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Specific responses in carbohydrate metabolism of pigeonpea to heavy metal stress

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SUMMARY

Cultivar LRG30 and cv.T21 of pigeonpea seedlings grown in 0.5, 1.0 and 1.5mM concentrations of lead and cadmium showed specific responses in carbohydrate metabolism. An accumulation of soluble sugars, reducing sugars and non-reducing sugars were observed with increasing lead and cadmium concentrations. Further the reduction of starch content in seedling axes and its retention in cotyledons were observed in both the cultivars of pigeonpea in response to lead and cadmium.

Key words : Cadmium, Carbohydrate metabolism, Heavy metal stress, Lead, Pigeonpea

Plants cannot usually utilize all the carbon skeletons resulting from photosynthesis. Therefore, they store carbon skeletons as short or longer term reserve carbohydrates. Several pathways that link the generation, utilization and storage of various storage carbohydrates dominate plant intracellular metabolism.

Heavy metal stress represent the major limiting abiotic stress factors for agricultural productivity. Severe abiotic stresses cause detrimental changes in cellular compounds. Sugars can be regarded as one of the metabolites that can prevent these detrimental changes (Ravi valluru and Wim Van den End, 2008). Long-term stress conditions lead to higher soluble sugar concentrations and lower amounts of starch (Silva and Arrabaca, 2004). Both mono and disaccharides interact with lipid membranes and are effective against abiotic stresses (Ohtake *et al*., 2006). To improve our knowledge in specific responses of carbohydrates exposed to lead and cadmium, the present study was designed to assess in two cultivars of pigeonpea.

MATERIALS AND METHODS

The seeds of uniform size and free from infection were selected for the experiment. The seeds of pigeonpea cv. T21 and cv.LRG30 were surface sterilized by using 0.01M sodium hypochlorite for 2min, washed thoroughly with distilled water and were placed separately in trays lined with whatman No.1 filter papers containing 0, 0.5, 1.0 and 1.5mM of lead (lead acetate : $(CH_3\ COO)_2\ Pb.3H_2O$) and cadmium (cadmium chloride : $CdCl_2\ 2.5\ H_2O$). Seedlings raised in distilled water served as controls. The seeds were allowed to germinate at 30 ± 2^{0}C for 8 days under a photoperiod of 12hrs, and at 195m mol m^{-2} s^{-1} PPFD. Twenty five seeds were taken in each tray. Data represent means of three separate experiments and seedlings were collected for biochemical analysis.

Carbohydrate fractions:

Starch and total soluble sugars:

The starch and total soluble sugars were estimated according to the method of Clegg (1956). Soluble sugars were separated by alcohol extraction and the residue containing starch was brought into solution with perchloric acid.

Reducing sugars:

Total reducing sugars were estimated according to the phenol sulphuric acid method of Smyth and Dugger (1980).

Non reducing sugars:

The reducing sugar content substracted from the total soluble sugar content was considered as non reducing sugars.

RESULTS AND DISCUSSION

In the control seedlings, starch content of the seedling axes of two pigeonpea cultivars showed a continuous increase with an associated decrease in their cotyledons throughout the period of study. Though the seedling axes of treatments showed a continuous increase in starch content with age they always recorded lower values than corresponding controls. The cotyledons of lead and

