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RESEARCH REPORT

Comparative responses of the action of different mercury compounds on barley

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Mercury is a hazardous pollutant in the environment and can be introduced into the environment in many forms. Experiments were performed to study the toxic effects of various mercury compounds, viz. inorganic, monovalent mercurous chloride, divalent mercuric chloride and organic compounds mercuric acetate and phenyl mercuric acetate on percentage germination, pigment concentrations, root-shoot lengths and fresh weight-dry weight of seven days old seedlings of barley. The phenyl mercuric acetate was found to be the most toxic, followed by mercuric acetate and mercuric chloride, while the mercurous chloride was found to be least toxic.

INTRODUCTION

The principal sources of different forms of mercury compounds in the environment are the various applications of pesticides, chloralkali production, fuel burning, catalytic processes, ore refining, sewage treatment, waste incineration, paint manufacture and use and breakage of mercury containing devices.[1] Various reviews on metal toxicity have been published.[2–4] Current emphasis on environmental pollution makes it desirable to examine the role of various forms of mercury compounds on plant growth. The objective of our experiment is to assess the toxicity of organic and inorganic as well as monovalent and divalent forms of mercury on barley seedlings with particular emphasis on seed germination, pigment concentrations, root-shoot length, fresh and dry weight of seedlings.

MATERIALS AND METHODS

Seeds of Barley (*Hordeum vulgare* Linn. Var. RD 137) were surface sterilized with 0.01 percent solution of mercuric chloride for five minutes and washed thoroughly with sterilized distilled water. Different range of mercury concentrations were prepared for mercurous chloride (Hg^{+}), mercuric chloride (Hg^{++}), mercuric acetate and phenyl mercuric acetate (PMA). The concentrations of mercury were 1, 5, 10, 50, 100, 200, 300, 400 and 500 mg l^{-1}. The surface sterilized seeds of barley were placed for germination in petri dishes having Whatman No. 1 filter paper rinsed with various ranges of mercury, using different mercury compounds at constant temperature 25°C. All observations were taken for seven days old barley seedlings except for percentage germination of seeds. Control sets were also performed throughout the experiments. Observations were made in duplicate.

Percentage germination was determined for various concentrational range of mercury for different mercury compounds. The seven days old seedlings from various concentrations of each compounds were taken for fresh weight and dry weight. The average root and shoot length was determined by measuring the length of root and shoot of 100 seedlings in each case of seven days old seedlings.

For chlorophylls and carotenoids pigments of seven days old seedlings 100 mg of fresh leaves were ground with 10 ml of 80:20 acetone; alcohol mixture and extract was centrifuged at 3000 rpm for three minutes.

The clear supernatant solution was examined for chlorophyll 'a' 'b', total chlorophyll and carotenoids at the wave lengths of 665, 652, 645, 630, 510 and 480 nm, as suggested by Duxbury and Yentsch.[5]

RESULTS AND DISCUSSION

The results led to various interesting observations. All the four mercury compounds, viz. mercurous

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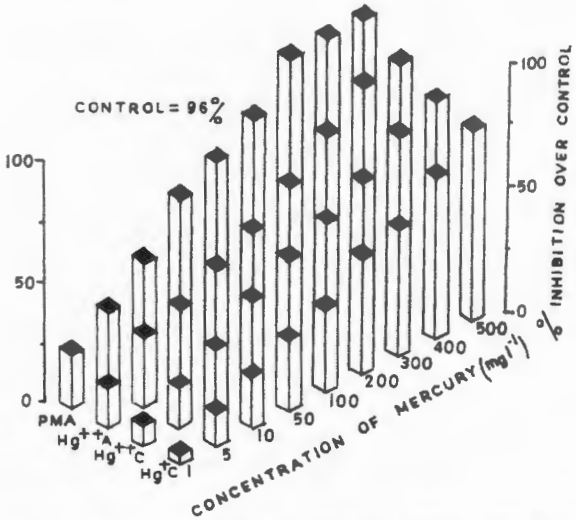

FIGURE 1 Percentage inhibition in percentage seed germination of Barley over control as influenced by mercury concentrations for various mercury compounds viz. Mercurous chloride ($Hg^{+}C$). Mercuric chloride ($Hg^{++}C$), Mercuric acetate ($Hg^{++}A$) and Phenyl Mercuric Acetate (PMA).

