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Effects of Cadmium on the growths and morphological characteristics in Cajanus (C_3) and Sorghum (C_4)

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Abstract:

Heavy metal (HM) toxicity is thought to be one of the major abiotic stresses leading to hazardous effects in plants. In spite of its potential physiological and economical significance, morphological alterations induced by heavy metals in plants have so far been grossly overlooked. The objective of this study was to find the effect of cadmium on germination and early seedling growth in the cajanus (C_3) and sorghum (C_4) plants treated with different concentrations (0, 50, 100, and 150 mM) of $CdCl_2$. Results linked to morphological changes that plants treated with cadmium, suffered reduction in germination percentage, root length, shoot length, fresh weight, and dry weight. The growth of cajanus and sorghum seedlings treated with 150 uM Cd was more inhibited than that of cajanus and sorghum seedlings treated with 100 mM Cd, 50mM and control and the fresh weights of roots and shoots were reduced by treated Cd than that of control plant. Cadmium stress inhibited the root elongation after growing in the presence of Cd.

Introduction:

Heavy metals are the natural components of the earth crust and are present in soil, water and living matter, but there levels are escalating due to unsustainable anthropogenic activities. Cadmium, one of the toxic heavy metals has no essential function in plants and thought to be a highly toxic heavy metal in the environment. Actually, Cd is a non-essential nutrient for plants, and excessive Cd has not only

significant adverse effects, but also endangers human health via food chain. However, heavy metal has an adverse impact on growth and development of the plants which showing some morphological and physiological characteristics of damages (Kasim & Wedad 2006). Particularly, amongst the heavy metal, Cd is caused increasing international concern due to its toxicity. It is generally considered to be much higher than those of other heavy metals and plants readily take it up. The impact of cadmium on various crop plants and their morphological, physiological and molecular responses during stress has been well elucidated by many authors, here in the study an attempt was made for comparative study between cajanus (C_3) and sorghum (C_4) on the on growth and morphological characters caused by Cd stress.

Pigeon pea (*Cajanus cajan* L.) is an important legume crop in the semiarid tropics. It has high commercial and nutritive value. It is an ideal source of protein. The symptoms of cadmium toxicity and seedling survival have close association with each other and determine the final plant stand. Despite scattered information existing (Meena & Laura 2014 and Aruna & Mohanty, 2013), the present study is carried out to explore the effect of cadmium on germination and early seedling growth of Pigeon- pea.

Sorghum bicolor L. is an important crop due to its wide use as food, feed and energy crop. In addition, sorghum appears promising as a cereal crop, which has some non- food uses, particularly for bioethanol production (Xin Z, et al. 2008). The research of the poisoning effect of the heavy metal, Cd on plant mainly focuses on food crops such as rice, wheat and maize, but less on sorghum plants, which is often as animal feed sources.

Materials and Methods

Seeds of *Cajanus* and Sorghum were surface sterilized using 0.1% $HgCl_2$ followed by 70% ethanol then rinsed with sterile water to remove the remnants of adsorbed sterilants. The seeds were then transferred to the petri-dishes with sterile filter papers for germination and subjected to varying concentrations of cadmium solutions (50, 100, and 150 µmol) made using anhydrous $CdCl_2$. Distilled water was used in place of cadmium solution to maintain the control. The experiment was conducted with three replications of 10 seeds each, placed in growth chambers and grown in controlled environment at 25°C with light intensity 8000 lux and 70% humidity.

For growth analysis, samples were collected on 7th day after sowing and growth parameters like % seed germination, fresh and dry weights were measured. Emergence of the radicle was taken as an index for the purpose of identifying seed germination. Fresh weight of the seedlings was recorded to the nearest mg using an electronic balance. The seedlings were oven dried at 800C in a hot air oven to a constant dry weight and the data was recorded to the nearest mg using sensitive electronic balance. All the observations are means of three replications.

Results:

Knowledge of crop plant biology, particularly germination requirements, is important while developing effective plant management programs. The response pattern of germination are regarded as a key feature because it is a sensitive stage in the life cycle of plants as the seed makes the transition from a metabolically quiescent to an active and growing entity.

