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APPENDIX A

Hoagland's solution

Chemical used for 1 liter preparation of full strength Hoagland's solution are as follows.

1. 5 cm³ of 1 M KNO₃
2. 5 cm³ of 1 M Ca(NO₃)₂
3. 2 cm³ of 1 M MgSO₄
4. 1 cm³ of 1 M KH₂PO₄
5. 1 cm³ of mixed micronutrient*
6. 1 cm³ of 5 mg/cm³ Fe-EDTA

* Mixed micronutrient is prepared by dissolving the following chemicals in 1 liter of distilled water one by one.

H₃BO₃ 2.86 g

CuSO₄.5H₂O 0.08 g

MnCl₂.4H₂O 1.81 g

ZnSO₄.7H₂O 0.019 g

H₂MoO₄ 0.019 g

APPENDIX B

Table B-1 Shoot dry weight of four plant species of the 5 and 20 ppm Cd treatment

Duration (days)	<i>I. aquatica</i>		<i>B. oleracea</i>		<i>E. prostrata</i>		<i>C. barbata</i>	
	0 ppm	5 ppm	0 ppm	5 ppm	0 ppm	5 ppm	0 ppm	5 ppm
2d	0.896	0.793	0.511	0.490	0.434	0.381	0.440	0.273
11d	1.333	0.791	1.050	0.965	1.311	0.994	0.739	0.420
20d	1.385	0.735	1.572	1.208	3.198	1.580	1.556	0.703
7d (27)	1.362	1.134	2.639	1.195	2.404	1.036	2.739	1.140
14d (34)	2.069	1.343	3.523	1.776	4.683	1.201	2.939	1.218
Duration (days)	<i>I. aquatica</i>		<i>B. oleracea</i>		<i>E. prostrata</i>		<i>C. barbata</i>	
	0 ppm	20 ppm	0 ppm	20 ppm	0 ppm	20 ppm	0 ppm	20 ppm
2d	0.896	0.806	0.511	0.516	0.434	0.441	0.440	0.369
5d	1.351	1.066	0.728	0.512	0.700	0.548	0.350	0.328
8d	1.792	0.979	1.096	0.503	0.821	0.648	0.438	0.314
7d (15)	1.728	0.556	1.673	0.436	1.180	0.732	1.013	0.483
14d (22)	1.441	1.057	1.687	0.930	2.136	0.962	2.484	0.684

The shoot dry weight is based on gram unit.

APPENDIX C

Table C-1 Cadmium accumulation in different plant parts exposed to 0 and 5 ppm Cd.

Duration	Conc	Rep.	<i>I. aquatica</i>			<i>B. oleracea</i>			<i>E. prostrata</i>			<i>C. barbata</i>	
			Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf	Root	Shoot
2d	0 ppm	1	0.12	0	0.25	0.50	0.125	0.25	0.60	0	0.25	0.12	0.5
		2	0.12	0.25	0.37	0.50	0.62	0.25	0.66	0.54	0	0	0
		3	0.25	0	0.25	0.25	0.25	0	1.23	0.37	0.50	1.00	0.25
	5ppm	1	232.92	36.32	14.92	1152.04	145.43	77.06	351.03	78.00	3.88	480.19	23.59
		2	322.40	35.16	12.22	1042.67	160.33	74.89	346.69	69.00	2.49	464.33	19.74
		3	408.78	38.24	10.88	899.80	153.42	65.82	355.88	57.96	2.62	484.09	22.82
20d	0 ppm	1	0.12	0.45	0.62	0.12	0	0.25	0.25	0.38	0.87	0.30	0.25
		2	0.75	0.37	0.62	0	0	0	0.50	0.25	0.62	0.62	0.50
		3	1.37	0.25	0.75	0.12	0	0.25	0.62	0.12	0.50	0.80	0.75
	5ppm	1	1411.65	86.37	32.70	3936.09	257.5	198.25	1023.92	305.41	64.24	685.44	38.71
		2	1002.92	42.31	22.66	3162.99	243.77	143.67	1210.80	296.62	68.85	813.48	32.33
		3	1347.66	81.46	43.66	3319.73	294.22	148.13	1137.29	425.92	77.27	817.08	37.35
14d (34)	0ppm	1	1.00	0.37	0	0.37	0	0.12	0.12	0.25	0.37	0.75	0
		2	0.25	0.87	0.37	0.62	0.25	0	0.87	0.50	0.25	0	0
		3	1.50	0	0.25	1.00	0	0	0.25	1.00	0.37	0.12	0
	5ppm	1	393.74	80.00	20.99	1979.09	78.44	156.87	354.62	75.86	107.82	256.38	26.70
		2	396.68	98.68	37.80	2895.31	115.52	103.75	385.74	162.79	72.50	342.71	27.46
		3	354.62	59.06	16.48	2625.48	192.29	132.59	285.33	175.95	93.030	311.44	25.30

Table C-2 Cadmium accumulation in different plant parts exposed to 0 and 20 ppm Cd.

