J Indian bot Soc Vol 77 (1998) 13-18

EFFECTS OF COBALT AND MERCURY ON SEEDLING VIGOUR IN *BRASSICA CAMPESTRIS* VAR. *TORIA* P.T. 303.

RAJESH KUMAR JAIN, HARENDRA KUMAR AND N.P. SAXENA
Botany Department, D.N. College, Meerut, India
(Accepted March, 1998)

The present communication embodies the results of observations relating to the effect two heavy metals, Co and Hg in the seedling vigour in *Brassica campestris* var *toria* PT 303. Significant differences have been observed for all the concentration of the two metals in seed germination and seedling establishment. The 10^{-5}M concentration of $HgCl_2$ has the highest toxic effect, whereas 10^{-5}M concentration of $CoCl_2$ shows retarded growth of seedling. Maximum tolerance has been observed at 26.69% of 10^{-5}M concentration of $CoCl_2$. At 10^{-5}M concentration of $HgCl_2$ they failed to establish. The seedling vigour shows positive and highly significant correlation coefficient with hypocotyl length, seedling length, radicle and hypocotyl elongation rates. The seedling length and absolute seedling water content show highest positive and direct effect on seedling vigour.

Key Words : Cobalt, Mercury, Variability, Tolerance-index, Correlatioon and Path Coefficient.

The pollution caused by heavy metals has created a significant ecological disbalance. Being non-degradable, they persist in the environment and accumulatte in different parts of living organisms. The accumulatioon of such components which do not constitute a part of any biogeochemical cycle is obviously harmful. It was with this intention that we undertook a study dealing with the effect of heavy metals particularly Co and Hg on various phases of seedling establishment of *Brassical campestris* var *toria* P.T. 303.

The information on the toxic effects and Co and Hg in *Brassica campestris* is very scanty. Sethi *et al.*, (1990); Gupta (1991) and Mahajan and Dug (1993) did contribute a little on germination and seedling establishment of this plant. The present investigation deals with the variability in toxicity level, degree of tolerance, correlation as also the direct and indirectt effect on various parameters of seedling vigour, the aspects heitherto unexamined by these workers.

MATERIALS AND METHODS

The certified seeds of *Brassica campestris* var. *toria* P.T. 303 were procured from National Seed Corporation, New Delhi. Germination of seeds has been carried in four replications according to international rules for seed testing 1976. The speed of germination index was calculated using modified formula of Cooper and Quales (1968). The seedling vigour and seed vigour index has been calculated by using the method of Abdulbaki and Anderson (1973). The tolerance index has been calculated with the help of Wilkins (1957) formulae. The speed of organ elongation (i.e., radicle and hypocotyl), absolute seedling water content and specific seedling water content have been determined in the following manner.

(A) Speed of Elongation $= \left[\frac{\text{Mean length of the organ}}{\text{Days first count}} +\!+\!-\!-\!+\!+ \frac{\text{Mean increase in the length from previous count}}{\text{Days last count}} \right]$

(B) Absolute Seedling Water Content = Seedling Fresh Weight — Seedling Dry weight

(C) Specific Seedling Water Content $= \frac{\text{Absolute seedling water content}}{\text{Seedling Dry Weight}}$

10^{-5}, 10^{-6} and 10^{-7} molar concentration of $CoCl_2$ and $HgCl_2$ were prepared in tapwater. Seeds were soaked in these solutions for 24 hours alongwith the control (in tap water). The visual emergence of protrusion of radicles was taken as criteria for germination. The observations on germination were recorded upto 5th day after sowing and the length of radicle and hypocotyl was measured from 5th day of sowing to the 7th day. All experiments were conducted at room temperature. The data accumulated during the course of investigation has been statistically analysed.

RESULTS

Analysis of variance :The analysis of variance

Received October, 1997

Table 1: Analysis of variance among different concentration for 15 characters (mean square)

Source of variation	d.f.	Percentage germination	Germination rate index	Radicle length	Radicle elongation rate	Hypocotyl length	Hypocotyl elongation rate	Seedling length	Cotyledonary area	Seedling fresh weight	Seedling dry weight	Absolute seedling water content	Specific seedling water content	Seedling vigour	Seed vigour index	1000 seed weight
Replication	3	17.6562	6357.3333	0.01984	0.004979	0.01342	0.022321	0.061686	0.0002166	1.010416	0.047170	0.710937	1.152018	468.3333	249.75000	0.0022881
Treatment	7	1146.3036**	758090.29**	6.163521**	0.251269**	19.85994**	0.866505**	47.91735**	0.0241357**	1936.0737**	4.776328**	1750.7868**	198.4236**	465647.86	45375.643**	0.0017918
Error	21	7.540178	14518.85	0.0054481	0.0013363	0.0064057	0.026192	0.0183163	0.0009286	0.669642	0.020909	0.488467	1.21884	598.1428	168.65476	0.00164649

