CHAPTER 4

RESULTS

4.1 Physiological responses of plants to cadmium stress

4.1.1 Proline accumulation

Proline accumulation of all the control plants did not show the increasing trend when the plants aged, but *B. oleracea* and *E. prostrata* had more tendency to accumulate proline with increasing age (see Tables 4.1 and 4.2). However, the maximum value did not greater than 0.567 µmol/gFW. Proline accumulation in the other species fluctuated in a narrow range from 0.065 to 0.432 µmol/gFW. *C. barbata* was the least accumulated species.

Data from Tables 4.1 and 4.2 indicate that plants accumulated proline when subjected to Cd stress. While cadmium concentration of 5 ppm raised proline content of stress plants, compared with the controls, from 1- to 10-fold in *E. prostrata* and 1- to 3-fold in *B. oleracea*, *I. aquatica* and *C. barbata* did not show significant difference from the controls. With more Cd concentration in solution (20 ppm), the plants accumulated more proline from 1.2- to 2- fold in *I. aquatica* and 0.8 to 9 fold in *C. barbata*. Marked increases above the controls level were observed in *E. prostrata* (4- to 28-fold) and *B. oleracea* (3- to 135-fold), but only *B. oleracea* showed significant difference from the controls. While lower Cd concentration significantly increased proline level in *E. prostrata* when the plants encountered the toxic metal for a long period (Fig 4.1), the high concentration caused rapid increase in this amino acid content within a few days. The highest value were obtained from the 8^{th} day treated plants (Fig 4.2) accompanying the severe root damage and wilting leaves (see appendix E). Proline content of the 20 ppm treatment rapidly reduced after elimination of Cd in nutrient solution. However, *B. oleracea* and *E. prostrata* still accumulated proline during the rest of the experiment. Significant differences were observed at day 7 (*B. oleracea*) and day 14 (*E. prostrata*) after the plants had been transferred to Cd-free solution.

Table 4.1 Proline accumulation of four plant species with 0 and 5 ppm Cd treatment

Proline	Cd	Exposure time			Duration after exposure		SL
(μmol/gFW)	(ppm)	2d	11d	20d	7d (27)	14d (34)	
1. *I. aquatica*	0	0.228^{abAB}	0.255^{bAB}	0.269^{bA}	0.160^{bB}	0.296^{aA}	**
	5	0.174^{bcB}	0.527^{bA}	0.350^{bAB}	0.201^{bB}	0.201^{aB}	**
2. *B. oleracea*	0	0.242^{abB}	0.283^{bAB}	0.242^{bB}	0.432^{bAB}	0.567^{aA}	**
	5	0.269^{aA}	0.459^{bA}	0.921^{aA}	0.581^{bA}	1.532^{aA}	NS
3. *E. prostrata*	0	0.065^{dE}	0.202^{bC}	0.120^{bD}	0.270^{bB}	0.311^{aA}	**
	5	0.283^{aA}	1.143^{aA}	0.365^{bA}	2.684^{aA}	0.747^{aA}	NS
4. *C. barbata*	0	0.133^{cdB}	0.160^{bAB}	0.147^{bB}	0.228^{bA}	0.133^{aB}	*
	5	0.174^{bcB}	0.133^{bB}	0.187^{bB}	0.323^{bA}	0.133^{aB}	**
SL		**	NS	NS	NS	NS	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.2 Proline accumulation of four plant species with 0 and 20 ppm Cd treatment

Proline	Cd	Exposure time			Duration after exposure		SL
(μmol/gFW)	(ppm)	2d	5d	8d	7d (15)	14d (22)	
1. *I. aquatica*	0	0.228^{bB}	0.214^{bB}	0.255^{bB}	0.214^{bB}	0.378^{aA}	*
	20	0.283^{bBC}	0.418^{bAB}	0.527^{bA}	0.201^{bC}	0.337^{aBC}	**
2. *B. oleracea*	0	0.242^{bB}	0.242^{bB}	0.201^{bB}	0.283^{bAB}	0.364^{aA}	**
	20	0.799^{aB}	13.187^{aAB}	27.077^{aA}	10.735^{aAB}	0.337^{aB}	**
3. *E. prostrata*	0	0.065^{bB}	0.269^{bA}	0.270^{bA}	0.174^{bAB}	0.229^{bAB}	*
	20	0.269^{bA}	4.229^{bA}	7.644^{bA}	0.529^{bA}	0.420^{aA}	NS
4. *C. barbata*	0	0.133^{bAB}	0.106^{bAB}	0.187^{bA}	0.079^{bB}	0.120^{cAB}	**
	20	0.106^{bB}	0.255^{bAB}	1.695^{bA}	0.214^{bAB}	0.133^{cB}	**
SL		NS	NS	**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