Duration	Conc.	Rep.	<i>I. aquatica</i>			<i>B. oleracea</i>			<i>E. prostrata</i>			<i>C. barbata</i>	
			Root	Stem	Leaf	Root	Syem	Leaf	Root	Stem	Leaf	Root	Shoot
2d	0 ppm	1	0.12	0	0.25	0.50	0.12	0.25	0.60	0	0.25	0.12	0.50
		2	0.12	0.25	0.37	0.50	0.62	0.25	0.66	0.54	0	0	0
		3	0.25	0	0.25	0.25	0.25	0	1.23	0.37	0.50	1.00	0.25
	20ppm	1	1056.4	45.26	9.00	3674.24	154.09	11.00	1153.32	59.54	7.36	984.73	43.23
		2	913.09	29.44	5.24	3411.13	95.56	10.61	867.15	57.16	2.12	859.95	30.50
		3	1379.29	18.75	4.62	3169.07	67.25	9.25	1110.72	85.75	3.37	1610.13	37.35
8d	0 ppm	1	0.87	0.62	0.45	0.12	0	0	0.12	0	0.12	1.50	0
		2	1.00	0.45	0.62	0.25	0	0.12	0.5	0	0	0.50	0
		3	0.45	0.12	1.88	0.37	0	0.12	0.12	0	0.12	0.65	0
	20 ppm	1	1736.14	25.75	3.86	4223.67	207.00	84.00	2223.93	176.59	34.13	1982.32	159.47
		2	1495.36	30.22	5.99	4354.94	155.22	35.82	2125.06	177.34	28.46	1702.55	162.74
		3	1683.21	27.72	7.50	4921.66	296.91	51.39	2084.68	94.09	17.18	1730.08	67.32
14d (22)	0 ppm	1	1.62	0.37	0.62	0.50	0	0	0.62	1.12	1.12	0.50	0
		2	0.87	0.50	0.50	0.25	0	0.12	0.75	0.75	1.38	0.87	0
		3	0.75	0	0.37	0.50	0.25	0	1.00	1.12	0.62	0.10	0
	20 ppm	1	768.34	84.54	42.25	2364.42	142.33	142.71	823.95	164.66	67.86	894.89	68.34
		2	544.56	54.32	24.15	2715.96	138.61	129.24	1184.18	198.72	53.12	418.32	60.19
		3	510.20	60.82	21.65	2403.27	120.27	88.25	924.96	201.95	64.97	456.69	62.66

APPENDIX D

Table D-1 Proline accumulation at different RWC of four plant species

<i>I. aquatica</i>		<i>B. oleracea</i>		<i>E. prostrata</i>		<i>C. barbata</i>	
RWC (%)	Pro (mol/gFW)	RWC(%)	Pro(mol/gFW)	RWC (%)	Pro (mol/gFW)	RWC (%)	Pro (mol/gFW)
96.34	0.187	96.34	0.228	100.00	0.147	100.00	0.147
95.65	0.187	95.65	0.187	94.87	0.147	100.00	0.106
92.31	0.187	92.31	0.269	92.86	0.106	100.00	0.065
77.17	0.310	77.17	0.310	83.02	0.187	86.49	0.106
76.71	0.269	76.71	0.310	78.05	0.269	86.36	0.065
74.71	0.269	74.71	0.310	75.68	0.187	85.71	0.065
65.38	0.350	65.38	4.914	71.43	16.265	74.19	0.391
64.29	0.432	64.29	2.795	67.74	10.170	73.53	0.473
55.95	0.432	55.95	8.458	60.71	13.657	65.12	0.269
53.93	0.717	53.93	7.155			44.44	6.462
45.65	0.839	45.65	8.621			40.74	3.447
41.67	0.717	41.67	24.275			37.93	4.140
r = -0.913**		r = -0.793**		r = -0.753*		r = -0.837**	

