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Aluminium toxicity on cowpea genotypes and its effect on plant and soil characteristics

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ABSTRACT

In order to observe the effect of aluminium toxicity on plant and soil parameters investigation was carried out on twenty cowpea genotypes grown in pots with four aluminium levels *i.e*. 0, 20, 40, 60 ppm with three replications following factorial complete randomized design. After five weeks of growth, individual, main effect and their interaction were studied for uptake of Aluminium and Manganese by root and shoot, post-cropping parameters of soil (pH, available P, extractable Al and extractable Mn) were observed. Genotypes of cowpea and aluminium treatments exhibited significant differences for all characters. However, interaction effect was found significant for all studied character except manganese content in soil. The genotypes $G_{2,}$ $G_{3,}$ G_5 and G_{15} were found superior for studied character.

Key words: Acidic soil, Aluminium tolerance, Aluminium toxicity, $AlCl_3$ levels, Cowpea, Extractable aluminium, Screening method.

INTRODUCTION

In India, 49 million hectare area is affected by soil acidity and 25 million hectares has pH below 5.5 (Raju and Singh, 2008). So, there is increasing interest in the inclusion of grain legumes in improved cropping systems followed in the acid soils. The successful inclusion of grain legumes will depend on the mitigation of the Al toxicity toxicity (Kolawole *et al*., 2000). One of the approaches to resolve this problem is the selection of species or varieties with genetic potential for tolerate to the Al stress associated with acid soils (Foy, 1988). Significant potential tolerance to soil acidity exists within the cowpea species and they have high yield potential even in circumstances where lime is not available (Edwards *et al*., 1981). Cowpea is mainly grown in tropical and sub-tropical regions of the world for vegetable and seed purpose and to a lesser extent as a fodder crop. It is an essential component of cropping systems in the Arid and Sub arid regions of the tropics covering parts of Asia and Oceania, the Middle East, Southern Europe, Africa, Southern USA, and Central and South America (Singh *et al*., 2002). A major constraint to production of the crop is Aluminium (Al) toxicity particularly in many humid tropical regions (Minella and Sorellis, 1992). To enhance the cultivation of cowpea in acid soil regions, research is needed to test existing germplasm for Al tolerance and select suitable varieties. Keeping this view in mind, present experiment was executed to study the effect of aluminium toxicity on cowpea genotypes and also on uptake of phosphorus, aluminium and manganese in root and shoot of cowpea genotypes and post-cropping parameters of experimental soil (pH, available P, extractable Al and extractable Mn).

MATERIALS AND METHODS

The present investigation was carried out during *Kharif*, 2013 at Vegetable Research Farm, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. The experiment was laid out in complete randomized design (CBD) in factorial concept. The experimental material for the present study was comprised of 20 genotypes of cowpea [*Vigna unguiculata* (L.) Walp.]. The treatments included four levels of Aluminium *i.e*. A_0 (0 ppm), A_{20} (20 ppm), A_{40} (40 ppm) and A_{60} (60 ppm). Seeds of twenty cowpea genotypes were collected from IIVR, Varanasi (UP). The genotypes include G1 (Kashi Unnati), G2 (Kashi Shyamal), G3 (Kashi Gauri), G4 (Kashi Kanchan), G5 (Kashi Nidhi), G6 (IC-202711), G7 (IC-202786), G8 (IC-249588), G9 (IC-201098), G10 (IC-33922), G11 (IC-202776), G12 (IC-201081), G13 (IC-559386), G14 (IC-559397), G15 (IC-259063), G16 (EC-9738), G17 (EC-9736), G18 (EC-19736), G19 (EC-97306) and G20 (EC-37587). Each genotype was treated with all four levels of aluminium. The experimental soil used for this study was collected from the Vegetable research farm, College of Horticulture and Forestry, Pasighat, Arunachal Pradesh. Plastic pots were filled with experimental soil of 15 Kg and mixed with 0 g, 2.6828 g, 5.3656 g and 8.0484 g of Aluminium chloride hexahydrate ($AlCl_3.6H_2O$) for A_0 (0 ppm), A_{20} (20 ppm), A_{40} (40 ppm) and A_{60} (60 ppm), respectively. Pots were kept in low cost polyhouse. Five pre-

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germinated seeds of each genotype were sown in each pot. After one week, plants were thinned and maintained @ three plants per pot. After two and six weeks of seed sowing, an insecticide spray was given to control incidence of pests.

For estimation of P, Al and Mn by plant in root and shoot samples were collected after five week of growth in a properly labelled polythene bags and brought to laboratory within 24 hours. The samples were dried, powdered and finally used for nutrient analysis.