** Exceeds 1% level of significance.

Table 2: Estimation of variability for various seed germination characters in different concentrations

S. No.	Characters	Mean	S.E. of difference between means	Coefficient of variation (C.V.)	Genotypic co-efficient of variation (G.C.V.)	Phenotypic co-efficient of variation (P.C.V.)
1.	Percentage germination	73.7969	1.9416	3.7209	22.86	23.16
2.	Germination rate index	1681.6250	85.2022	7.1653	25.64	26.62
3.	Radicle length	2.3594	0.05219	3.1284	53.59	52.68
4.	Radicle elongation rate	0.4431	0.02584	8.2497	56.41	57.01
5.	Hypocotyl length	4.3134	0.05659	1.8555	51.65	51.68
6.	Hypocotyl elongation rate	0.8231	0.11432	19.6430	55.68	59.05
7.	Seedling length	6.6731	0.09569	2.0281	51.86	51.90
8.	Cotyledonary area	0.1762	0.006814	5.4675	43.99	44.33
9.	Seedling fresh weight	49.5062	0.57863	1.6530	44.43	44.46
10.	Seedling dry weight	2.4266	0.10224	5.9591	44.93	45.33
11.	Absolute seedling water content	47.1000	0.49420	1.4839	44.41	44.44
12.	Specific seedling water content	17.1734	0.78065	6.4286	40.89	41.39
13.	Seedling vigour	543.0844	17.2936	4.5033	62.78	62.95
14.	Seed Vigour index	194.1403	9.18299	6.6893	54.76	55.17

Table 3: Comparison of toxicity level of the different concentrations of both heavy metal and control one by C.D. values

Characters/ Treatments	Mean values													
	Percentage germination	Germination rate	Radicle length	Radicle elongation rate	Hypocotyl length	Hypocotyl elongation rate	Seedling length	Cotyledonary area	Seedling fresh weight	Seedling dry weight	Absolute seedling water content	Specific seedling water content	Seedling vigour	Seed vigour index
Unsoaked Control	91.25	2170.75	3.78	0.75	6.56	1.54	10.34	0.24	67.18	3.41	63.80	18.72	943.84	311.62
Soaked Control	95.00	2217.00	3.48	0.66	6.78	1.22	10.26	0.24	69.68	3.36	66.30	3.36	974.55	319.22
10^{-5} $CoCl_2$	58.75	1311.00	1.51	0.25	2.91	0.51	4.43	0.16	51.92	2.17	39.75	18.41	260.17	127.81
10^{-6} $CoCl_1$	71.12	1496.00	2.01	0.33	4.20	0.73	6.21	0.19	51.80	2.50	49.43	19.77	442.81	178.19
10^{-7} $CoCl_2$	84.88	1986.00	3.06	0.58	5.46	0.96	8.52	0.22	59.77	3.12	56.65	18.15	724.56	265.56
10^{-5} $HgCl_2$	45.62	1009.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10^{-6} $HgCl_2$	65.00	1433.00	1.98	0.37	3.37	0.67	5.35	0.16	49.12	2.24	46.90	21.07	347.18	145.28
10-7 HgCl2	78.75	1830.25	3.05	0.60	5.23	0.96	8.28	0.22	56.58	2.60	53.97	21.52	651.55	205.44
C.d. 5%	3.783	166.144	0.10177	0.05040	0.11035	0.22294	0.186609	0.013282	1.1283	0.19938	0.9636	1.5222	33.7226	17.90683
C.d. 1%	5.0052	219.821	0.13465	0.06666	0.146010	0.29496	0.24689	0.017574	1.4928	0.263801	1.2750	2.01408	44.6176	23.6921

for all the above characters was carried out for testing the significant difference among the control and the various concentrations of the two heavy metals. The mean square for all the characters are presented in Table-1.

The 'F'-test indicates significant differences in the three concentrations used i.e., 10^{-5}, 10^{-6} and 10^{-7} mole of both the heavy metals with respect to the control experiment. The value of standard error difference between means (S.E.D.M.), coefficient of variation (C.V.) genotypic coefficient of variation (G.C.V.) and phenotypic coefficient of variatioon (P.C.V.) are presented in Table-2.

