUMINIUM PHYTOREMIDIATION POTENTIAL OF *PEDILANTHUS* VARIETIES

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Abstract:-Al toxicity is an important limitation to worldwide crop production, which is more prevalent in acidic soils. Since % of the world's potentially arable lands are acidic, the problem needs more attention. Therefore the present study was undertaken to evaluate the Al remediating potential of *Pedilanthus* varieties. Plants were grown in various concentrations of AlCl3 treated soils for 12weeks. Root and shoot lengths were measured and recorded. Al accumulated and remained in plants and soil respectively was quantified using inductively coupled plasma-optical emission spectrometry (ICP-OES). Results of the present study revealed high accumulation of Al in both the varieties of *Pedilanthus* without any signs of Al toxicity in terms of root and shoot lengths. Therefore both the varieties may be used to combat Al toxicity and protect the crop plants from loss of productivity.

Keywords: Aluminium Phytoremidiation Potential ,acidic soils ,after oxygen and silicon.

INTRODUCTION

Aluminium (Al) is the third most abundant metallic element in soil after oxygen and silicon. It is largely present in the form of aluminosilicate minerals, and so very small quantities appear in the soluble form, capable of affecting biological systems (May and Nordstrom, 1991). Al bioavailability for plants and its toxicity is a major constraint for crop production in acidic soils worldwide. When the soil pH drops below 5, Al^{3+} ions are released in to the soil and enter into root tip cells ceasing the root growth. So, the main target of Al is the root tip. It causes inhibition of cell elongation and cell division, leading to root stunting accompanied by reduced water and nutrient uptake. At tissue level, the distal part of the transition zone is most sensitive to Al. Many cell components are implicated in the Al toxicity including DNA in nucleus, numerous cytoplast compounds, mitochondria, the plasma membrane and the cell wall at cellular and molecular level.

Many of the agricultural practices such as removal of products from the farm, leaching of nitrogen below the plant root zone, inappropriate use of nitrogenous fertilizers, and build-up in organic matter, are causing acidification of agricultural soils. Therefore production of staple food crops, in particular grain crops, is badly affected (Kochian *et al.,* 2005).

There are a number of conventional remediation techniques which can be employed to remove Aluminim such as stabilization, soi1 flushing, soil washing, excavation, retrieval and offsite disposal. But a majority of these technologies are costly to implement and cause further disturbances to the already damaged environment (Lasat, 2000). Due to these drawbacks, phytoremediation technologies are continuously being researched for possible solutions.

In spite of lot of researches done on many plants and many metals, the studies on phytoremediation of Aluminium are comparatively overlooked/left aspect. *Pedilanthus tithymaloides* belonging to the family, Euphorbiaceae is a small tropical shrub. The two varieties of *Pedilanthus* viz., *Pedilanthus tithymaloides* var. variegatus and *P. tithymaloides* var. *tithymaloides. P. tithymaloides* var. tithymaloides were studied by Jamil *et al.* (2009) for their dust trapping and metal accumulation capacity in their leaves when they were grown at road side. They reported accumulation of Fe, Zn, Cr, Cd, Ni, Mn and Cu efficiently among the 10 plant species chosen for their work. Hence, in the present study the phytoremedation potential of Pedilanthus varieties for Al was assessed.

MATERIALS & METHODS

1. Collection of plant materials

Two varieties of *Pedilanthus tithymaloides* were collected from the Botanical garden, S.V.University, Tirupati and the identification was confirmed with taxonomist, Department of Botany Sri Venkateswara University, Tirupati, A.P., India. Voucher specimen was deposited for future reference.

2. Experimental procedure

Pedilanthus var.. A (*Pedilanthus tithymaloides* L. var. *variegatus*) *Pedilanthus* var B (*Pedilanthus tithymaloides* L. var. tithymaloides) stem cuttings of 8g weight were planted in plastic pots containing 500g of sieved soil (sieved through 2mm pores). The pots were grouped (n=3) in to C-Control,1-100ppm,2-200ppm,3-300ppm,4-400ppm,5-500ppm based on Al treatments. To the treatment groups Aluminum chloride solution was added at their respective concentrations. All the groups were allowed to grow for 12 weeks and at the end plants were harvested, the root and shoot lengths were measured using scale. Plant biomass and soil of each group was retained and stored for estimation of Al accumulated and remained in them respectively.