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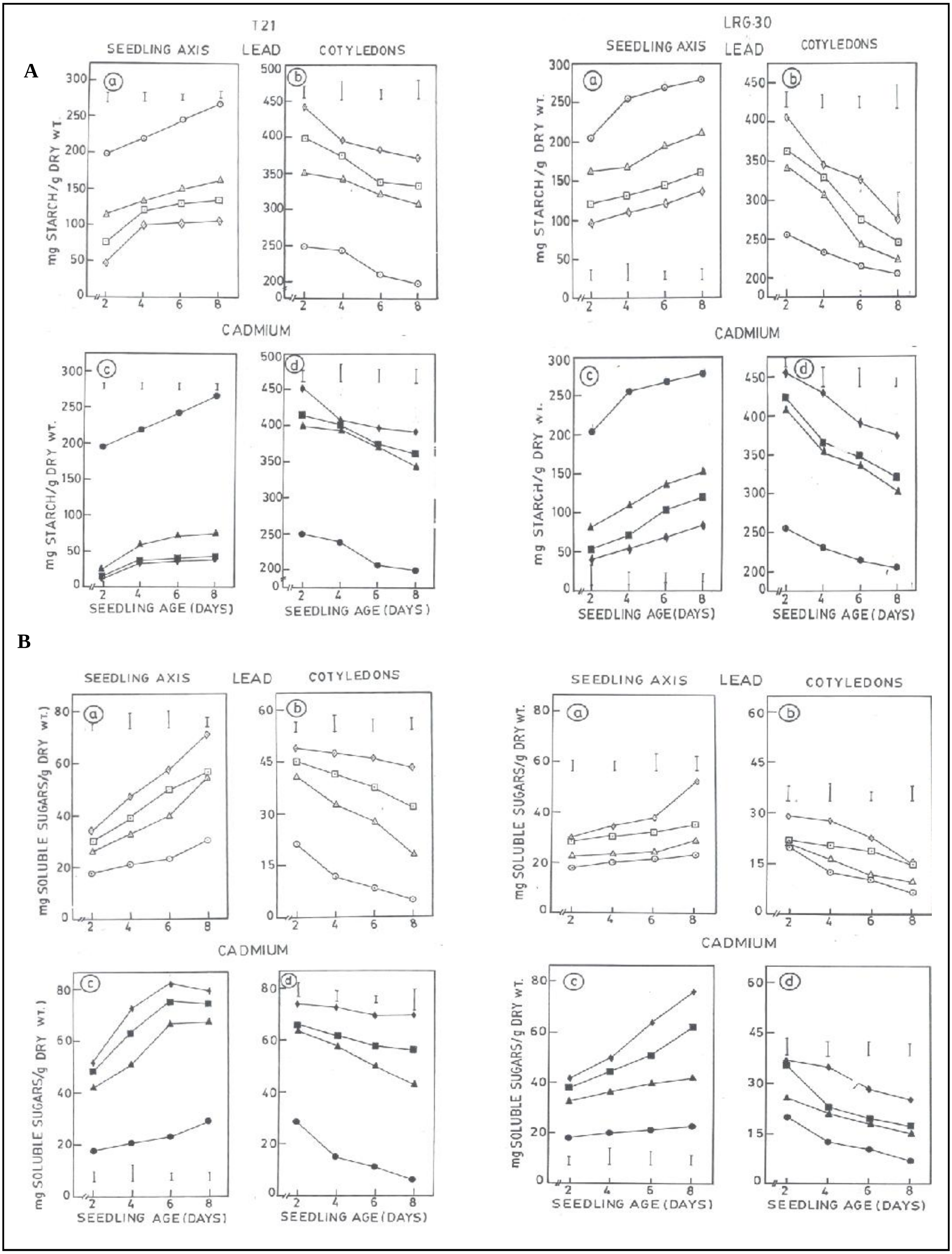
A
T21
LRG-30
SEEDLING AXIS
LEAD
COTYLEDONS
CADMIUM
mg STARCH/g DRY WT.
SEEDLING AGE (DAYS)
B
mg SOLUBLE SUGARS/g DRY WT.