** = Significant at $P \leq 0.01$

* = Significant at $P \leq 0.05$

Table D-2 Proline accumulation at various leaf Cd content of three plant species exposed to 0, 5 and 20 ppm Cd

treatment	Duration (days)	Position of leaves	<i>B. oleracea</i>		<i>E. prostrata</i>		<i>C. barbata</i>	
			Cd (ppm)	Proline ($\mu\text{mol/gDW}$)	Cd (ppm)	Proline ($\mu\text{mol/gDW}$)	Cd (ppm)	Proline ($\mu\text{mol/gDW}$)
0	15d	Y	0	6.812	0	1.043	0	2.331
0	15d	O	0	11.131	0	2.143	0	4.123
5 ppm	2d	Y	74.917	7.383	20.916	1.369	4.314	11.050
5 ppm	2d	O	7.512	7.138	4.014	3.227	0.927	2.575
5 ppm	20d	Y	109.649	11.539	110.443	9.664	6.262	1.353
5 ppm	20d	O	63.563	15.043	48.891	45.502	39.449	3.308
5 ppm	14d (34)	Y	119.266	13.005	69.432	4.857	6.526	1.434
5 ppm	14d (34)	O	212.871	12.435	68.831	3.960	11.988	1.516
20 ppm	2d	Y	23.161	76.468	2.997	41.330	0.958	6.975
20 ppm	2d	O	20.192	75.490	1.231	19.117	23.401	7.709
20 ppm	8d	Y	76.904	77.771	1.655	66.689	28.373	6.486
20 ppm	8d	O	17.584	14.961	19.75	22.751	70.813	7.464
20 ppm	14d (22)	Y	96.339	16.754	79.934	3.960	7.000	1.51
20 ppm	14d (22)	O	22.706	57.840	17.436	2.819	40.333	3.879
			r = -0.216		r = -0.228		r = 0.271	

Y = young leaves as described in chapter 3

O = leaves near the position of the cotyledon(s) including living and dead leaves

The unit of proline was $\mu\text{mol/gDW}$.

DW refers to dry weight. The plant leaves were dried immediately in 105°C oven for half an hour and then they were dried for the next 24 hours at 80°C .

APPENDIX E

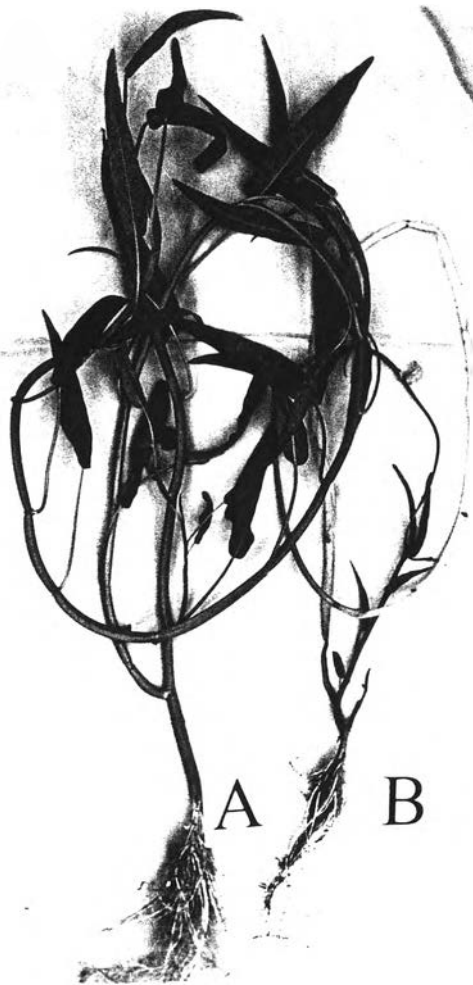


Fig E-1

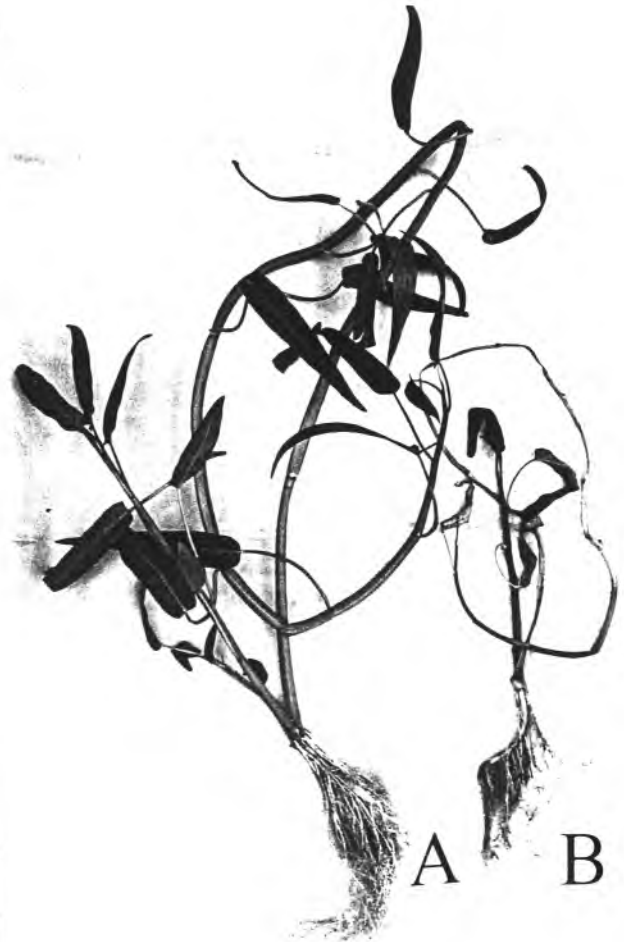


Fig E-2

Fig E-1 *I. aquatica* exposed to 0 ppm (A) and 5 ppm (B) Cd treatment at day 20 of exposure