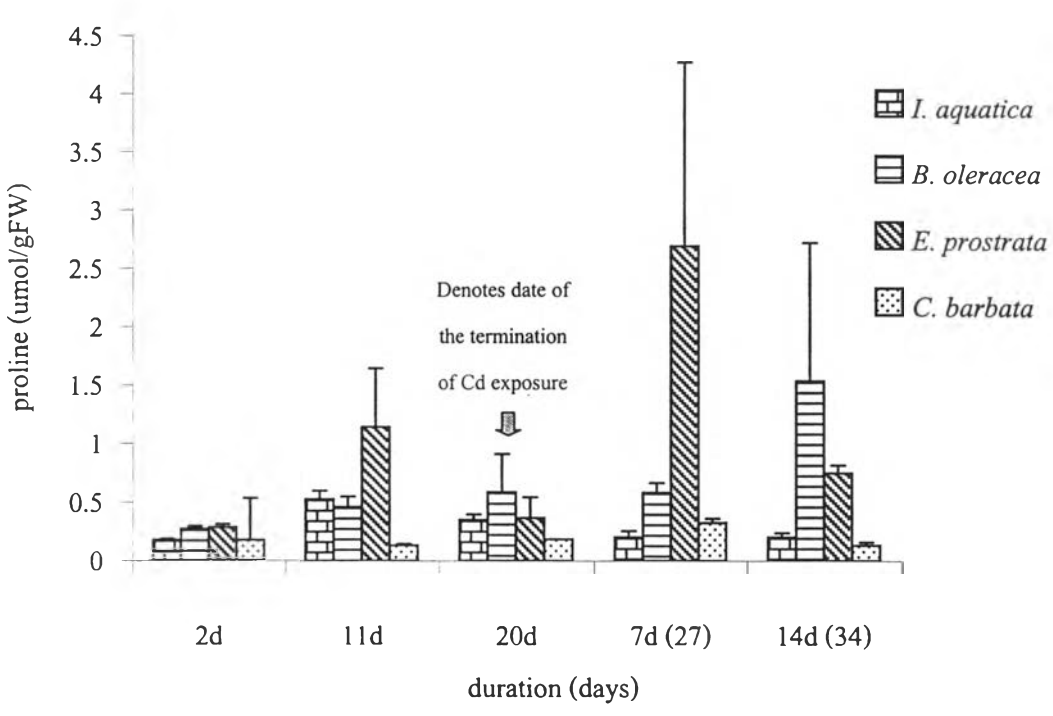

Fig. 4.1 Proline accumulation of four plant species exposed to 5 ppm Cd; vertical bars indicate SE.

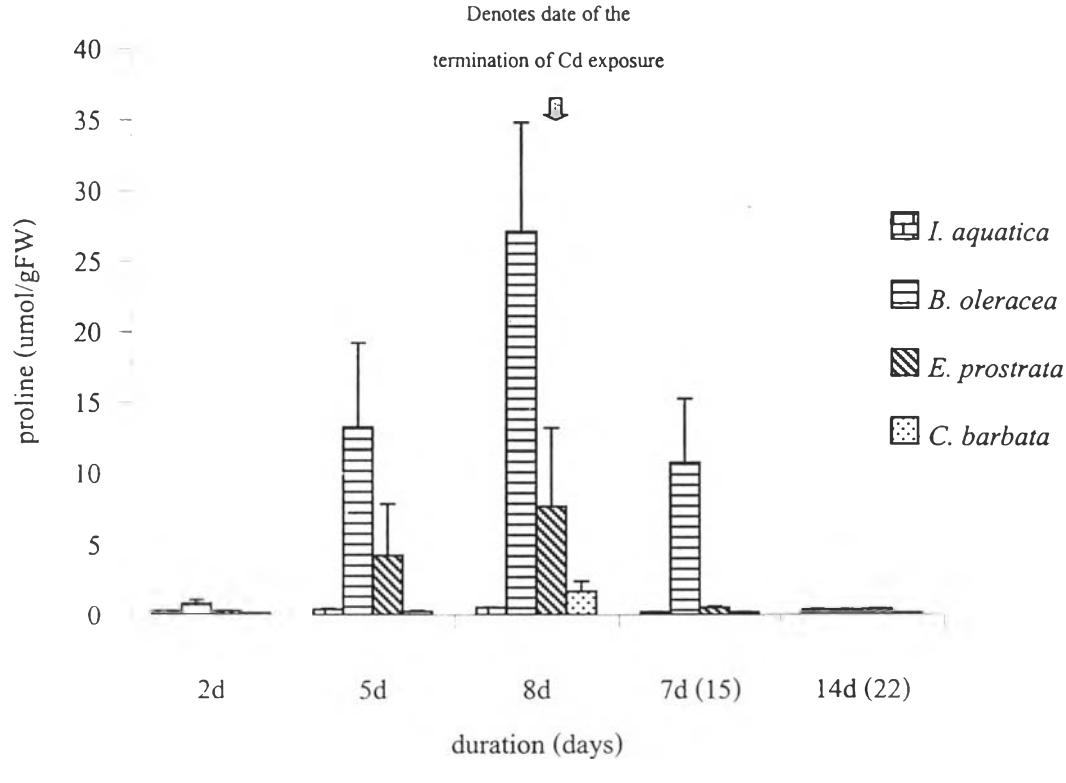

Fig 4.2 Proline accumulation of four plant species exposed to 20 ppm Cd; vertical bars indicate SE.

4.1.2 Chlorophyll contents

Tables 4.3 to 4.8 show that chlorophyll a, b and a+b contents of *I. aquatica* and *E. prostrata* at each duration of treatment were significantly greater than *B. oleracea* and *C. barbata*. Treatments of 5 and 20 ppm Cd lowered the chlorophyll contents significantly.

leaf chlorophyll a, b and a+b contents of the controls remained constant as the plant developed. However, *E. prostrata* showed increasing trend with time. Chlorophyll a content was 2.8- to 3-fold higher than chlorophyll b content for *I. aquatica* and *C. barbata* leaves. *E. prostrata* showed lower chlorophyll a to chlorophyll b ratio, but both of them were greater than the other species.

The decreasing trend of chlorophyll a, b and a+b contents with time was observed in *C. barbata* and *B. oleracea* exposed to 5 ppm Cd. However, the chlorophyll b content of *B. oleracea* was rather constant . *E. prostrata* had uncertain trend, but the lowest point was found at the 34-day duration. *B. oleracea*, on the other hand, had lowest chlorophyll a, b and a+b content when exposed to Cd for 20 days, and recovered after having been transferred to normal nutrient solution. The similar results were obtained when this plant experienced the 20 ppm treatment. Chlorophyll contents of *C. barbata* were slightly decrease with time, except day 5 samples. The high concentration treatment resulted in slight reduction in chlorophyll contents of *B. oleracea* at day 5 of Cd exposure. Chlorophyll contents slightly rose in the 8^{th} day samples, but then dramatically decreased after the plants were transferred to normal nutrient solution. Unlike the others, *E. prostrata* had slight reduction in the chlorophyll contents and the remarkable decrease was observed later from day 22 sample. This decrease was mainly from the reduction of chlorophyll a content, whereas the chlorophyll b content was rather stable, significant differences from the controls were also obtained.