3. INDUCTIVELY COUPLED PLASMA-OPTICAL EMISSION SPECTROMETRY (ICPOES)
Sample preparation by microwave digestion method

Sample preparation of plant and soil samples was carried out by microwave digestion system (CEM corporation ltd.). Approximately 1 g (dry mass) of the sample was weighed directly into the PTFE vessels, to which 10 mL of concentrated HNO3 was added and the vessels were capped immediately. The digestion programme consisted of a ramp time of 10 min to reach 150 °C and a dwell time of 10 min at 150 °C. The power was 800 W. After the completion of programme, vessels were cooled, vented and opened and then 2mL of 30% H_2O_2 was added, and the solution was filtered into 25 mL volumetric flasks and the volume was made up with double distilled water. Blanks were prepared by following similar digestion procedure without plant or soil sample.

These digested samples (plant or soil) were subjected for quantification of Al and other soil nutrients by ICPOES.

RESULTS & DISCUSSION

1. Al ABSORBED BY *PEDILANTHUS* VARIETIES

In both the varieties of *Pedilanthus* the amount of Al absorbed was found to increase significantly from 1st to 2nd concentration and then decreased at 3rd concentration followed by an increase from3rd to 5th concentration as shown in the Table-1 and Figure-1.

This shows the Al accumulating ability of both the varieties of *Pedilanthus*. The ANOVA data indicate that both the varieties are equally effective in accumulating Al Table-2, however, the accumulation capacity among the two were not statistically different from each other.

Table-1 Amount of Al absorbed by *Pedilanthus* varieties

Treatments	*Pedilanthus*	
	Var. A	Var. B
1	17.82±5.34	16.56±2.55
2	22.15±2.75	20.51±1.84
3	18.83±0.93	19.77±2.50
4	20.89±2.89	20.43±3.93
5	22.46±7.56	23.13±1.06

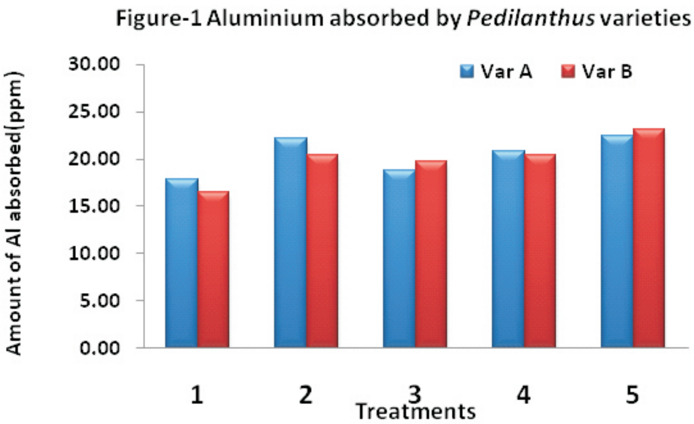


Table -2 Analysis of variance results of Aluminium content in two varieties of *Pedilanthus*

Source of variation	Degree of freedom	Sum of squares	Mean squares	Computed f	Significance
Replication	2	2.914	1.457	0.133	ns
Varieties	1	18.003	18.003	1.645	ns
Error a	2	21.884	10.942		
Concentration of Aluminium	4	60.283	15.071	1.277	ns
Error b	8	94.424	11.803		
Interaction between Varieties and concentration of Aluminium	4	32.529	8.132	0.431	ns
Error c	8	151.084	18.885		
Total	29	11972.66			

2. Al REMAINED IN SOIL AFTER PHYTOREMEDIATION WITH *PEDILANTHUS* VARIETIES

Table -3 and Figure-2 indicates that in both the varieties of *Pedilanthus*, there was a significant decrease in soil Al content of all the treated groups after phytoremediation. This shows that both the varieties are capable of absorbing Al from soil. ANOVA data reveals that there was no significant difference between soils' Al content of both the varieties Table-4.