Fig E-2 *I. aquatica* exposed to 0 ppm (A) and 20 ppm (B) Cd treatment at day 8 of exposure

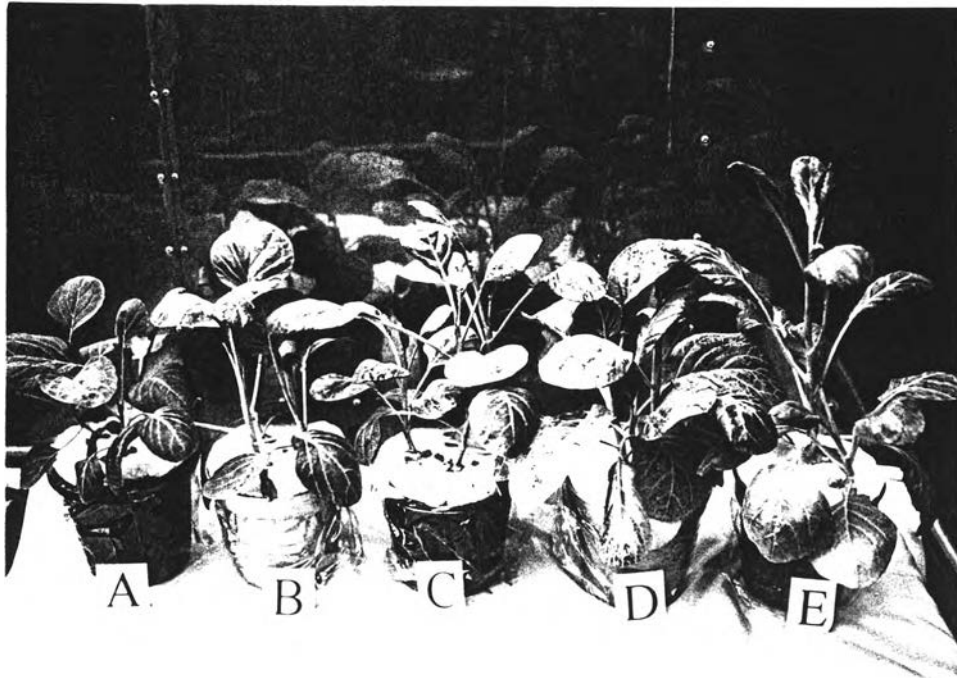


Fig E-3 Normal Growth of *B. oleracea* (the controls) of the 0 and 5 ppm Cd treatment. A-E are 2d, 11d, 20d, 7d (27) and 14d (34), respectively.

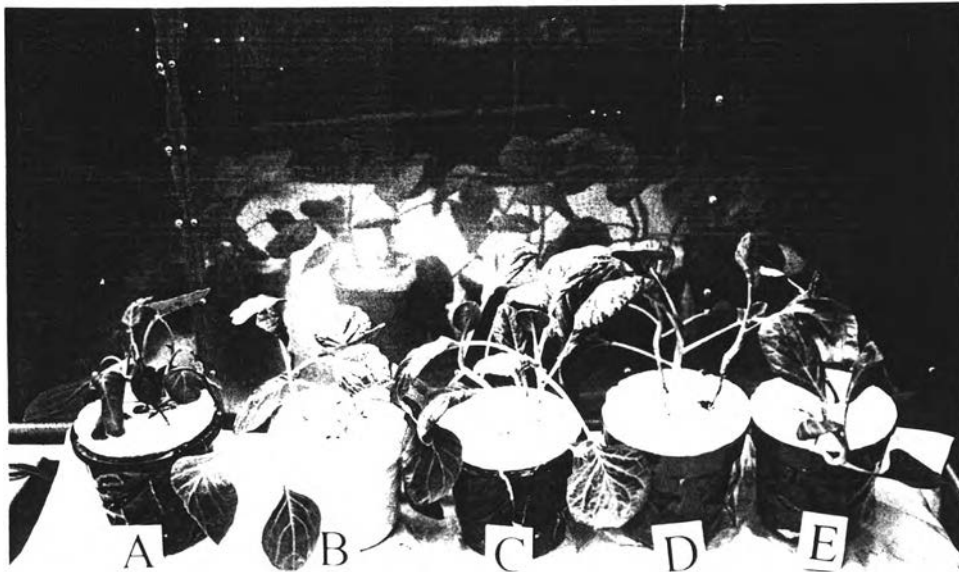


Fig E-4 Symptoms of Cd-treated *B. oleracea* (5 ppm Cd) of the 0 and 5 ppm Cd treatment. A-E are 2d, 11d, 20d, 7d (27) and 14d (34), respectively.