In stressed plants, the proportion of chlorophyll a to chlorophyll b was slightly lower than the control plants except *E. prostrata* of which the ratio reduced from 2.5 - 2.7 to less than 2 compared to the controls when the duration was prolonged though Cd in solution was eliminated.

Table 4.3 Chlorophyll a content of four plant species with 0 and 5 ppm Cd treatment

Chl a	Cd	Exposure time			Duration after exposure		SL
(mg/gFW)	(ppm)	2d	11d	20d	7d (27)	14d (34)	
1. *I. aquatica*	0	0.502^{aAB}	0.480^{aAB}	0.553^{aA}	0.541^{aA}	0.442^{bB}	*
	5	0.486^{aA}	0.319^{bB}	0.322^{bB}	0.429^{bAB}	0.408^{bAB}	*
2. *B. oleracea*	0	0.294^{bA}	0.296^{bA}	0.226^{cA}	0.244^{cA}	0.256^{cdA}	NS
	5	0.282^{bA}	0.260^{bAB}	0.224^{cAB}	0.202^{cdAB}	0.188^{cdeB}	**
3. *E. prostrata*	0	0.451^{aB}	0.507^{aAB}	0.505^{aAB}	0.564^{aA}	0.566^{aA}	*
	5	0.447^{aA}	0.459^{aA}	0.224^{cB}	0.246^{cB}	0.179^{deB}	**
4. *C. barbata*	0	0.277^{bAB}	0.295^{bA}	0.196^{cdB}	0.223^{cAB}	0.265^{cAB}	*
	5	0.244^{bA}	0.235^{bA}	0.153^{dB}	0.166^{dB}	0.138^{eB}	**
SL		NS	NS	**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.4 Chlorophyll a content of four plant species with 0 and 20 ppm Cd treatment

Chl a	Cd	Exposure time			Duration after exposure		SL
(mg/gFW)	(ppm)	2d	5d	8d	7d (15)	14d (22)	
1. *I. aquatica*	0	0.502^{aAB}	0.531^{aAB}	0.423^{aB}	0.546^{aA}	0.512^{aAB}	**
	20	0.497^{aA}	0.398^{bcAB}	0.169^{dC}	0.309^{cBC}	0.346^{bB}	**
2. *B. oleracea*	0	0.294^{cA}	0.256^{eA}	0.313^{bcA}	0.253^{cA}	0.269^{cA}	NS
	20	0.291^{cA}	0.244^{eAB}	0.285^{cA}	0.162^{dC}	0.183^{deBC}	**
3. *E. prostrata*	0	0.451^{abAB}	0.440^{bAB}	0.397^{abB}	0.483^{abAB}	0.495^{aA}	**
	20	0.404^{bA}	0.453^{bA}	0.418^{aA}	0.429^{bA}	0.281^{cB}	**
4. *C. barbata*	0	0.277^{cAB}	0.339^{dA}	0.324^{abcA}	0.265^{cAB}	0.233^{cdB}	*
	20	0.186^{dB}	0.344^{cdA}	0.142^{dB}	0.128^{dB}	0.147^{eB}	**
SL		NS	**	**	*	*	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.5 Chlorophyll b content of four plant species with 0 and 5 ppm Cd treatment

Chl b	Cd	Exposure time			Duration after exposure		SL
(mg/gFW)	(ppm)	2d	11d	20d	7d (27)	14d (34)	
1. *I. aquatica*	0	0.169^{aAB}	0.172^{aAB}	0.196^{aA}	0.191^{bA}	0.150^{bB}	*
	5	0.172^{aA}	0.110^{bB}	0.108^{bB}	0.154^{bcAB}	0.137^{bAB}	*
2. *B. oleracea*	0	0.110^{bA}	0.077^{bA}	0.091^{bcA}	0.102^{cdA}	0.106^{bcA}	NS
	5	0.102^{bAB}	0.107^{bA}	0.094^{bAB}	0.092^{dAB}	0.076^{cB}	*
3. *E. prostrata*	0	0.166^{aC}	0.185^{aBC}	0.195^{aBC}	0.257^{aAB}	0.281^{aA}	**
	5	0.174^{aAB}	0.210^{aA}	0.113^{bB}	0.181^{bAB}	0.103^{bcB}	**
4. *C. barbata*	0	0.093^{bA}	0.100^{bA}	0.070^{cdA}	0.076^{dA}	0.092^{bcA}	NS
	5	0.086^{bA}	0.088^{bA}	0.058^{dB}	0.061^{dB}	0.050^{cB}	**
SL		NS	*	**	NS	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.6 Chlorophyll b content of four plant species with 0 and 20 ppm Cd treatment

Chl b	Cd	Exposure time			Duration after exposure		SL
(mg/gFW)	(ppm)	2d	5d	8d	7d (15)	14d (22)	
1. *I. aquatica*	0	0.169^{aAB}	0.186^{aAB}	0.143^{bB}	0.195^{aA}	0.179^{aAB}	**
	20	0.170^{aA}	0.135^{bAB}	0.054^{bC}	0.104^{cBC}	0.126^{bcAB}	**
2. *B. oleracea*	0	0.110^{bA}	0.100^{cA}	0.116^{bA}	0.089^{cdA}	0.103^{cdA}	NS
	20	0.116^{bA}	0.102^{cAB}	0.115^{aA}	0.070^{deB}	0.077^{deB}	**
3. *E. prostrata*	0	0.166^{aB}	0.163^{aB}	0.145^{bB}	0.174^{abAB}	0.203^{aA}	**
	20	0.145^{aA}	0.177^{aA}	0.151^{bA}	0.158^{bA}	0.146^{bA}	NS
4. *C. barbata*	0	0.093^{bA}	0.109^{bcA}	0.109^{bA}	0.092^{cdA}	0.081^{dA}	NS
	20	0.068^{cB}	0.121^{bcA}	0.051^{bB}	0.053^{eB}	0.053^{eB}	**
SL		NS	**	**	**	NS	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.7 Chlorophyll a+b content of four plant species with 0 and 5 ppm Cd treatment