Table-3 Amount of Al remained in soil after phytoremediation with *Pedilanthus* varieties

Treatments	Soil data	
	VarietyA	Variety B
1	80.53±2.85	80.77±2.82
2	166.50±4.27	169.87±5.49
3	279.41±3.30	280.12±3.79
4	360.32±4.93	358.43±4.13
5	455.47±4.85	457.43±3.57

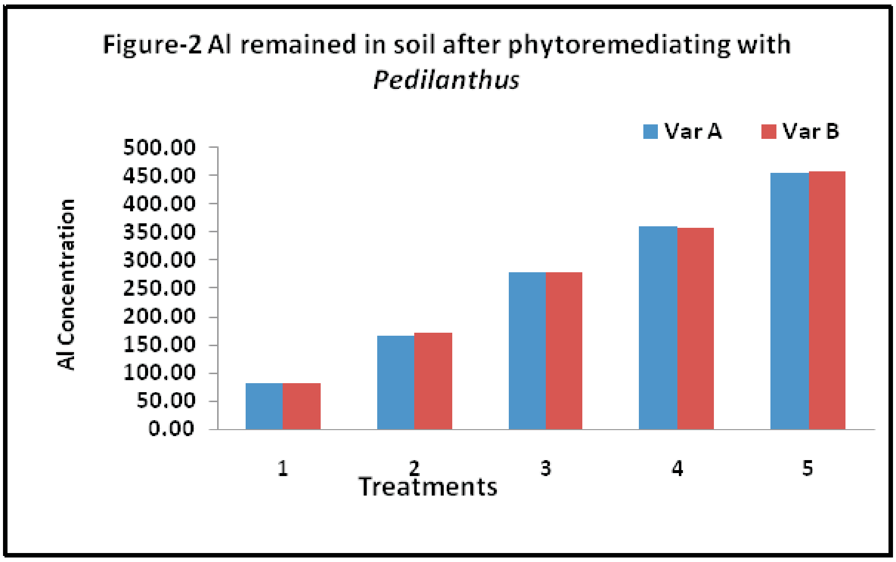


Table-4 Analysis of variance results of Aluminium content of soil with two varieties of *Pedilanthus*

Source of variation	Degree of freedom	Sum of squares	Mean squares	Computed f	Significance
Replication	2	8717.75	4358.875	1.107	ns
Varieties	1	353.5	353.5	0.0876	ns
Error a	2	7875.75	3937.875		
Concentration of Aluminium	4	5799.5	1449.875	0.313	ns
Error b	8	37005.25	4625.657		

Interaction between Varieties and concentration of Aluminium	**4**	**29851.5**	**7462.875**	**2.900**	**ns**
Error c	**8**	**20584.25**	**2573.031**		
Total	**29**	**2244**			

3. EFFECT OF AL ON ROOT GROWTH

Figure-3 indicates that in *Pedilanthus* var A, there was a decrease in the length of adventitious roots from 1st to 5th concentration when compared to control. But the numbers of roots were found to increase in treated plants when compared with control. Maximum numbers of roots (8) were observed at 3rd concentration.

Figure-4 indicates that in *Pedilanthus* var B, there was an increase in number of roots from 1st to 5th concentration when compared with control. At 3rd concentration maximum root length was observed when compared to the control plants.

Figure-3 Adventitious Root Length of *Pedilanthus tithymaloides L.* var. *variegatus* after exposure to Al Stress