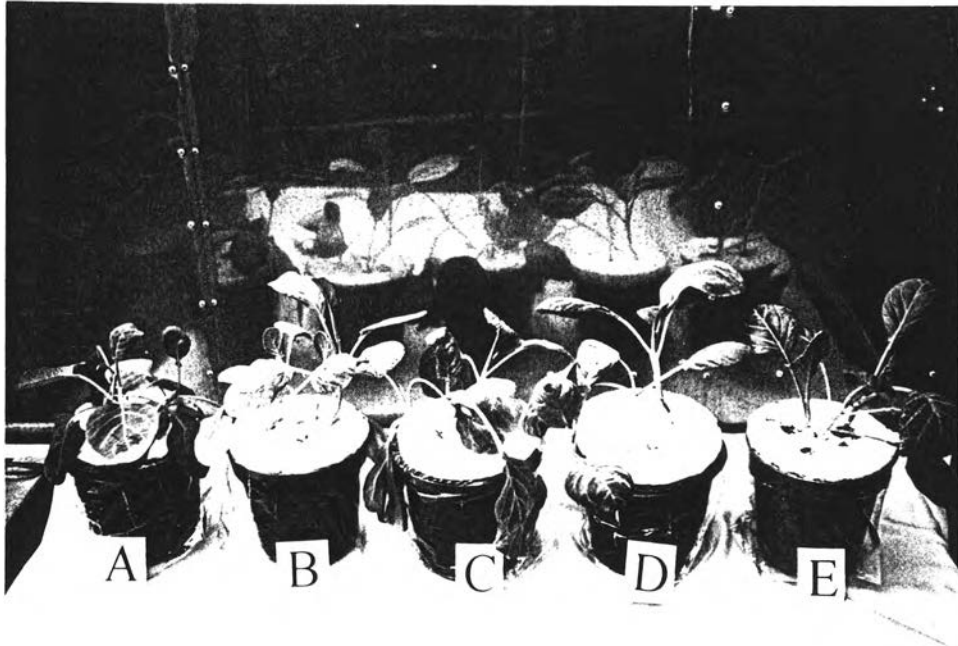


Fig E-5 Symptoms of Cd-treated *B. oleracea* (20 ppm Cd) of the 0 and 20 ppm Cd treatment. A-E are 2d, 5d, 8d, 7d (15) and 14d (22), respectively.



Fig E-6 *B. oleracea*'s root browning after 8 days of 20 ppm treatment

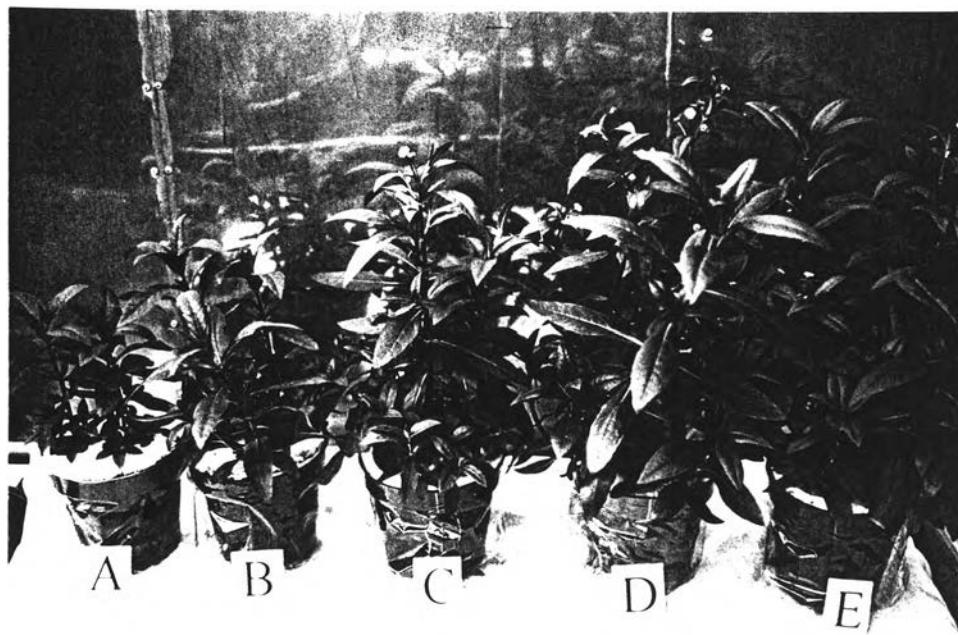


Fig E-7 Normal Growth of *E. prostrata* (the controls) of the 0 and 5 ppm Cd treatment. A-E are 2d, 11d, 20d, 7d (27) and 14d (34), respectively.