Chl a+b	Cd	Exposure time			Duration after exposure		SL
(mg/gFW)	(ppm)	2d	11d	20d	7d (27)	14d (34)	
1. *I. aquatica*	0	0.670^{aAB}	0.651^{aAB}	0.749^{aA}	0.733^{aA}	0.593^{bB}	*
	5	0.658^{aA}	0.428^{bB}	0.429^{bB}	0.582^{bAB}	0.545^{bAB}	*
2. *B. oleracea*	0	0.404^{bA}	0.373^{bA}	0.317^{cA}	0.345^{cdA}	0.362^{cA}	NS
	5	0.384^{bA}	0.367^{bAB}	0.319^{cABC}	0.294^{dBC}	0.264^{cdc}	*
3. *E. prostrata*	0	0.617^{aB}	0.693^{aAB}	0.700^{aAB}	0.822^{aA}	0.847^{aA}	**
	5	0.621^{aA}	0.668^{aA}	0.337^{cB}	0.428^{cB}	0.282^{cdB}	**
4. *C. barbata*	0	0.370^{bAB}	0.395^{bA}	0.266^{cdB}	0.299^{dAB}	0.357^{cAB}	*
	5	0.330^{bA}	0.323^{bA}	0.211^{dB}	0.227^{dB}	0.189^{dB}	**
SL		NS	NS	**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.8 Chlorophyll a+b content of four plant species with 0 and 20 ppm Cd treatment

Chl a+b	Cd	Exposure time			Duration after exposure		SL
(mg/gFW)	(ppm)	2d	5d	8d	7d (15)	14d (22)	
1. *I. aquatica*	0	0.670^{aAB}	0.717^{aAB}	0.567^{aB}	0.741^{aA}	0.691^{aAB}	**
	20	0.666^{aA}	0.532^{bcAB}	0.223^{dC}	0.414^{cBC}	0.472^{bAB}	**
2. *B. oleracea*	0	0.404^{cA}	0.357^{deA}	0.429^{bcA}	0.342^{cA}	0.372^{cdA}	NS
	20	0.407^{cA}	0.345^{fAB}	0.401^{cA}	0.232^{dB}	0.259^{efB}	**
3. *E. prostrata*	0	0.617^{abAB}	0.604^{bAB}	0.543^{abB}	0.657^{abA}	0.697^{aA}	**
	20	0.549^{bAB}	0.630^{abA}	0.569^{aAB}	0.587^{bA}	0.427^{bcB}	**
4. *C. barbata*	0	0.370^{cAB}	0.448^{cdA}	0.434^{bcAB}	0.357^{cAB}	0.314^{deB}	*
	20	0.253^{dB}	0.466^{cA}	0.193^{dB}	0.181^{dB}	0.200^{fB}	**
SL		NS	**	**	*	*	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Comparing to the controls, Plants exposed to higher concentration of Cd led to severe reduction of chlorophyll contents. Chlorophyll a, b and a+b contents diminished 61, 63 and 61%, respectively in *I. aquatica*, 57, 53 and 56%, respectively in *C. barbata*. This greatest reduction was from the 8th day samples. At 5 ppm concentration, the 42, 45 and 53% reduction of chlorophyll a,b and a+b were observed in *I. aquatica* from the 20th day treatment, whereas *C. barbata* had maximum decrease of these contents (46, 48 and 46%) after having been transferred to normal nutrient solution for 14 days (the 34th day treatment).

In contrast, *E. prostrata* had dramatically decrease of the chlorophyll contents when it was subjected to toxic Cd for a long time (even when the Cd in solution was deprived). That is, at the final day of each treatment (the 34th and 22nd day for 5 and 20 ppm Cd respectively), the plants reached the maximum decrease and chlorosis was obviously observed (see appendix E). However, four times lower Cd concentration, but longer in exposure time, had more influence on the reduction, the 68, 63 and 67% reduction of the 34th day samples compared to the 43, 28 and 39% decrease of chlorophyll a, b and a+b, respectively from the 22nd day samples. *B. oleracea* also had a 30% reduction of chlorophyll contents at this stage (Figs 4.3 and 4.4).

4.1.3 Relative Water Content (RWC)

Relative water content of the control plants was absolutely greater than 88%. Addition of Cd to the nutrient solution led to the decrease of RWC in plant tissues (Tables 4.9-4.10 and Figs 4.5-4.6). The RWC of the plants was in the order: *C. barbata* > *E. prostrata* and *B. oleracea* > *I. aquatica*, when the plants were subjected to the same level of Cd. However, all the plants could regain the water more effectively after Cd removal. *I. aquatica* was the most effective The reduction was maximum after exposed to 5 and 20 ppm Cd for 20 and 8 days, respectively with the exception of *B. oleracea* which had low RWC, but it was insignificantly different from other duration.