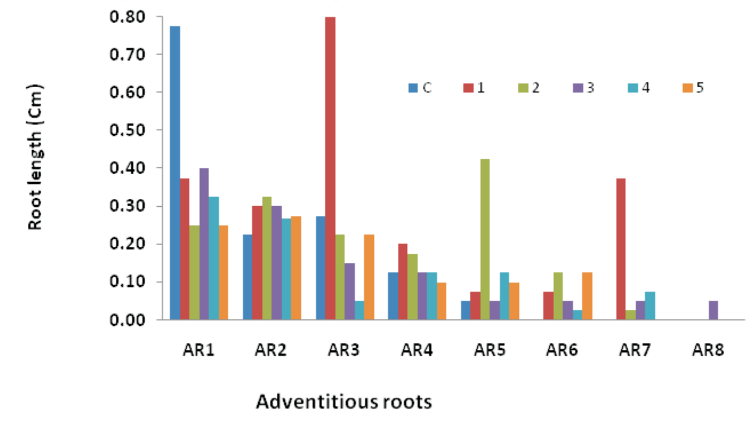
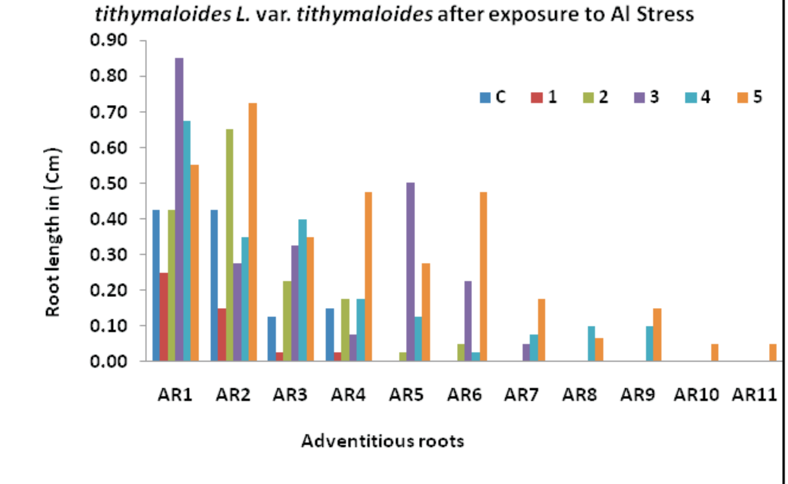
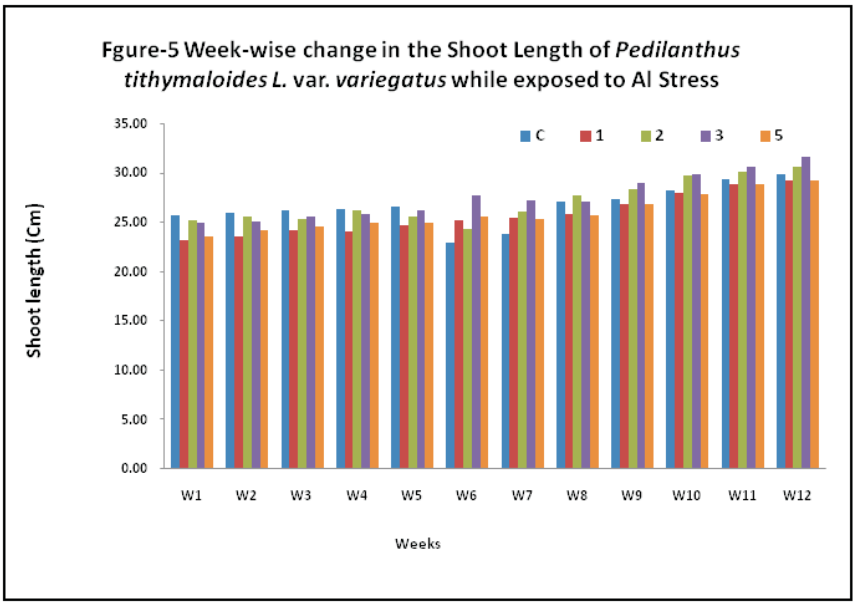


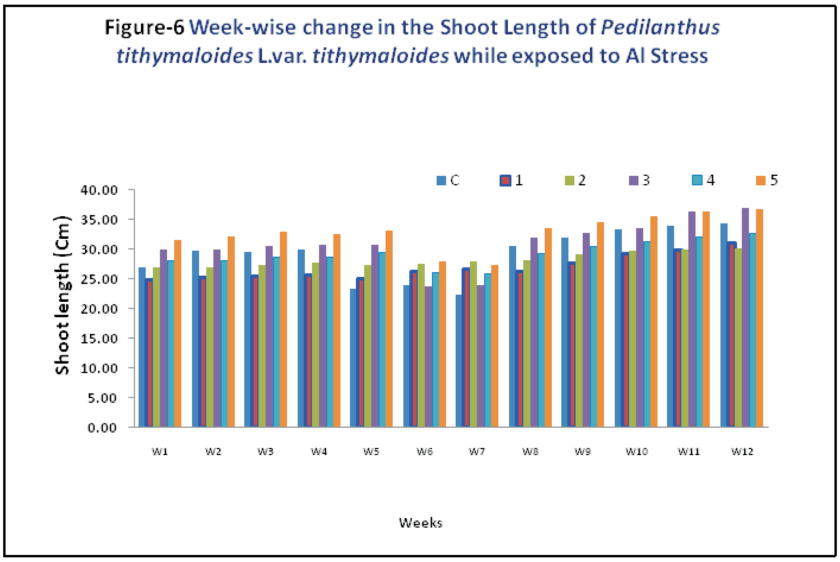
Figure-4 Adventitious Root Length of *Pedilanthus tithymaloides L.* var. *tithymaloides* after exposure to Al Stress



4. EFFECT OF Al ON SHOOT LENGTH

In case of *Pedilanthus* var A, Shoot length increased from 1st to 3rd concentration but decreased in 4th and again increased in 5th concentration in comparison to control, as shown in Figure-5. In case of *Pedilanthus* var B, same trend was observed with respect to shoot length (Figure-6).