Germination percentage: The process of germination involves: imbibitions of water, activation of enzymes, hydrolysis of stored material, initiation of growth, breakage of seed coat and emergence of the seedling. The experiment to study the germination ability of ***Cajanus cajan*** ***(C_3)*** and ***Sorghum bicolor*** ***(C_4)*** at different Cd concentration (C0, C1, C2, & C3, in ascending order) has revealed that, in both Cajanus cajan and sorghum bicolor the germination percentage decreased with increase in Cd conc. when compared to control i.e., C0, where as sorghum bicolor has shown better germination percentage than Cajanus cajan at C1, C2 and C3 conc. with 91, 79, and 55% respectively and Cajanus cajan has shown 87, 71 and 45% respectively. This phenomenon was statistically significant at $p \leq 0.05$.

Table 1: Germination percentage

Plant	Germination percentage after 4 days (20 seeds per treatment)			
	C_0	C_1	C_2	C_3
Cajanus	100±0.0*	87±1.24#	71±0.91	48±1.20
Sorghum	100±0.0*	91±1.09	79±1.21	55±2.06

The values followed by * in the row are statistically significant at $p \leq 0.05$.
The values followed by # in the column are statistically significant at $p \leq 0.05$.

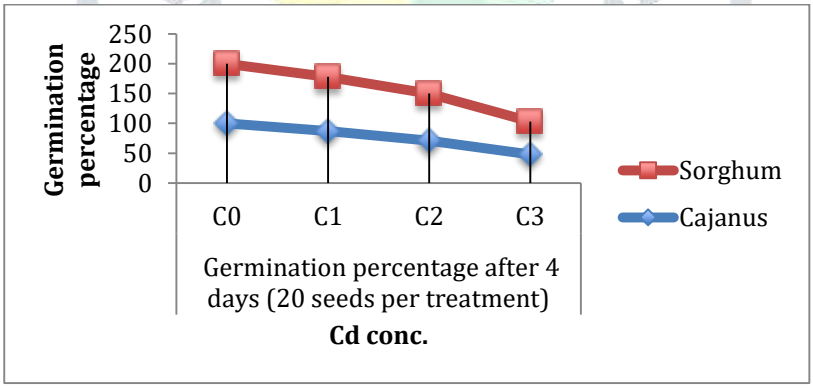

Fig no. 1: Line Graph showing germination percentage of both Cajanus cajan and sorghum.

Dry weight and fresh weight of C_3 ***(Cajanus cajan) and C_4 (sorghum bicolor):*** Cd stress adversely affects important physiological and biochemical processes in plants ultimately leading to reduction in plant growth and development (Munns, 2002; Tester & Davenport, 2003). These adverse effects are induced by either restricting the flow of water and nutrients into the plants or by direct injury to plant cells through the accumulation of toxic ions (Apse and Blumwald, 2002). This can be characterized by reduction in generation of new leaves, leaf expansion, development of lateral buds leading to fewer

braches or lateral shoots formation, reduction in photosynthesis in plants (Munns & Tester, 2008) leading to lesser biomass. Here in the study, series of experiments were conducted to make a comparative study on fresh weight and dry weight of C_3 (***Cajanus cajan)*** and C_4 (***Sorghum bicolor***).

Fresh weight

Table 2.a: Fresh weight of ***Cajanus cajan.***

Plant part	Cajanus cajan (Fresh weight) 7 days after germination. Gm/plant			
	C_0	C_1	C_2	C_3
Shoot	1.71±0.11*	1.44±0.24	1.32±0.10	1.09±0.20
Root	0.15±0.05	0.17±0.09	0.18±0.20*	0.17±0.06

The values followed by * in the row are statistically significant at p≤ 0.05.