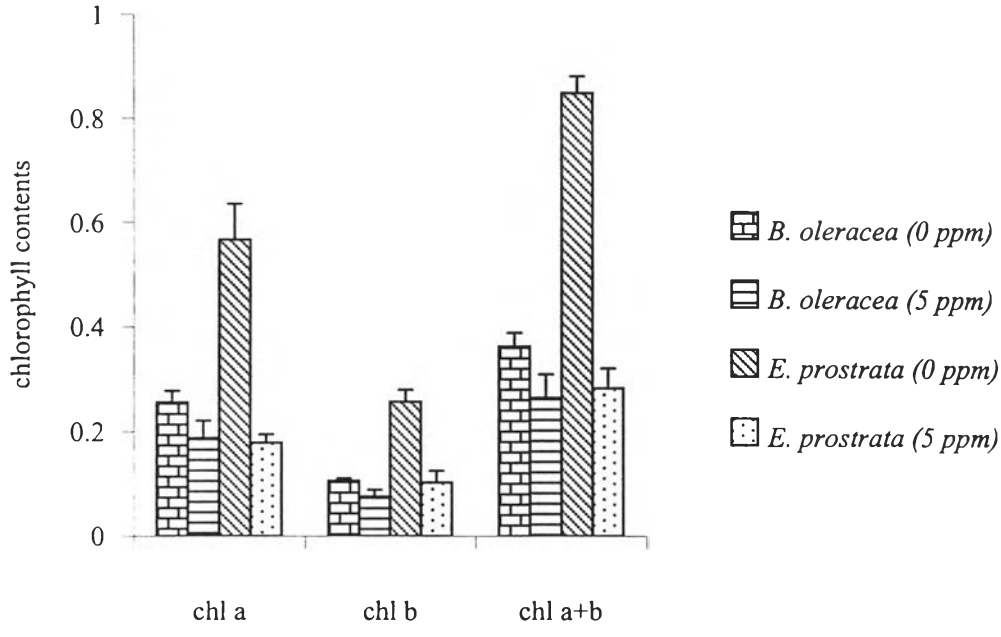

Fig 4.3 Leaf chlorophyll a, b and a+b contents of *B. oleracea* and *E. prostrata* at day 14 after Cd elimination of the 5 ppm treatment; vertical bars indicate SE.

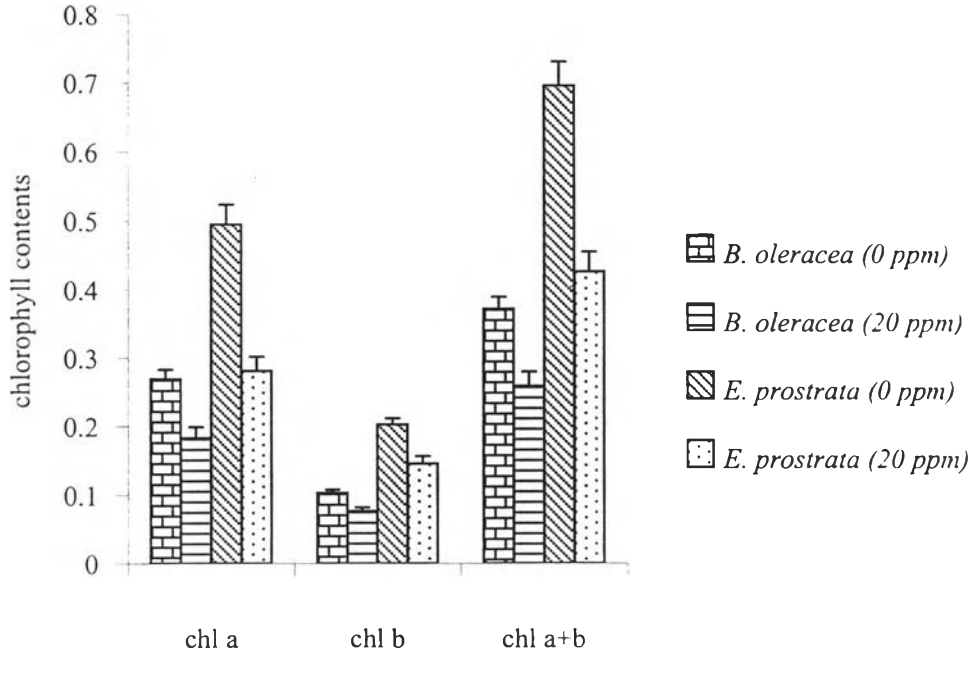

Fig 4.4 Leaf chlorophyll a, b and a+b contents of *B. oleracea* and *E. prostrata* at day 14 after Cd elimination of the 20 ppm treatment; vertical bars indicate SE.

Table 4.9 Relative Water Content (RWC) of four plant species with 0 and 5 ppm Cd treatment

RWC (%)	Cd	Exposure time			Duration after exposure		SL
	(ppm)	2d	11d	20d	7d (27)	14d (34)	
1. *I. aquatica*	0	93.823^{abA}	94.587^{abA}	94.270^{abA}	92.427^{abA}	94.610^{abA}	NS
	5	89.473^{bAB}	69.333^{cB}	83.440^{cAB}	96.780^{aA}	91.603^{bcA}	**
2. *B. oleracea*	0	93.747^{abAB}	98.460^{aA}	91.783^{abA}	88.587^{bB}	88.690^{cB}	**
	5	89.333^{bA}	83.450^{bA}	87.003^{bcA}	88.303^{bA}	88.440^{cA}	NS
3. *E. prostrata*	0	97.737^{aA}	92.397^{abBC}	91.977^{abC}	96.897^{aAB}	93.203^{bcABC}	*
	5	97.607^{aA}	91.453^{abb}	90.233^{abcB}	93.390^{abAB}	94.777^{abAB}	**
4. *C. barbata*	0	99.223^{aA}	98.923^{aA}	96.017^{aA}	95.580^{aA}	98.973^{aA}	NS
	5	94.830^{abA}	96.297^{aA}	95.183^{abA}	91.573^{abA}	99.207^{aA}	NS
SL		NS	**	NS	NS	NS	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.10 Relative Water Content (RWC) of four plant species with 0 and 20 ppm Cd treatment