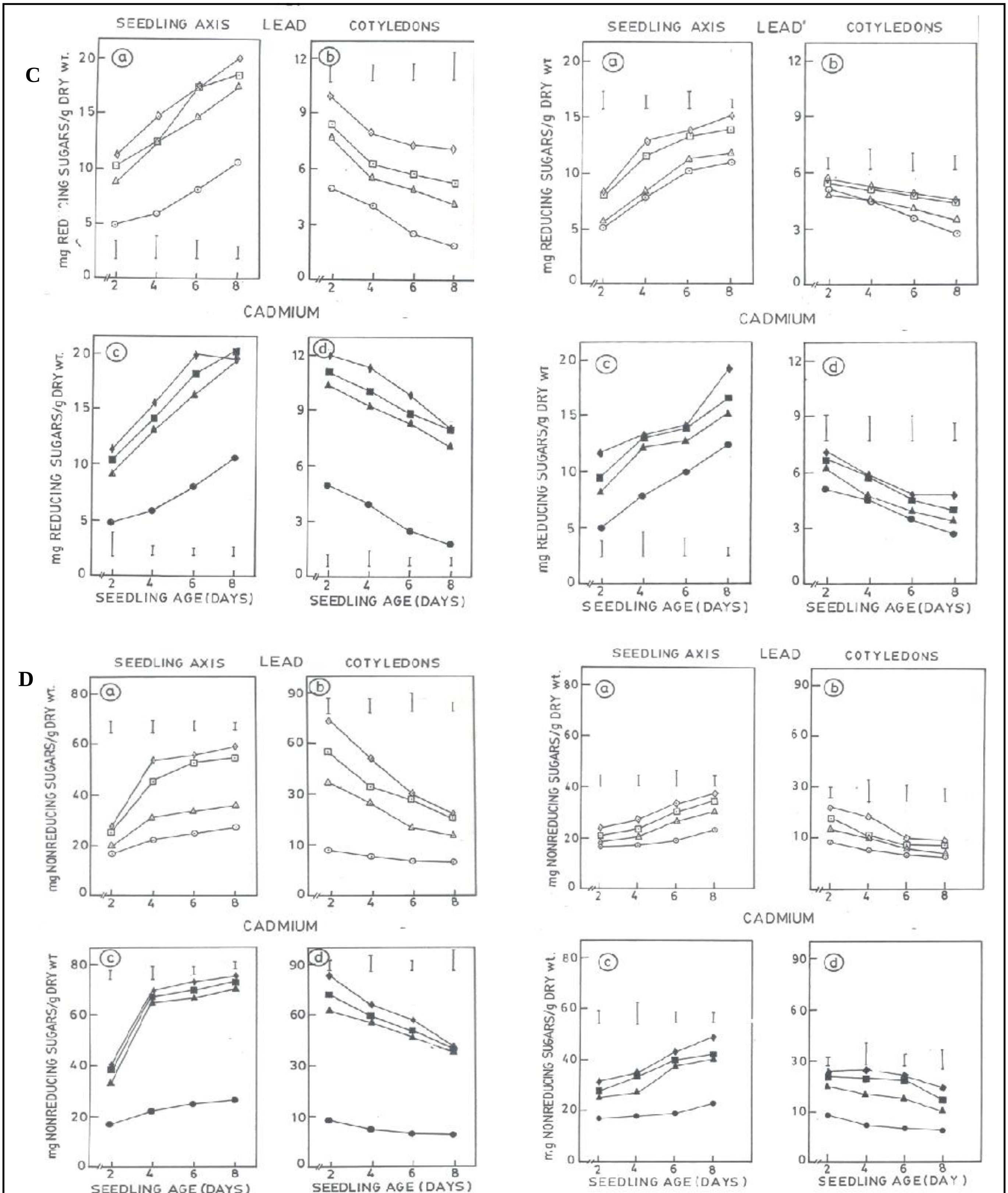

Fig. 1 and 2 : A) Starch B) Total soluble sugars C) Reducing sugars D) Non reducing sugars content of seedlings of pigeonpea, cv.T21 and cv.LRG30 in response to lead and cadmium stresses (Vertical lines represent S.E.).

Seedling axis	**: a and c**	**Cotyledons**	**: b and d**	**Lead**	**: a and b**
Control :	**O - O; 0.5: mM Δ- Δ ; 1.0: mM ☐-- ☐ ; 1.5: mM ◇-◇**			**Cadmium**	**: c and d**
Control :	**õ-õ ; 0.5: mM ▲-▲; 1.0: mM ■-■ ; 1.5: mM ♦–♦**				

cadmium treated seedlings retained more starch with increasing concentrations of lead and cadmium when compared to their controls.

Seed germination is characterized by mobilization of storage reserves in the reserve tissue, their hydrolysis and their subsequent transfer and utilization by the growing embryonic axis (Bewley and Black, 1978). Lead and cadmium presumably interfered with the hydrolysis and translocation of soluble products of starch hydrolysis and therefore, affects the growth and development of seedling axes of treatments. Since the starch hydrolysis is affected by the lead and cadmium, the cotyledons retain more of starch in the cotyledons when compared to the respective cotyledons of the control seedlings.

Total soluble, reducing and non-reducing sugar levels in the control seedling axes of the two pigeonpea cultivars increased continuously with age. The cotyledons of the control seedlings showed a continuous decrease in their contents with increasing age. Although soluble reducing and non-reducing sugar levels of the treated seedlings showed a trend similar to controls, their values were higher in lead and cadmium treatments. It may be due to decreased conversion of soluble sugars to starch in the seedling axes as well as reduced translocation of soluble sugars from the cotyledons to the seedling axes in response to lead and cadmium treatments. This was reflected in our previous work in the decreased growth of seedling axes. It may also be due to the reduction of phloem loading by heavy metals thus inhibiting the export of soluble sugars from the cotyledons (Rauser and Samarakoon, 1980). Further in *Triticum aestivum* reducing sugars increased with chromium treatment and their accumulation is considered to be a heavy metal induced alteration of carbohydrate metabolism (Sharma *et al.*, 1995).

Among the cultivars T21 exhibit greater levels of soluble, reducing and non-reducing sugar levels than the cv.LRG30. More soluble, reducing and non-reducing sugars were observed under cadmium exposure than the lead exposure in both the cultivars of pigeonpea.

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