Plant sample preparation: Fresh root and shoots were decontaminated from dust and others by washing them in a liquid detergent solution having concentration of 2ml/liter followed by washing them in N/10 HCl solution. After washing them in acid solution, the leaves were rinsed with distilled water 2 to 3 times. The extra moisture was wiped out and the samples were placed in paper bag and dried in an oven at 70-^{0}C with proper labels. The plant samples were dried for 24 hours to 36 hours. After drying, the leaves were milled and sieved through 1 mm sieve. The ground samples were stored in air tight plastic vials with clear labels.

Digestion of plant samples: The triacid digestion was used for the determination of root and shoot P, Al and Mn. In this digestion 1g of ground plant material was taken in 100 ml volumetric flasks. To this, 20 ml of triacid mixture (9:4:1 mixture of HNO_3:$HClO_4$:H_2SO_4) was added and the contents of the flasks were mixed by swirling. These flasks were placed in low heat hot plate in a digestion chamber. Then, the flasks were heated at higher temperature until the production of red NO_2 fumes ceases. The contents were further evaporated until the volume was reduced to about 4 to 6 ml. Completion of digestion process was confirmed when the liquid became colourless.

After cooling the flasks, 20 ml of distilled water was added to each flask. The solution was filtered through Whatman No. 1 filter paper. Volume was made upto 100 ml with distilled water in a 100 ml volumetric flask. Available phosphorus in the soil was determined as per standard procedure described by Bray and Kurtz (1945) while available Mn and Al in soil as per method outlined by Lindsay and Norvell (1978).

RESULTS AND DISCUSSION

The basic physical, physico-chemical characteristics and fertility status of the soil used as an experimental material are presented in Table 1. Available N, P_2O_5 and K_2O content in the soil used were 344.96 kg/ha, 16.8kg/ha, 100.8kg/ha, respectively. Extractable Al and Mn in the soil were 92.42 mg/kg and 24.87 mg/kg, respectively. Uptake of phosphorus, aluminium and manganese by plant in root and shoot was found significantly different for different genotypes, aluminium treatment (different level of Al) and their interaction effect. Table 2 and 3 showed that phosphorus content both in root and shoot was found to be lesser at all levels of aluminium than control.

However, genotype G_3 had highest P content in root (0.142 %) and G_{17} in shoot (0.101%) (Table 2).

Decrease of phosphorus content in different plant species due to excess aluminium was also reported by Jemo *et al*. (2007). The results obtained are in conformity with those of Kolawole *et al*. (2000) who observed similar reduction in nutrient acquisition by Al treatment in sorghum and cowpea genotypes. Short and long term exposure of plant roots to toxic concentrations of Al lead to root-growth inhibition (Kochian, 1995) thus impairing the acquisition of soil P (Foy, 1984). Findings of these workers highlights that, Al binds to the sites of adsorption on cell wall root tip. The amorphous form of Al hydroxides precipitates phosphate in solution. For this reason, phosphorus deficiency is one of the principal factors which limit the vegetable production in the presence of Al (Ward *et al*., 2011). Further, this immobilization of phosphorus in or upon the root may subsequently induce deficiency of phosphorus (Foy *et al*., 1978).

Aluminium content was found to be lowest in genotype G_9 (1.226 ppm) followed by G_{16} (1.715 ppm), G_8 (1.789 ppm) in root and it was observed to be lowest in G_{20} (9.311ppm) followed by G_8 (9.389 ppm) and G_3 (9.548 ppm) in shoot. From Table 2, it is evident that cowpea genotypes were found more efficient in excluding aluminium absorption by certain mechanism. Al content in roots was lowest at 0 ppm and gradually increased at higher concentration. It may probably due to increased aluminium concentration in soil at higher levels of Al (Table 3). G_1A_0 (0.131) in root (Fig 1) and $G_{20}A_0$ (8.971) in shoot absorbed lowest amount of aluminium among interaction effects. Observations are in conformity with the findings of Rangel *et al.* (2007).

Uptake of manganese in root and shoot was found highest in genotype G_5 and G_{15} (Table 2). At higher concentration of aluminium, root and shoot showed higher manganese content than control (Table 3) which showed that

Table 1: Physico-chemical properties of experimental soil before cowpea seed sowing.