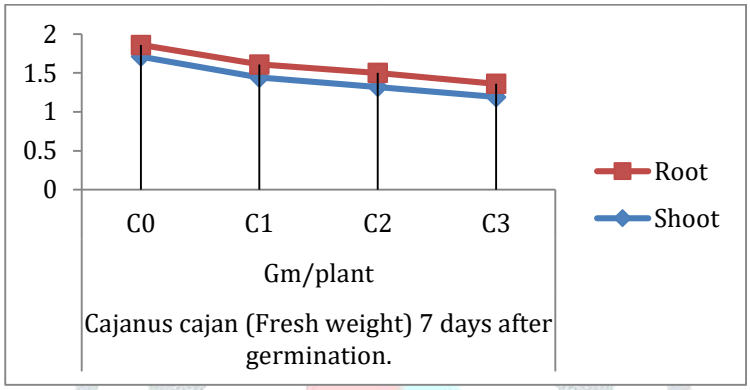

Fig no. 2.a: Line Graph showing germination percentage of both ***Cajanus cajan*** and ***Sorghum bicolor***.

Table 2.b: Fresh weight of ***Sorghum bicolor.***

Plant part	Sorghum bicolor (Fresh weight) 7 days after germination. Gm/plant			
	C_0	C_1	C_2	C_3
Shoot	2.01±0.09*	1.77±0.19	1.42±0.09	1.19±0.13
Root	0.16±0.002	0.17±0.009	0.17±0.001*	0.16±0.006

The values followed by * in the row are statistically significant at p≤ 0.05.

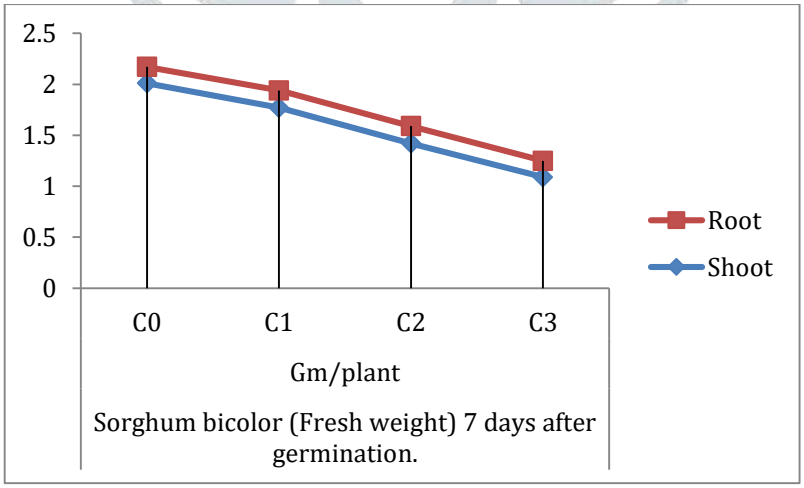

Fig no. 2.b: Line Graph showing germination percentage of both ***Cajanus cajan*** and ***Sorghum bicolor***.

The experiment on fresh weight of shoots in Cajanus cajan and Sorghum bicolor resulted in decrease in dry weight with increase in Cd conc. (C0, C1, C2, & C3) with respect to control (C0) with 1.71, 1.44, 1.32 & 1.09 respectively in Cajanus and 2.01,177, 1.42 and 1.19 respectively in Sorghum

(Table 2.a & 2.b and Fig 2.a & 2.b). But within the shoots of Cajanus and Sorghum, the fresh weight in Cajanus is lesser than Sorghum at all Cd concentrations. Contradicting to the above, the fresh weight of roots in both Cajanus and Sorghum increased slightly with increase in Cd conc. in comparison to control C0. But the increase in fresh weight is up to C2 conc. only, there after the fresh weight decreased slightly at C3 conc. in both Cajanus and Sorghum. These entire phenomenons are statistically significant at $p \leq 0.05$.

Dry weight

Table 3.a: Dry weight ***Cajanus cajan***

Plant part	Cajanus cajan (Dry weight) 7 days after germination. Gm/plant			
	C_0	C_1	C_2	C_3
Shoot	0.40±0.02*	0.37±0.04	0.30±0.01	0.28±0.09
Root	0.06±0.002*	0.05±0.009	0.05±0.004	0.04±0.006

The values followed by * in the row are statistically significant at p≤ 0.05.