chloride, mercuric chloride, mercuric acetate and phenyl mercury acetate showed inhibitory effects on barley seedlings although their toxic ranges were different. Percentage germination was inhibited from 4.1 to 98.1 percent, 9.3 to 82.2 percent and 15.6 to 90.6 percent, respectively, for mercurous chloride, mercuric chloride and mercuric acetate for concentrations of mercury 1 mg l^{-1} to 500 mg l^{-1} accordingly, while in case of PMA the 100 percent reduction is observed at the concentration of 300 mg l^{-1} mercury (Figure 1). 200 mg l^{-1} mercury plants died in the case of PMA. The percentage germination was 96 percent in control sets. The inhibition in percentage germination in certain crops was also observed by Hinesly, *et al.*[6]

Singh and Mukhiya[7] observed reduction in percentage germination of Buckwheat in relation to mercury toxicity.

Average lengths of root and shoot also decreased with increase in concentration of mercury. The inhibition percentage were varied according to mercury compounds. From Table I it is clear that PMA is the most toxic compound followed by mercuric acetate, mercuric chloride and mercurous chloride, which is found to be least toxic.

Average fresh weight and dry weight were also inhibited by various concentration ranges of mercury (Table I). In the control average dry weight was 3.60g/100 seedlings, but a 72 percent, 81 percent and 89 percent reduction in dry weight was observed for mercurous chloride, mercuric chloride and mercuric acetate respectively for 500 mg l^{-1} mercury. While in the case of PMA a 71 percent reduction in dry weight was observed at 200 mg l^{+1} concentration of mercury. Our results agree with the observations of Mukherji and Mitra,[8] who reported that root growth, fresh weight and dry weight was reduced due to metal toxicity. The same reduction was observed in case of Buckwheat by Singh and Mukhiya.[7]

From Table II it is evident that these four mercury compounds also inhibit the pigments in leaves of seven days old barley seedlings. The total chlorophyll in control set was 2.063 mg g^{-1}. Fresh weights were reduced to 0.582, 0.438, 0.283 mg g^{-1} for mercurous, mercuric chloride and mercuric acetate respectively for Conc. 500 mg l^{-1} mercury, while in case of PMA 0.451 mg g^{-1} fresh weight was observed at a concentration 200 mg l^{-1}. The same results were noted for chlorophyll 'a' and 'b' (Table II). The reduction in the carotenoids were also observed for different mercury compounds. In the control set carotenoid contents were 0.553 mg g^{-1}. Fresh weight was reduced to 62 percent, 70 percent and 80 percent for mercurous, mercuric chloride and mercuric acetate respectively for 500 mg l^{-1} concentration of mercury. While considering the observation of PMA a 72 percent reduction was found at Conc. of 200 mg l^{-1} mercury.

Harris *et al.*[9] reported a significant reduction in photosynthesis and growth in marine and fresh

TABLE I

Showing the effect of different mercury compounds on root-shoot length, fresh-dry weight of seven days old barley seedlings