Properties	Value
pH (H_2O)	5.21
pH (KCl)	4.02
EC (H_2O)	44.7 µS/m
EC(KCl)	6.25 mS/m
Soil texture	Sandy loam
Sand	67.4%
Silt	12.94%
Clay	19.66%
Organic carbon	0.463%
Available Nitrogen	344.96 kg/ha
Available phosphorus	16.8 kg/ha
Available Potassium	100.8 kg/ha
Extractable Al	92.42 mg/kg
Extractable Mn	24.87 mg/kg

Table 2: Response of cowpea genotypes for different aluminium levels on some plant parameters and soil nutrient content

Genotype	Phosphorus (%)		Aluminium (ppm)		Manganese (ppm)		pH of Soil	Available P_2O_5 (kg/ha)	Al in experimental soil	Mn in experimental soil
	Root	Shoot	Root	Shoot	Root	Shoot				
G1	0.121	0.097	2.41	10.11	5.97	6.03	4.53	27.29	96.74	22.70
G2	0.116	0.098	3.14	10.11	5.79	7.42	4.79	23.77	102.53	24.82
G3	0.142	0.083	3.07	9.55	6.86	5.97	4.70	28.99	95.14	22.07
G4	0.120	0.073	6.14	10.15	5.81	5.86	4.89	25.83	94.55	21.38
G5	0.114	0.083	3.82	9.85	5.58	5.40	4.93	30.55	97.44	18.79
G6	0.111	0.079	3.56	9.55	6.04	7.59	4.85	29.80	96.60	27.43
G7	0.112	0.086	6.74	10.50	6.09	6.79	4.93	26.93	89.02	23.29
G8	0.120	0.076	1.79	9.39	6.64	6.82	4.95	28.81	83.98	19.80
G9	0.122	0.079	1.23	9.76	6.83	7.91	5.16	25.55	82.43	20.07
G10	0.123	0.086	3.85	9.73	6.43	7.00	5.00	24.26	76.39	21.20
G11	0.119	0.090	5.74	10.52	6.16	6.70	4.61	33.21	63.80	21.09
G12	0.112	0.093	4.75	9.79	6.08	7.13	4.69	30.93	58.12	23.65
G13	0.112	0.092	7.96	9.92	6.05	5.92	4.88	31.22	61.80	22.72
G14	0.117	0.082	2.64	10.24	5.79	6.46	4.81	26.08	68.62	22.48
G15	0.124	0.091	2.63	9.74	5.53	5.86	4.54	34.74	73.03	23.08
G16	0.123	0.089	1.72	9.77	6.78	6.37	4.66	29.31	79.34	23.70
G17	0.123	0.101	7.84	10.01	5.71	6.59	4.75	34.76	86.61	20.92
G18	0.114	0.093	8.95	9.69	5.95	6.21	4.59	31.16	85.44	19.90
G19	0.124	0.097	2.41	11.48	6.59	6.03	4.61	27.96	79.22	20.26
G20	0.117	0.086	3.32	9.31	6.01	6.12	4.91	31.91	81.30	22.51
CD	0.002	0.002	0.05	0.07	0.07	0.14	0.05	0.94	0.89	0.80
SE (d)	0.001	0.001	0.03	0.03	0.03	0.07	0.03	0.48	0.45	0.41
SE (m)	0.001	0.001	0.02	0.02	0.02	0.05	0.02	0.34	0.32	0.29

Table 3: Influence of Aluminium levels across twenty cowpea genotypes on some plant and soil chemical properties.

Levels of Aluminium	Phosphorus (%)		Aluminium(ppm)		Manganese (ppm)		pH of Soil	Available Phosphorus	Al in soil	Mn in Soil
	Root	Shoot	Root	Shoot	Root	Shoot				
A_0	0.172	0.141	3.418	9.497	5.627	6.076	5.487	31.970	77.679	20.367
A_{20}	0.136	0.100	3.987	9.804	5.994	6.490	4.854	29.900	80.730	21.898
A_{40}	0.104	0.071	4.488	10.126	6.355	6.565	4.499	28.145	84.366	22.313
A_{60}	0.065	0.038	4.843	10.406	6.560	6.903	4.309	26.593	87.643	23.790
CD	0.001	0.001	0.024	0.029	0.030	0.062	0.023	0.422	0.396	0.359
SE (d)	0.001	0.001	0.012	0.015	0.015	0.031	0.011	0.213	0.200	0.182
SE (m)	0.000	0.000	0.008	0.010	0.011	0.022	0.008	0.151	0.142	0.129