Comparison of toxocity level : The comparision of toxicity level of different concentrations for both the heavy metals on the seedling establishment has been studied. This has been done with the help of 'critical difference' (C.D.) values, by comparing the difference at 5% and 1% level of significance. These results are given in Table-3. The characters show significant variation in different concentrations which indicates that these differences are not merely due to chance or fluctuation of sampling.

Tolerance index : The seed or the seedling can obtain the degree of tolerance to a certain limits, which can be shown by the extent of colonisation in metal contaminated environments. According to Dickinson *et al.*, 1991, there is a lack of knowledge with respect to the quantitative limits of tolerance. The actual dosage level at which a chemical became toxic and the point beyond which no further adaptation can be achieved by a species is variable. Wilkins, 1957, 1978 determined the relative tolerance by measuring different organs of seedlings in metal contained solution. The results of degree of tolerance for different seedling vigour have been tabulated in Table-4.

Correlation coefficient : The corelation studies are carried out to find out the suitability of varioous characters for indirect selection of one or more traits. They influence in correlated response for several other traits too. The results of correlation coefficient estimates from 15 characters at phenotypic level are presented in Table-5.

Path Coefficient : The correlation coefficient refers to the degree of association between two variables irrespective of their cause and effect relationship, and the results have been given in Table-6.

DISCUSSION

The present investigation embodies the resultts of observations of different concentrations of Cobalt and Mercury on certain seedling characteristics. The values of standard error difference between two means and coefficient of variation are low. Therefore, they show high variability and significant differences among various concentrations for both the heavy metals. These results further suggests that the seed germination and seedling establishment are significantly influenced by their environment *i.e.*, due to different concentrations of the heavy metals. The phenotypic responses for different concentrations of these metals are not the same for the different genotypes. This contention supports the work of Wilkins, 1978 as also of Coughtrey and Martin, 1979. They suggested that use of single metal and application of a single concentration in determining the heavy metal toxicity effect may not give a true picture with respect to the nature of variation. Accordingly, we used atleast three concentrations of two different heavy metals in determining their toxicity effect on certain characters.

Table 4: Response of seedlings establishment to heavy metals in the form of tolerance index (%)

Treatments/Characters	Tolerance Index					
	CoCl2			HgCl2		
	10^{-5} M	10^{-6} M	10^{-7} M	10^{-5} M	10^{-6} M	10^{-7} M
Percentage germination	61.84	74.86	89.34	48.02	68.42	82.89
Radicle length	43.39	57.75	87.93	0.00	56.89	87.64
Hypocotyl length	42.92	61.94	80.53	0.00	49.70	77.13
Seedling length	43.17	60.52	83.04	0.00	52.14	80.70
Cotyledonary area	66.66	79.16	91.66	0.00	66.66	79.16
Seedling vigour	26.69	45.43	74.34	0.00	38.39	66.85

The characters selected during the course of present study, have high phenotypic variance. It indicates that these characters are very sensitive to their modified environmental influence. A significant difference in seedling vigour between unsoaked and soaked control experiments has been also observed. The highest toxic effect has been found at 10^{-5} molar concentration of $HgCl_2$ for all the characters under study. There was a total inhibition of radicle and hypocotyl growth under this concentration. These results are thus in agreement with the those of Gupta, 1991 in bean and mustard.

The toxicity effect of 10^{-5} molar $CoCl_2$ concentration has been studied on seed germination and seedling vigour. It shows retarded growth of radicle, hypocotyl and cotyledonary area. While assessing the threshold value of toxic concentration of Co and Hg on the growth of 28 day old maize plant, Kamenova *et al*, 1983 reported retardation of growth at higher concentration of both heavy metals. Vergano and Hunter, 1952 reported production of adverse effects in many crop plant even in 0.1 ppm concentration of Co in solution culture. A similar observation was made by Austenfield, 1979 in beans and corns.

The seedling growth inhibition is similar to what was reported by Mukherji and Ganguly, 1974 in rice, Puerner and Siegel, 1972, in cucumber and Janardahan, 1989 in groundnut, sunflower and sesame. Siegel *et al.*, 1984 reported that elemental Hg and non-ionic Hg were the active toxicant.