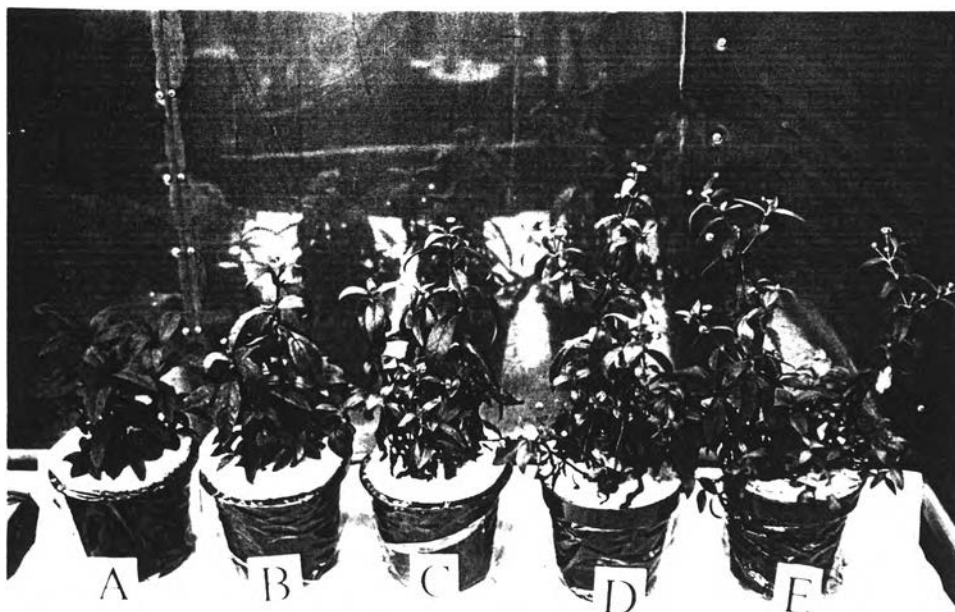


Fig E-8 Symptoms of Cd-treated *E. prostrata* (5 ppm Cd) of the 0 and 5 ppm Cd treatment. A-E are 2d, 11d, 20d, 7d (27) and 14d (34), respectively.

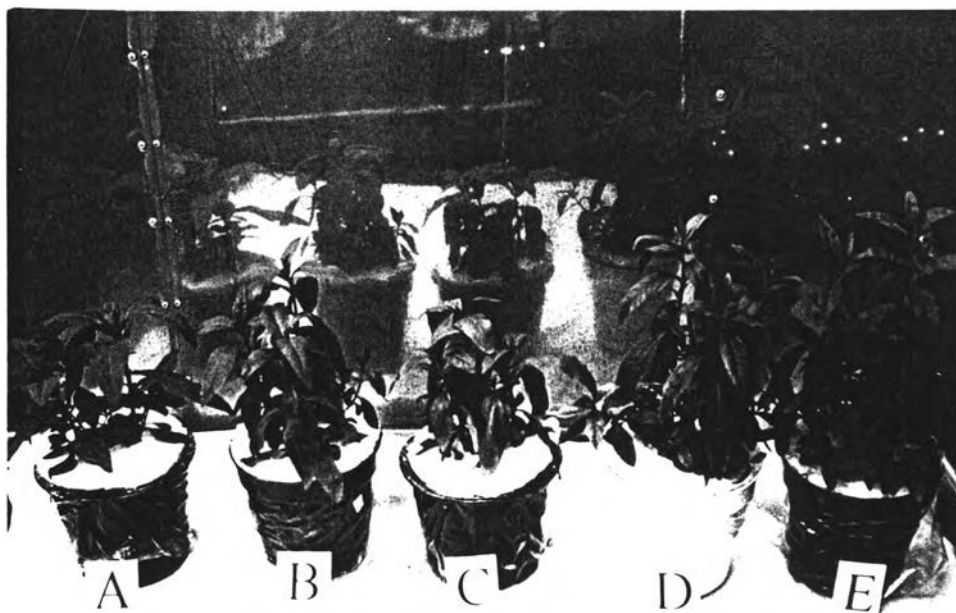


Fig E-9 Symptoms of Cd-treated *E. prostrata* (20 ppm Cd) of the 0 and 20 ppm Cd treatment. A-E are 2d, 5d, 8d, 7d (15) and 14d (22), respectively.