RWC (%)	Cd	Exposure time			Duration after exposure		SL
	(ppm)	2d	5d	8d	7d (15)	14d (22)	
1. *I. aquatica*	0	93.823^{abA}	94.477^{aA}	94.327^{aA}	92.463^{aA}	91.600^{bcA}	NS
	20	85.347^{bA}	62.510^{cB}	67.513^{cB}	90.230^{abA}	93.543^{bB}	**
2. *B. oleracea*	0	93.747^{abAB}	97.053^{aA}	98.767^{aA}	91.820^{aB}	91.200^{bcB}	*
	20	75.607^{cA}	74.620^{bcA}	73.670^{bcA}	82.393^{bA}	89.557^{cA}	NS
3. *E. prostrata*	0	97.737^{aA}	98.413^{aA}	94.760^{aAB}	92.123^{aB}	92.187^{bcB}	**
	20	93.667^{abA}	83.597^{abAB}	68.790^{cB}	88.890^{abAB}	92.140^{bcA}	*
4. *C. barbata*	0	99.223^{aA}	96.297^{aA}	96.957^{aA}	96.627^{aA}	100.00^{aA}	NS
	20	98.097^{aA}	88.707^{abAB}	86.797^{abB}	95.653^{aAB}	99.020^{aA}	*
SL		NS	NS	NS	NS	NS	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

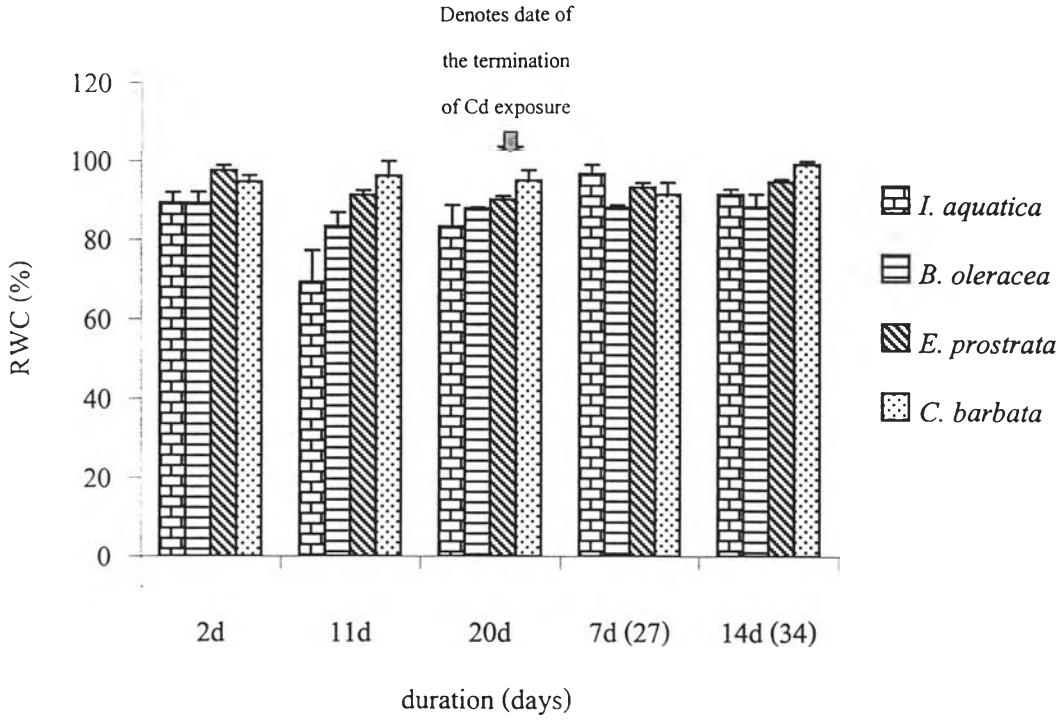

Fig 4.5 RWC of four plant species exposed to 5 ppm Cd; vertical bars indicate SE.

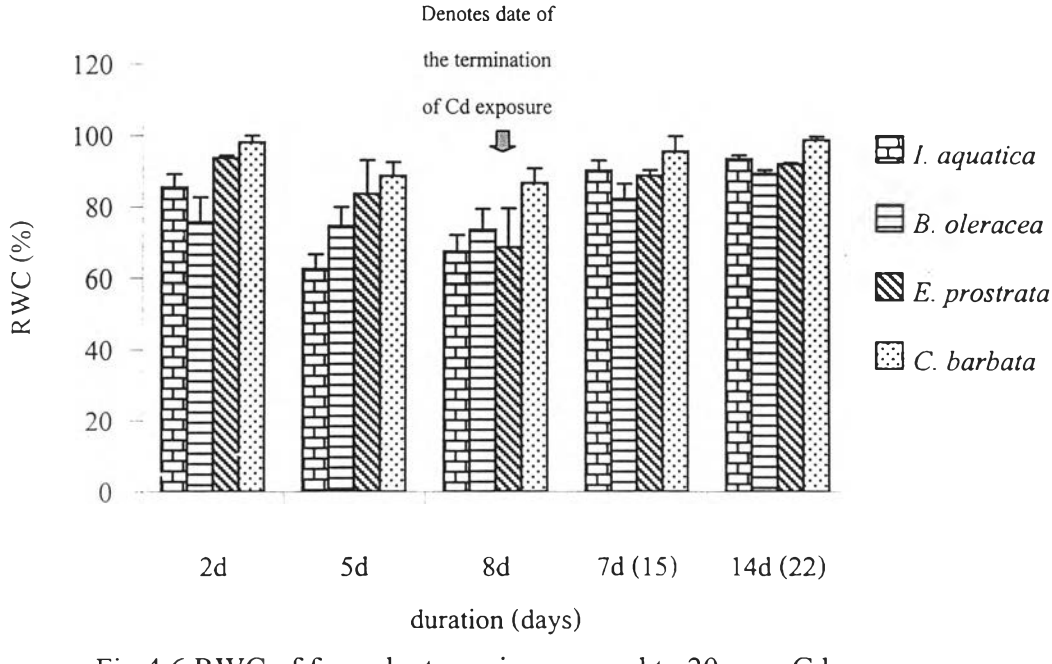

Fig 4.6 RWC of four plant species exposed to 20 ppm Cd; vertical bars indicate SE.