During the course of present study it was observed that the 10^{-6} and 10^{-7} molar concentration of both the metals did not inhibit seedling establishment. However, in these concentrations, more depressant effect of Hg was observed in the establishment of seedling. These findings are in agreement with those of Xu *et al.*, 1993. They observed arrest of growth at 1 M.M. concentration in groundnut. Thus, Hg has been found to be more toxic than Co in seedling establishmentt. A similar result has been reported by Hara and Sonoda, 1979; Gupta, 1991, in *Brassica oleracea.*

The seedling vigour showed the maximum tolerance at 26.69% at 10^{-5}M $CoCl_2$, whereas they failed to establish 10^{-5}M $HgCl_2$. The hypocotyl elongation showed less tolerance in comparison to radicle. To sum up, the tolerance limit sequence stand as $10^{-5}<10^{-6}<10^{-7}$ for the both the metals. Our findings

Table 5: Correlation coefficient estimates among 15 characters at phenotypic level

Characters	Germination rate index	Radicle length	Radicle elongation rate	Hypocotyl length	Hypocotyl elongation rate	Seedling length	Cotyledonary area	Seedling fresh weight	Seedling dry weight	Absolute seedling water content	Specific seedling water content	Seedling vigour	Vigour index	1000 seed weight
Percentage germination	0.784**	0.304	0.306	0.060	0.014	0.170	-0.363	-0.290	-0.265	-0.291	-0.078	0.547	0.118	-0.494
Germination index		0.261	0.261	0.052	-0.001	0.147	-00.359	-0.340	-0.330	-3.340	-0.037	0.519	0.048	-0.511
Radicle length			0.771**	0.222	0.365	0.577**	-0.089	0.621	0.621*	0.620*	0.178	0.638*	0.759**	-0.007
Radicle elongation rate				0.260	0.388**	0.597	-0.118	0.598*	0.603	0.596*	0.156	0.650 **	0.737**	0.027
Hypocotyl length					0.764**	0.724**	0.524*	0.477	0.438	0.478	0.284	0.790	0. 790	0.357
Hypocotyl elongation rate					0.466	0.576 *	0.580*	0.530*	0.581	0.336	-0.719*	0.566*	0.354	
Seedling lenght							0.405	0.643**	0.643*	0.308	0.811**	0.711**	0.296	
Cotyledonary area								0.436	0.282	0.442	0.551*	0.163	0.151	0.623*
Seedling fresh weight									0.751**	0.806**	0.357	0.429	0.763**	0.685**
Seedling dry weight										0.746**	0.057	0.419	0.724	0.561
Absolute seedling water content											0.370	0.428	0.758**	0.689**
Specific seedling water content												0.209	0.028	0.485
Seedling vigour													0.660**	0.02
Seed vigour index														0.380

* Significant at 5% level.
** Significant at 1% level.

Table 6: Path coefficient analysis showing the direct and indirect effect of various characters on seedling vigour at phenotypic level.

Characters	Correlation with seedling vigour	Direct effect	Indirect Effect													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percenttage germination	0.547	0.350	-	0.091	-0.058	-0.009	-0.032	0.001	0.238	0.014	0.396	-0.013	-0.294	-0.009	0.036	0.019
Germinate rate index	0.519	-0.090	0.341	-	-0.050	-0.008	-0.028	0.000	0.205	0.014	0.464	-0.016	-0.344	-0.004	0.015	0.020
Radicl lenght	0.638	-0.182	0.106	-0.024	-	0.030	0.118	0.023	0.798	0.003	-0.847	0.030	0.627	0.020	0.230	0.000
Radicle elongation rate	0.650	-0.031	0.107	-0.024	-0.186	-	-0.139	0.024	0.836	0.004	-0.815	0.030	0.603	0.018	0.224	-0.001
Hypocotyl length	0.790	-0.533	0.021	-0.005	-0.043	-0.008	-	-0.060	1.294	-0.020	-0.651	0.021	0.484	0.032	0.150	-0.014
Hypocotyl elongation rate	0.719	0.062	0.005	0.000	-0.070	-0.012	-0.514	-	1.331	-0.022	-0.790	0.026	0.588	0.038	0.172	-0.014
Seedling length	0.811	1.200	0.060	-0.014	-0.111	-0.018	-0.492	0.059	-	-0.015	-0.877	0.030	0.451	0.035	0.216	-0.012
Cotyledonary area	0.163	-0.038	-0.127	0.033	0.017	0.004	0.278	0.036	0.567	-	-0.594	0.014	0.447	0.062	0.046	-0.024
Seedling fresh weight	0.429	-1.303	-0.042	0.032	-0.119	-0.018	-0.254	0.036	0.900	-0.016	-	0.047	1.012	0.040	0.260	-0.027
Seedling dry weight	0.419	0.049	-0.093	0.031	-0.119	-0.018	-0.233	0.033	0.854	-0.011	-1.296	-	0.958	0.006	0.280	-0.022
Absolute seedling water content	0.428	1.000	-0.102	0.032	-0.119	-0.018	-0.255	0.036	0.900	-0.017	-1.363	0.046	-	0.042	0.260	-0.027
Specific seedling water content	0.209	0.112	-0.027	0.003	-0.034	-0.005	-0.152	0.021	0.431	-0.021	-0.486	0.003	0.375	-	0.008	-0.019
Seed vigour index	0.660	0.303	0.041	-0.004	-0.146	-0.023	-0.263	0.035	0.896	-0.006	-1.176	0.045	0.868	0.003	-	-0.015
1000 seed weight	0.380	-0.039	-0.173	0.047	0.001	-0.001	-0.190	0.022	0.415	0.023	-0.934	0.028	0.698	0.055	0.115	-