Fig E-10 *E. prostrata*'s roots development after being transferred to Cd-free solution for 14 days of the 0 and 5 ppm treatment.

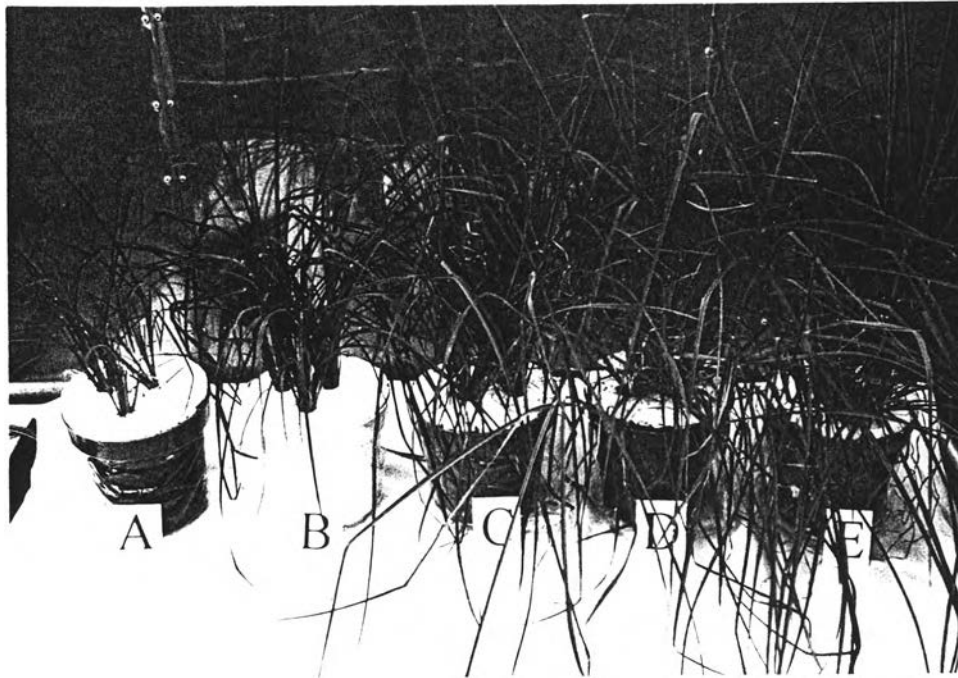


Fig E-11 Normal growth of *C. barbata* (the controls) of the 0 and 5 ppm Cd treatment. A-E are 2d, 11d, 20d, 7d (27) and 14d (34), respectively.

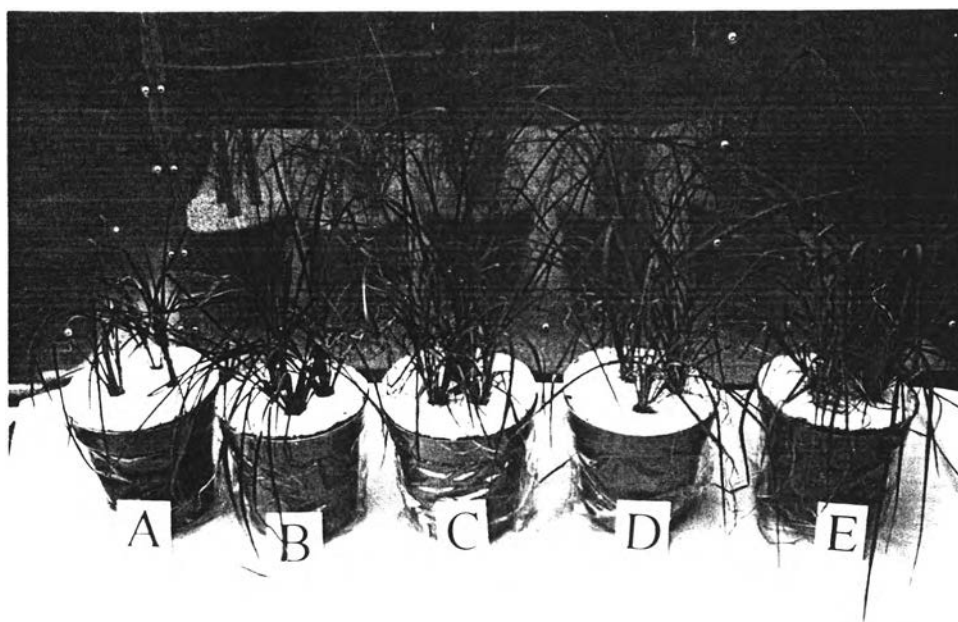


Fig E-12 Symptoms of Cd-treated *C. barbata* (5 ppm Cd) of the 0 and 5 ppm Cd treatment. A-E are 2d, 11d, 20d, 7d (27) and 14d (34), respectively.