Compounds	Parameters	Concentration of metal in mgl^{-1}									
		Control	1	5	10	50	100	200	300	400	500
	Root length (cm)	14.30	14.01 (2)	13.15 (8)	12.58 (12)	11.15 (22)	10.29 (28)	8.72 (39)	7.72 (46)	5.86 (59)	5.00 (65)
Mercurous	Shoot length (cm)	18.82	18.44 (2)	17.12 (9)	16.74 (11)	15.24 (19)	13.92 (26)	11.85 (37)	9.97 (47)	8.46 (55)	7.15 (62)
Chloride	Fresh weight (g/100 seedlings)	38.80	37.24 (4)	35.30 (9)	34.14 (12)	29.10 (25)	26.38 (32)	19.78 (49)	17.46 (55)	13.96 (64)	10.86 (72)
(72)	Dry weight (g/100 seedlings)	3.60	3.45 (4)	3.24 (10)	3.09 (14)	2.88 (20)	2.48 (31)	1.87 (48)	1.72 (52)	1.33 (63)	1.11 (69)
	Root length	14.30	13.58 (5)	12.87 (10)	12.15 (15)	10.29 (28)	9.0 (37)	7.86 (45)	7.15 (50)	5.43 (62)	4.29 (70)
Mercuric Cloride	Shoot length	18.82	18.06 (4)	16.56 (12)	16.18 (14)	14.11 (25)	13.17 (30)	11.10 (41)	9.22 (51)	7.90 (58)	5.83 (69)
	Fresh weight	38.80	35.30 (9)	34.14 (12)	31.04 (20)	26.77 (31)	22.11 (43)	17.07 (56)	13.58 (65)	10.86 (72)	7.37 (81)
	Dry weight	3.60	3.31 (8)	3.09 (14)	2.95 (18)	2.70 (25)	2.23 (38)	1.69 (53)	1.40 (61)	1.11 (69)	0.90 (75)
	Root length	14.30	13.50 (8)	12.15 (15)	11.01 (23)	9.72 (32)	8.15 (43)	6.72 (53)	6.00 (58)	4.86 (66)	3.14 (78)
Mercuric acetate	Shoot length	18.82	17.50 (7)	15.80 (16)	15.24 (19)	12.98 (31)	11.10 (41)	9.41 (50)	7.71 (59)	6.21 (67)	3.95 (79)
	Fresh weight	38.80	34.53 (11)	31.81 (18)	27.93 (28)	23.66 (39)	19.01 (51)	13.58 (65)	10.86 (72)	7.76 (80)	4.26 (89)
	Dry weight	3.60	3.24 (10)	2.91 (19)	2.77 (23)	2.34 (35)	1.80 (50)	1.40 (61)	1.15 (78)	0.90 (75)	0.68 (81)
	Root length	14.30	13.15 (8)	11.72 (18)	10.43 (27)	8.72 (39)	7.15 (50)	5.43 (62)	—	—	—
Phenyl Mercuric acetate	Shoot length	18.80	16.74 (11)	15.62 (27)	14.30 (24)	11.66 (38)	9.59 (49)	7.90 (58)	—	—	—
	Fresh weight	38.80	34.14 (12)	29.87 (23)	27.16 (30)	23.28 (40)	17.46 (55)	11.25 (71)	—	—	—
	Dry weight	3.60	3.09 (14)	2.70 (25)	2.52 (30)	2.23 (38)	1.80 (50)	1.11 (69)	—	—	—

Figures in parentheses are percentage inhibition over control.

'ater phytoplankton exposed to methyl mercury ompounds. Our results are also in the support of ıe observation of Agarwala *et al.*,[10] Singh and lukhiya[7] and Mukherji and Mitra.[8]

Higgins and Burns[11] reported that toxicities of ompounds are according to the nature of toxicant 'hether it is organic or inorganic in nature, as well s to the valency whether it is mono, bi, tetra or exa valent.

All the data were statistically analysed (Table I). Analysis of variance was applied to three arameters—chlorophyll 'a', dry weight and per-ntage germination and it was found that there was a significant decrease in Chl. 'a', dry weight and percentage germination as we proceed from inorganic compounds to organic compounds of mercury, and there is also a significant decrease with increase in concentration of each compound. (Significant at $P \ll 0.01$ level.)

In light of our results it is obvious that the effect of mercury compounds on barley varied accordingly to their nature. Organic compounds of mercury are more toxic because it is supposed that organic mercury is easily transported and persists in the natural environment due to the occurrence of co-valent bonding, while in case of inorganic

TABLE II

Showing the effect of different mercury compounds on chlorophyll and carotenoid contents of seven days old seedlings of barley.