4.1.4 The number of leaves

The number of leaves of the non-stressed plants increased with time. *E. prostrata* produced the highest value due to development of branches. On the other hand, the broad leaf vegetable, *B. oleracea*, normally never produced more than 10 leaves (Tables 4.11-4.12). The plants responded to the Cd stress by decreasing the number of leaves. Tables 4.11 and 4.12 revealed that higher concentration strongly influenced the development of the new leaves. In other words, Plants exposed to 5 ppm Cd recovered quickly and produced new leaves rapidly when stress was released. Nevertheless, this was not observed in the case of *E. prostrata*. *E. prostrata* exposed to 20 ppm Cd had more leaves than the ones exposed to 5 ppm Cd, but exposure time was longer.

4.1.5 Leaf area

Leaf area of the healthy plants soared up with time and reached a maximum value when the plants fully matured. *I. aquatica* , for example, had maximum leaf area at the 27^{th} day of treatment (about 2 months from germination stage). Maximum leaf area was measured from *E. prostrata*'s leaves.

Cadmium suppressed the expansion of leaf. Leaf area reduction was observed after exposure to Cd of both concentrations (Tables 4.13 and 4.14). *I. aquatica* and *C. barbata* had lowest leaf area at the last day of Cd exposure, whereas *E. prostrata* and *B. oleracea* had extensively reduction in leaf area to a lowest point after having been transferred to normal nutrient solution for 7 days. However, almost all species had lowest leaf area at the 7^{th} day after Cd was removed from the solution when compared to the control plants.

Table 4.11 The number of leaves of four plant species with 0 and 5 ppm Cd treatment

Number of leaves	Cd (ppm)	Exposure time 2d	11d	20d	Duration after exposure 7d (27)	14d (34)	SL
1. *I. aquatica*	0	11.780^{bcB}	14.333^{dB}	26.220^{cdA}	27.003^{dA}	31.000^{dA}	**
	5	12.780^{bcAB}	5.557^{dB}	7.557^{dB}	14.557^{deAB}	18.667^{ea}	**
2. *B. oleracea*	0	6.777^{cB}	8.777^{dAB}	9.333^{dA}	9.000^{eAB}	7.777^{fAB}	**
	5	6.887^{cA}	6.667^{dA}	4.557^{dAB}	4.113^{eB}	4.667^{fAB}	**
3. *E. prostrata*	0	40.780^{aC}	102.330^{aB}	157.667^{aA}	115.333^{aAB}	120.667^{aAB}	**
	5	47.443^{aA}	69.557^{bA}	53.777^{bA}	50.997^{bA}	61.777^{bA}	NS
4. *C. barbata*	0	14.890^{bcC}	30.890^{cB}	42.777^{bcA}	44.890^{bcA}	38.223^{cAB}	**
	5	21.110^{bBC}	15.890^{cdC}	21.223^{cdBC}	29.333^{cdA}	26.780^{dAB}	**
SL		NS	NS	**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.12 The number of leaves of four plant species with 0 and 20 ppm Cd treatment

Number of	Cd	Exposure time			Duration after exposure		SL
Leaves	(ppm)	2d	5d	8d	7d (15)	14d (22)	
1. *I. aquatica*	0	11.780^{bcC}	17.003^{bBC}	15.000^{cdBC}	19.443^{dAB}	24.333^{deA}	**
	20	11.887^{bcA}	9.443^{cdAB}	6.777^{deB}	6.663^{efB}	9.053^{efAB}	*
2. *B. oleracea*	0	6.777^{cB}	7.557^{cdAB}	7.443^{deAB}	9.333^{eA}	8.447^{efAB}	**
	20	6.890^{cA}	4.447^{dB}	3.777^{eB}	3.223^{fB}	3.890^{fB}	**
3. *E. prostrata*	0	40.780^{abB}	49.777^{aB}	109.223^{aA}	115.777^{aA}	129.667^{aA}	**
	20	42.997^{aB}	45.333^{aB}	66.890^{bAB}	73.667^{bA}	76.777^{bA}	**
4. *C. barbata*	0	14.890^{bC}	16.110^{bC}	22.333^{cBC}	33.667^{cB}	47.557^{cA}	**
	20	15.777^{bBC}	11.110^{bcC}	10.223^{deC}	23.887^{dAB}	30.557^{dA}	**
SL		NS	NS	**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.13 Leaf area of four plant species with 0 and 5 ppm Cd treatment

Leaf area (cm^2)	Cd	Exposure time			Duration after exposure		SL
	(ppm)	2d	11d	20d	7d (27)	14d (34)	
1. *I. aquatica*	0	162.740^{abC}	196.917^{cdBC}	385.657^{bcAB}	555.247^{bA}	364.857^{cB}	**
	5	132.973^{bcA}	65.567^{eA}	80.880^{dA}	179.387^{dA}	138.787^{dA}	NS
2. *B. oleracea*	0	148.130^{bcB}	285.620^{cB}	505.600^{bA}	548.997^{bA}	575.147^{bA}	**
	5	146.163^{bcA}	252.707^{cA}	202.127^{cdA}	144.177^{dA}	297.633^{cdA}	NS
3. *E. prostrata*	0	236.637^{aB}	629.707^{aB}	1006.497^{aA}	860.520^{aB}	1064.930^{aA}	**
	5	175.867^{abA}	392.907^{bA}	350.640^{bcA}	238.860^{cdA}	286.150^{cdA}	NS
4. *C. barbata*	0	109.873^{bcC}	159.813^{dC}	368.130^{bcB}	348.720^{cB}	542.847^{bA}	**
	5	81.567^{cBC}	67.680^{eC}	90.143^{dBC}	134.493^{dAB}	175.167^{dA}	**
SL		NS	*	*	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.14 Leaf area of four plant species with 0 and 20 ppm Cd treatment