Residual effect = 0.0008

are therefore, in agreement with what was recorded for maize by Kamenova *et al.*, 1983. The metal tolerence has been demonstrated in members of Brassicaceae by Hutchinson, 1984; Dueck *et al.*, 1987 as also by Baker and Procter, 1990. According to them the degree of tolerance is due to either genetic variability or the interactive effect of contaminaters. Gartside and Neilly, 1974 reported that only those plant species which possess the required genetic variation can develop tolerance in their population.

On the basis of present study some interesting correlation coefficients have been established. The percentage germination is positively correlated with germination rate index and seedling vigour. The radicle length is also positively correlated with radicle elongation rate, seedling length, mean fresh and dry weight, absolute seedling water content and seed vigour index. The seedling vigour too shows positive correlation with percentage germination, germination rate index, radicle length, radicle elongation rate, hypocotyl length, hypocotyl elongattion rate, seedling length and seed vigour index. The hypocotyl length too has been found to be positively correlated with hypocotyl elongation rate, cotyledonary area, mean fresh and dry weight, absolute seedling water content and seed vigour index. The vigour index also showed positive correlation with all characters except percentage germination, germination rate index, cotyledonary area, specific seedling water content and 1000 seed weight. All the correlations described above are significant at 5% and 1% level of significance.

Absolute seedling water content shows the significant positive correlation with seedling vigour and 1000 seed weight. It suggests that in higher concentration the water absorptioon and the mobilization of reserve food occurs in low quantity. In this response it is similar to the results of Siegel *et al.*, 1984. It is perhaps due to inhibition of seedling growth by heavy metals which by its association with cell wall or membrane inhibits water absorption and also interferes with mobilization of reserve food from cotyledons to the developing seedling. Mullettt and Wilkinson 1979 reportted that shoot length had significant positive correlation with fresh and dry weight in wheat. Nayeem and Deshpande, 1987, observed that seed index had significant positive correlation with the root length, fresh and dry weight of seeding in wheat. Later Mahajan and Nayeem, 1989 reported the significant positive correlation of root length and vigour index in the same plant.

A perusal of path coefficient analysis at phenotypic level reveals that the seeding length, absolute seeding water content showed highest positive direct effect on seedling vigour. The percentage seed germination and seed vigour index directly affected the seedling vigour to some extent. The path coefficient studies of Nayeem and Deshpande, 1987 in wheat revealed that seed index and root length had direct effect on dry matter. The residual effect was associated with the values of standard partial regression to the limit of 0.0008 at phenotypic level. This indicates the contribution of remaining factors other than those studied for the present investigattion.

The information gathered on variability, comparison of toxicity levels, tolerance index, correlation and direct and indirect effects of component characters on seedling vigour can be used further. These findings indicate that germination, radicle, hypocotyl, seedling length and vigour index are the important character for seedling vigour. They are primarily affected by heavy metal pollutants. In case of mercury, 10^{-5} molar concentration is the last limit for the degree of tolerance. However, for cobalt the last limit of degree of tolerance may vary between 10^{-3} to 10^{-4} molar concentration.

We are grateful to the authorities of National Seed Corporation I.A.R.I., New Delhi for supplying the seeds of *Brassica campestris* var. *toria* PT. 303. for the present study.

REFERENCES

Abdulbaki A A & J D Anderson 1973 Vigour determination in soybean seed by multiple criteria. *Crop Sci* **13** 630-633.