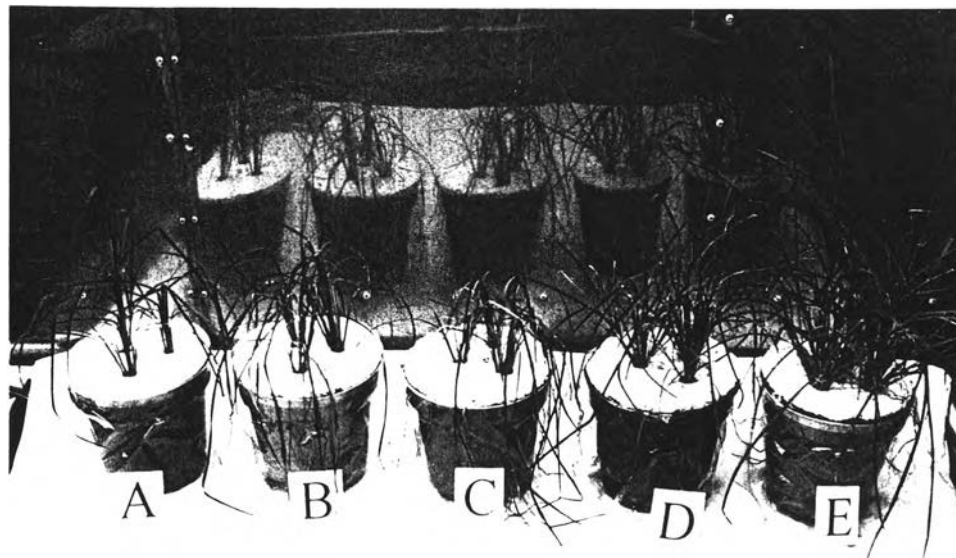


Fig E-13 Symptoms of Cd-treated *C. barbata* (5 ppm Cd) of the 0 and 5 ppm Cd treatment. A-E are 2d, 5d, 8d, 7d (15) and 14d (22), respectively.

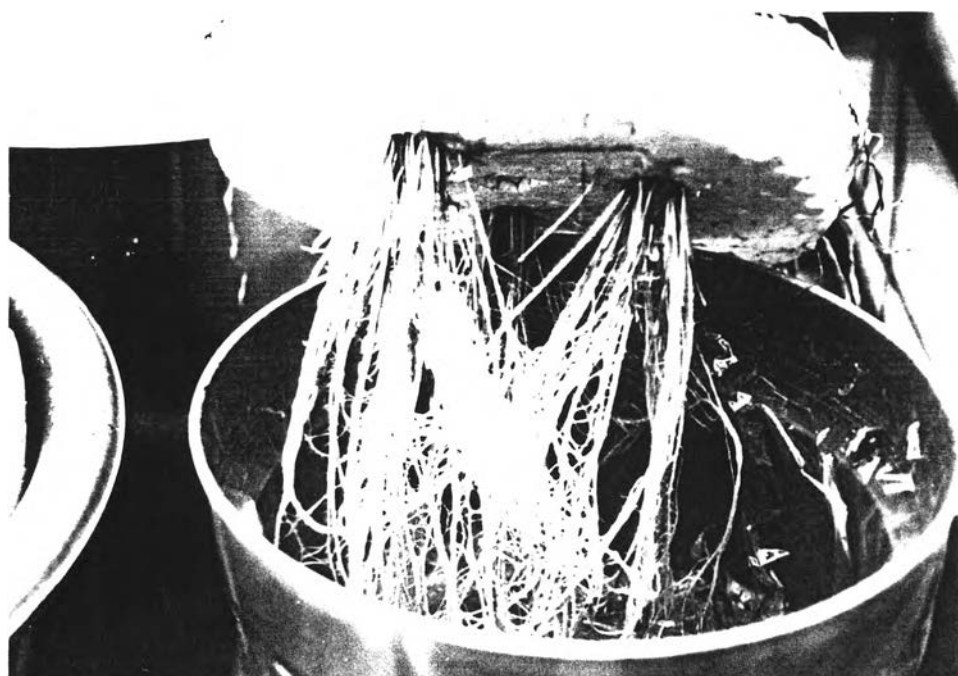


Fig E-14 *C. barbata*'s roots development after having been transferred to Cd-free solution for 14 days of the 0 and 5 ppm treatment.

BIOGRAPHY

Mr. Supat Posyawattanakul was born in Bangkok on March 22, 1971. He received a Bachelor of Science (Material Science) in 1992 from Faculty of Science, Chulalongkorn University and a Bachelor of Art in 1997 from Faculty of Humanities, Ramkhamhaeng University. He furthered his education at the Inter-department of Environmental Science, Chulalongkorn University in 1995.