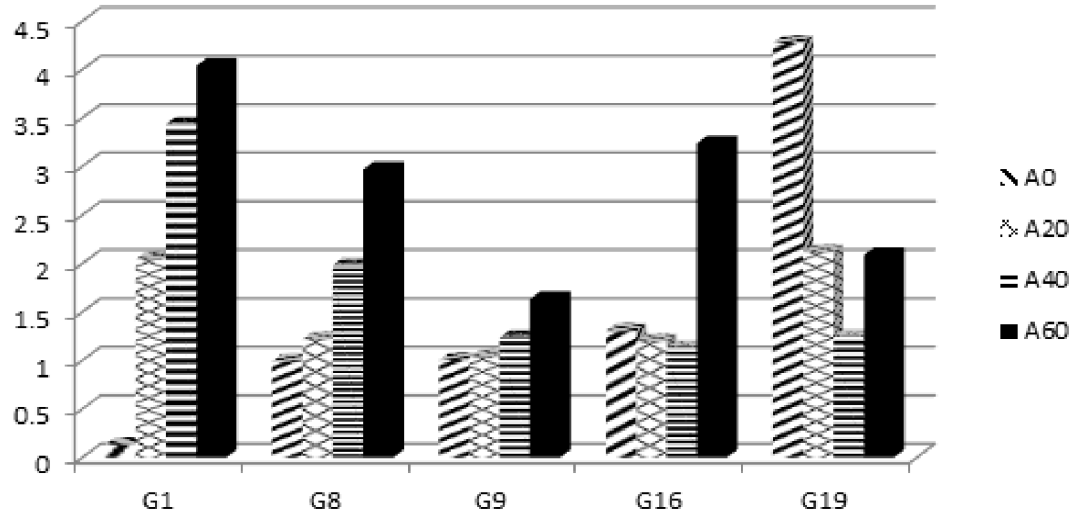

Fig 1: Root aluminium uptake of five genotypes of cowpea at four Al concentrations

higher accumulation of manganese in plant part, at higher levels of aluminium. This pattern of nutrient uptake of cowpea plant may be due to the toxicity of manganese in acid soil. In the interaction effect, minimum content of manganese was found in G_1 at 0 ppm for root and G_5 at 0 ppm for shoot. Similar findings were reported by Taylor *et al*. (1998) in cowpea. The pH of soil of different treatments was found significantly different for genotypes, aluminium levels and their interaction effect, after five week of crop stand. Different genotypes showed variable pH which ranges from 4.5 - 5.2 when compared to the initial pH of 5.21. Aluminium treatment had also significantly reduced the soil pH. The pH of soil was further reduced as the concentration of Aluminium increases in soil (Table 3 & Fig 2). Genotype G_9 at 0 ppm of aluminium concentration showed the highest pH of soil (6.1). The present findings had revealed that plants possess a well developed mechanism to ameliorate the toxic effects of aluminium. These findings are in agreement with those of Horst (1985). Phosphorus content in soil was also significantly different for genotypes, Aluminium treatment and their interaction effect. Phosphorus content in soil was found highest in G_{17} (34.8 %) followed by G_{15} (34.74%) (Table 2). Maximum concentration of phosphorus was found at 0 ppm and lowest at 60 ppm (Table 3). It showed that at higher concentration of Aluminium the phosphorus content of soil was reduced. Results also showed that phosphorus content of soil was decreased in all treatments which indicate the possibility of precipitation, immobilization and adsorption of P by soil colloidal particles after Aluminium addition (Ezeh *et al.*, 2007). Extractable aluminium and manganese was found significantly different for genotype and interaction effects. Aluminium addition significantly increased extractable aluminium content of soil but not extractable manganese in the soil significantly (Table 3). These findings were also supported by Ezeh *et al*. (2007). Though aluminium tolerance have always been associated with Mn tolerance either negatively (Foy *et al*., 1973) or positively (Macfie *et al*., 1989), co-occurrence of tolerance to both elements was reported by Macfie *et al*. (1989). Despite increase in aluminium and manganese in some genotypes over initial values, many genotypes managed to perform better. Zhang *et al*. (1999) reported such genotypic tolerance of plants to Al and Mn toxicity.

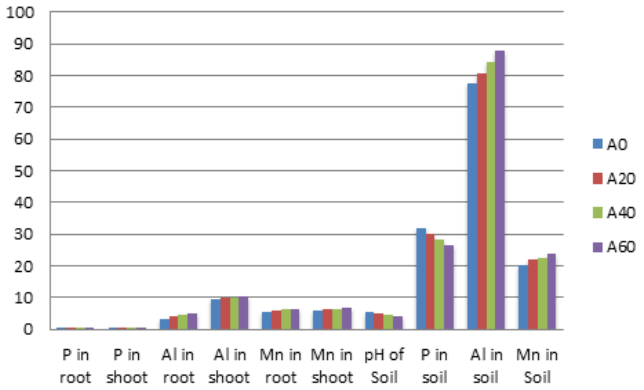

Fig 2: Influence of Aluminium levels across twenty cowpea genotypes on some plant and soil chemical properties.

Thus, from the findings of present study, it is concluded that genotypes/varieties Kashi Shyamal, Kashi Gauri, Kashi Nidhi and IC-33922 are having the potential to survive better in acid soils dominated with Al than others by some of their genetic mechanism or inherent mechanism. However, the present study had served only as the baseline information, which will form the basis for future line of research on the current topics of interest in NEH region.

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