Compounds	Parameters	Control	Concentration of metal in mgl^{-1} 1	5	10	50	100	200	300	400	500
Mercurous Chloride	Chlorophyll (a)	1.285	1.220 (5)	1.156 (10)	1.040 (19)	0.950 (26)	0.873 (32)	0.655 (49)	0.526 (59)	0.411 (68)	0.334 (74)
	Chlorophyll (b)	0.778	0.746 (4)	0.707 (9)	0.661 (15)	0.614 (21)	0.544 (30)	0.404 (48)	0.389 (50)	0.303 (61)	0.248 (68)
	Total Chlorophyll	2.063	1.966 (4.7)	1.863 (9.6)	1.701 (17.5)	1.564 (24.1	1.417 (31.3)	1.059 (48.6)	0.915 (55.6)	0.714 (65.3)	0.582 (71.78)
	Carotenoids	0.553	0.536 (3)	0.514 (7)	0.475 (14)	0.442 (20)	0.337 (39)	0.304 (45)	0.282 (49)	0.232 (58)	0.210 (62)
Mercuric Chloride	Chlorophyll (a)	1.285	1.182 (8)	1.079 (16)	0.925 (28)	0.835 (35)	0.706 (45)	0.539 (58)	0.411 (68)	0.346 (73)	0.244 (81)
	Chiorophyll (b)	0.778	0.731 (6)	0.676 (13)	0.614 (21)	0.536 (31)	0.482 (38)	0.451 (42)	0.318 (59)	0.248 (68)	0.194 (75)
	Total Chlorophyll	2.063	1.913 (7.2)	1.755 (14.9)	1.539 (25.3)	1.371 (36.1)	1.188 (42.4)	0.990 (52)	0.729 (64.6)	0.594 (71.2)	0.438 (78.7)
	Carotenoids	0.553	0.508 (8)	0.486 (12)	0.447 (19)	0.376 (32)	0.315 (43)	0.270 (51)	0.232 (58)	0.193 (65)	0.166 (70)
Mercuric acetate	Chlorophyll (a)	1.285	1.117 (13)	0.899 (30)	0.796 (38)	0.655 (49)	0.591 (54)	0.462 (64)	0.321 (75)	0.192 (85)	0.167 (87)
	Chlorophyll (b)	0.778	0.676 (13)	0.544 (30)	0.544 (30)	0.396 (49)	0.389 (50)	0.303 (61)	0.233 (70)	0.140 (82)	0.116 (85)
	Total Chlorophyll	2.063	1.793 (13)	1.443 (30)	1.340 (35)	1.051 (49)	0.980 (52.4)	0.765 (62.9)	0.554 (73.1)	0.332 (83.9)	0.283 (86.2)
	Carotenoids	0.553	0.492 (11)	0.403 (27)	0.387 (30)	0.304 (45)	0.254 (54)	0.176 (68)	0.166 (70)	0.121 (78)	0.110 (80)
Phenyl Mercuric acetate	Chlorophyll (a)	1.285	0.989 (23)	0.886 (31)	0.771 (40)	0.488 (62)	0.411 (68)	0.257 (80)	—	—	—
	Chlorophyll (b)	0.778	0.622 (20)	0.552 (29)	0.482 (38)	0.326 (58)	0.272 (65)	0.194 (75)	—	—	—
	Total Chlorophyll	2.063	1.611 (21.9)	1.438 (30.2)	1.253 (39.2)	0.814 (60.5)	0.683 (66.8)	0.451 (78.1)	—	—	—
	Carotenoids	0.553	0.447 (18)	0.403 (27)	0.342 (38)	0.243 (56)	0.215 (61)	0.154 (72)	—	—	—

Value are in mgg^{-1} Fresh Weight.
Figures in parentheses are percentage inhibition over control.

TABLE III

ANOVA table

Parameters	Source of variation	D.F.	S.S.	M.S.	F.	
Chlorophyll 'a'	Treatment	3	5.2836	1.7612	251.6	
	Concentrations	9	0.6119	0.0679	9.7	F 3.27 = 251.6 $P < 0.01$
	Error	27	0.1893	0.007	—	F 9.27 = 9.7 $P < 0.01$
	Total:	39	6.08	—	—	
Dry weight	Treatment	3	40.6007	13.5335	75.56	
	Concentrations	9	3.0483	0.3387	1.8953	F 3.27 = 75.56 $P < 0.01$
	Error	27	4.8371	0.1791	—	F 9.27 = 1.8953
	Total:	39	48.4861	—	—	
% seed germination	Treatment	3	29709.65	9903.2166	305.3937	F 3.27 = 305.3937
	Concentrations	9	3710.70	412.3	12.7144	F 9.27 = 12.7144
	Error	27	875.55	32.4277	—	$P < 0.01$
	Total:	39	34295.9	—	—	

compounds bivalent mercury is more toxic than that of the monovalent form.

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