Austenfield F A 1979 Phytotoxicity of nickle and cobalt on *Phaseolus vulgaris cv saxa, Z Pflanzen Bodenkd* **142** 786-791.

Baker A J M & J Proctor 1990 The influience of Cd, C, Pb and Zn on the distribution and evolution of metallophytes in British Isles. *Plant Syst Evol* **173** 91-108.

Cooper S C & M Quales 1968 Seedling vigour evaluation of four birds foot trefoil (*Lotus corniculatus*) varieties grown under two temperature regime. *Crop Sci* **8** 756-757.

Coughtrey P J, C H Jones & M H Martin 1979 Cd Pb and Zn interactions and tolerance in two population of *Holcus lanatus* L grown in solution culture. *Environ Exp Bot* **19** 85-290.

Dickinson N M, A P Turner & N W Lepp 1991b Survival of trees in a metal contaminated environment. *Water Air and Soil Pollution* **57-58** 627-633.

Dueck T A, H G Wotting D R Moet & F J M Pasman 1987 Growth and reproduction of *Silene cucubalus* intermittently exposed to low concentration of air pollutants Zn, Cu *New Phytol* **105** 633-645.

Gartside D W & T B Mc Neilly 1974 The potential for evolution of heavy metal tolerance in plant. II Cu tolerance in normal population of different plant species. *Heredity* **32** 335-348.

Gupta R 1991 Toxic effects of mercury on seed germination on bean *(Phaseolus vulgaris)* and mustard *(Brassica campestris). Com Physiol Ecol* **16** 43-45.

Hara J T & Y Sanada 1979 Comparison of the toxicity of heavy metals to cabbage growth *(Brassica oleracea var. capitata) Plant and Soil* **51** 127-133.

Hutchinson T C 1984 Adaptation of plants to atmospheric pollutants. *In Origin and Development of Adaptation.* (D Evered and G M Collins eds) Pitman, London p 52-57.

International rules for seed testing 1976 International seed testing association. *Seed Sci & Technol* **4** 3-49.

Kamenova Y, S Todoray K Drev & A Lenak 1983 Effect of cobalt and mercury on some maize plant reaction. *Fiziol Rast (Sofia)* **9** 78-82.

Mahajan A R & K A Nayeem 1989 Character association and path analysis for seedling vigour index in wheat, species and Triticale under different temperature. *Seed Res* **17** 32-35.

Mahajan A & S Dug 1993 Some characteristics of Indian rapeseed *(Brassica campestris var toria)* acid phosphatase. *Pl Physiol & Biochem, New Delhi* **20** 86-89.

Mukherji S & G Ganguly 1974 Toxic effects of Hg in germinating rice *(Oryza sativa L)* seed and their reversal. *Indian J Expt Bot* **12** 432-435.

Mullett J H & R I Wilkinson 1979 The relationship between amount of electrolytes loss on leaching in seed of *Pisum sativum* and some parameters of plant growth. *Seed Sci & Technol* **7** 381-398.

Nayeem K A & V S Deshpande 1987 Genetic variability and correlation coefficient relating to seed size, seedling vigour and some physiochemical properties in wheat. *Seed Sci & Technol* **15** 699-704.

Puerner N J & S M Siegal 1972 The effects of Hg compounds on the growth and orientation of cucumber seedling. *Plant Physiol* **26** 310-312.

Renjini M B J & K Janardahan 1989 Effect of some heavy metals on seed germination and early seedling growth of groundnut sunflower and gingelly. *Geob (Jodhpur)* **16** 164-170.

Siegel B Z, M Lasconia E Yaeger & S M Siegel 1984 The phytotoxicity of mercury vapour, *Water Air Soil Pollution* **23** 15-24.

Sethi U I, A Basu & S G Mukherjee 1990 Control of cell proliferation and differentiation by nodulators of ethylene biosynthesis and action in *Brassica hypocotyl* explants. *Pl Sci Limerick* **69** 225-229.

Vergaro O & J G Hunter 1952 Nickel and cobalt toxicities in oat plants. *Ann Bot* **17** 317-328.

Wilkins D A 1957 A technique for the measurement of lead tolerance in plants. *Nature* **180** 37-38.

Wilkins D A 1978 The measurement of tolerance of edaphic factors by means of root growth. *New Phytol* **80** 623-633.

Xu Y J, R B Van & H Van 1993 Effect of Ca, its inhibitors and heavy metals on the growth cycle of peanut cell aggregates. *Plant Cell Tissue and Organ Culture* **32** 319-328.