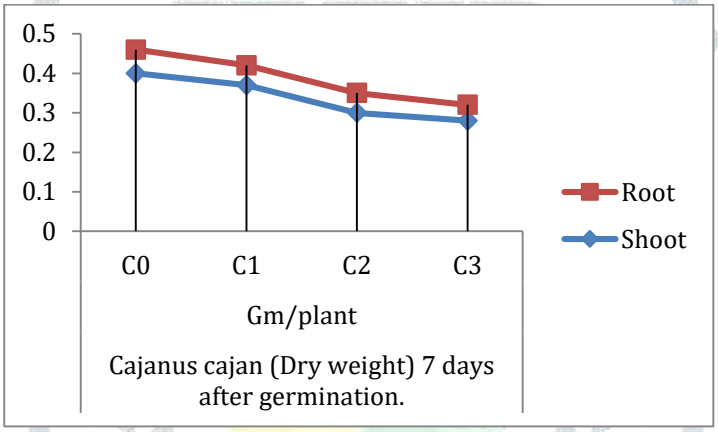

Fig no. 3.a: Line Graph showing germination percentage of both cajanus and sorghum.

Table 3.b: Dry weight of sorghum

Plant part	Sorghum bicolor (Dry weight) 7 days after germination. Gm/plant			
	C_0	C_1	C_2	C_3
Shoot	0.42±0.03*	0.38±0.01	0.32±0.07	0.30±0.05
Root	0.015±0.001	0.021±0.007	0.025±0.004	0.027±0.005*

The values followed by * in the row are statistically significant at p≤ 0.05.

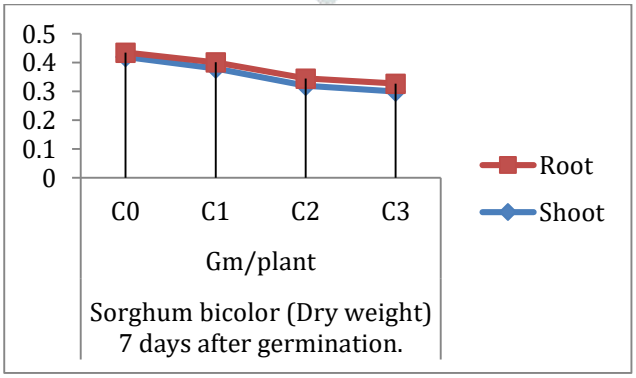

Fig no. 1.d: Line Graph showing germination percentage of both cajanus and sorghum.

The experiment on dry weight of shoots in Cajanus cajan and sorghum bicolor resulted in decrease in dry weight with increase in Cd conc. (C0, C1, C2, and C3) with respect to control (C0) with 0.40, 0.37,

0.30 & 0.28 respectively in cajanus and 0.42, 0.38, 0.32 & 0.30 respectively in sorghum. But within the shoots of cajanus and sorghum, the dry weight in cajanus is lesser than sorghum at all Cd concentrations. In roots, contradicting to the above, the dry weight of roots in sorghum increased slightly with increase in Cd conc. in comparison to control C0. Where as in cajanus the dry weight of roots decreased with increase in Cd conc. the results were tabulated in (Table 3.a & 3.b and Fig 3.a & 3.b). These entire phenomenon are statistically significant at $p \leq 0.05$.

From the above all experiments it is very clearly evident that sorghum C_4 plant has better adaptation to Cd stress conditions than cajanus a C_3 plant in terms of germination percentage, fresh weight and dry weight.

Discussion:

This study showed increasing levels of cadmium exposure is detrimental to *Cajanus* and sorghum, which is evident from gradual decrease in germination percentage and early seedling growth. Concentration dependent decrease in germination percentage might be attributed to physiological disturbance in mobilization of the reserve food materials (Andrade and da Silveira 2008). Reduction in root and shoot length may be due to alteration in water relations, nutrient uptake (Barcelo and Poschenrieder 1990). Similar observations of reduction in root length, shoot length, fresh weight and dry weight with Cdcl2 treatment to *Cajanus* and *sorghum* seeds were noticed (Aruna and Mohanty, 2013).

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