DISCUSSION

It is well known that some plant species can accumulate high concentrations of Al without showing symptoms of Al toxicity (Jian Feng Ma *et al*, 2001). This Al resistance depends on the ability of the plant to tolerate Al in symplast or to exclude it to soil (Taylor, 1991). In the present study two varieties of *Pedilanthus* viz., *Pedilanthus tithymaloides* var. variegatus and *P. tithymaloides* var. *tithymaloides* were analysed for their ability to accumulate and resist Al.

In both the varieties of Pedilanthus the amount of Al absorbed increased from 1st to 2nd concentration and then decreased at 3rd concentration followed by an increase from3rd to 5th concentration when compared to the control plants. The decrease at 3rd concentration could possibly indicate the threshold of plant species for Al toxicity. Increased absorption after 3rd indicates its adoptability beyond 300ppm. The accumulation levels observed in both the plants indicate that they are hyper accumulators of Al. The ANOVA data indicated that both the varieties are equally effective in accumulating Al.

The reasons for the tolerance of Al toxicity by plants are many; for example, organic acids play a central role in Al tolerance mechanisms. Some plants detoxify Al in the rhizosphere by releasing organic acids that chelate Al. In at least two species, wheat and maize, the transport of organic acid anions out of the root cells is mediated by Al-activated anion channels in the plasma membrane. Other plants, accumulate Al in their leaves, detoxify Al internally by forming complexes with organic acids.

Another set of mechanisms are; Malate which is released from the roots of Al-tolerant cultivars of wheat (Delhaize *et al*., 1993); citrate from Al-tolerant cultivars of snapbean (Miyasaka *et al*., 1991), maize (Pellet, 1995), Cassia tora (Ma *et al*., 1997) and soybean (Yang *et al*., 2001); and oxalate from buckwheat (Ma *et al*., 1997) and taro (Ma *et al.*, 1998).

There was a significant decrease in soil Al content of all the treated groups after phytoremediation. This can be naturally expected because Al accumulation in plant increased. Therefore, we can emphasize that both the varieties are capable of absorbing Al from soil and accumulate in them.

Regarding root length, although there was a decrease in the length of adventitious roots from 1st to 5th concentration when compared to control plants, the numbers of roots were found to increase in treated plants. Maximum numbers of roots 8 and 11 were observed at 3^{rd} concentration for variety A and variety B respectively. Under Al toxicity inhibition of root is a visible symptom. In other words, root stunting is a consequence of Al-induced inhibition of root elongation. Roots are usually stubby, brittle. Root tips and lateral roots become thick and may turn brown (Mossor-Pietraszewska *et al.*, 1997). Such roots are inefficient in absorbing both nutrients and water. Young seedlings are more susceptible than older plants. Al apparently does not interfere with seed germination, but does impair the growth of new roots and seedling establishment (Nosko *et al*., 1988). But these symptoms were not found in the present study.

The most common responses of shoots to Al toxicity include: cellular and ultrastructural changes in leaves, increased rates of diffusion resistance, reduction of stomatal aperture, decreased photosynthetic activity leading to chlorosis and necrosis of leaves, total decrease in leaf number and size, and a decrease in shoot bio-mass or length (Thornton *et al*., 1986). Both the varieties of Pedilanthus exhibited increased shoot length from 1st to 3rd concentration, decrease at 4th and again increase at 5^{th} concentration when compared to control. Also no other aforesaid symptoms were observed. This trend clearly indicates Al tolerance in both the varieties.

CONCLUSION

Aluminium toxicity is an important growth-limiting factor for many crop plants. Toxicity in such plants is often clearly identifiable through morphological and physiological symptoms finally affecting productivity. Our results had demonstrated that phytoremediation of Al with either of the varieties of *Pedilanthus* can restore fertility of soils and reduces the effect of Al toxicity on productivity of crop plants

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