Leaf area (cm^2)	Cd	Exposure time			Duration after exposure		SL
	(ppm)	2d	5d	8d	7d (15)	14d (22)	
1. *I. aquatica*	0	162.740^{abA}	228.253^{bAB}	267.543^{abAB}	252.290^{bAB}	334.970^{cA}	*
	20	134.290^{bcA}	100.840^{cdA}	73.977^{dA}	67.927^{dA}	80.240^{eA}	NS
2. *B. oleracea*	0	148.130^{bcC}	191.957^{bcBC}	278.607^{abABC}	367.723^{aAB}	394.01^{bcA}	**
	20	126.807^{bcAB}	81.817^{dB}	113.050^{cdAB}	101.770^{cdAB}	194.323^{dA}	**
3. *E. prostrata*	0	236.640^{aC}	372.977^{aB}	374.893^{aB}	414.990^{aB}	543.847^{aA}	**
	20	169.397^{abA}	220.893^{bA}	215.517^{bcA}	182.100^{bcA}	255.900^{bA}	NS
4. *C. barbata*	0	109.873^{bcB}	124.747^{bcdB}	102.980^{cdB}	190.387^{bcB}	455.160^{bA}	**
	20	65.903^{cAB}	59.377^{dAB}	27.593^{dB}	61.787^{dAB}	107.697^{eA}	**
SL		NS	NS	NS	NS	NS	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

4.1.6 Root to Shoot Ratio

Tables 4.15 and 4.16 show that *E. prostrata* had highest Root to Shoot Ratio and this ratio was significantly different from the others.

Five ppm Cd treatment slightly increased the Root to Shoot Ratio of *I. aquatica* from 1.05 to 1.5 over the controls'. Increment from 1.08- to 3.14-fold was obtained from the 20 ppm Cd treatment, but this increase was insignificant. *B. oleracea* also showed a slight increase in this ratio after Cd exposure. However, higher ratio was observed in the high concentration treatment. On the other hand, 4-29% reductions in this ratio were observed in *E. prostrata* at both Cd levels, whereas *C. barbata* had rather fluctuated trend.

4.1.7 Cadmium accumulation

Cadmium content in root

Cadmium content in root of the control plants were much lower as compared with stressed plants. The concentration of Cd detected in the root tissues was beyond the concentration added in the Hoagland's solution. In general, studied plants accumulated Cd rapidly during the onset of stress. However, *B. oleracea* significantly accumulated more Cd than the others (Tables 4.17 and 4.18). The high Cd content was observed in the root within 2 days of Cd exposure. A 18,000-fold of Cd accumulation was detected in *B. oleracea*'s roots at 8-day period as compared with the control plants. The maximum value for each Cd treatment was obtained when the plants had been exposed to this metal for 20 days (the 5ppm treatment) and 8 days (the 20 ppm treatment) (Figs 4.8 and 4.9). At this stage the studied plants showed severe root damage. Rotten roots of *I. aquatica* and *E. prostrata* was clearly observed (see appendix E).

Table 4.15 Root to Shoot Ratio of four plant species with 0 and 5 ppm Cd treatment

Root to Shoot Ratio	Cd (ppm)	Exposure time 2d	11d	20d	Duration after exposure 7d (27)	14d (34)	SL
1. *I. aquatica*	0	0.217^{bcA}	0.123^{dC}	0.190^{bcAB}	0.150^{cBC}	0.152^{dBC}	*
	5	0.230^{bcA}	0.165^{dA}	0.223^{bcA}	0.225^{bA}	0.168^{dA}	NS
2. *B. oleracea*	0	0.223^{bcA}	0.178^{cdAB}	0.152^{cB}	0.208^{bAB}	0.174^{dAB}	**
	5	0.202^{cdA}	0.233^{bcA}	0.206^{bcA}	0.239^{bA}	0.196^{cdA}	NS
3. *E. prostrata*	0	0.299^{aAB}	0.355^{aA}	0.350^{aA}	0.310^{aAB}	0.257^{bB}	**
	5	0.315^{aAB}	0.268^{bB}	0.256^{bB}	0.260^{abB}	0.358^{aA}	**
4. *C. barbata*	0	0.154^{dC}	0.144^{dC}	0.189^{bcBC}	0.247^{bAB}	0.272^{bA}	**
	5	0.268^{abA}	0.227^{bcAB}	0.184^{bcB}	0.223^{bAB}	0.241^{bcAB}	**
SL		*	**	NS	*	*	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.16 Root to Shoot Ratio of four plant species with 0 and 20 ppm Cd treatment

Root to Shoot Ratio	Cd (ppm)	Exposure time 2d	5d	8d	Duration after exposure 7d (15)	14d (22)	SL
1. *I. aquatica*	0	0.217^{cA}	0.157^{dA}	0.177^{cA}	0.143^{bA}	0.195^{cdA}	NS
	20	0.235^{cA}	0.320^{aA}	0.291^{bA}	0.449^{aA}	0.235^{bcdA}	NS
2. *B. oleracea*	0	0.223^{cA}	0.168^{dAB}	0.157^{cB}	0.183^{bAB}	0.160^{dB}	**
	20	0.206^{cdB}	0.242^{bcAB}	0.306^{abA}	0.274^{abAB}	0.212^{bcdB}	**
3. *E. prostrata*	0	0.299^{abA}	0.312^{aA}	0.384^{aA}	0.385^{abA}	0.396^{aA}	NS
	20	0.364^{aA}	0.299^{abA}	0.309^{abA}	0.296^{abA}	0.283^{bA}	NS
4. *C. barbata*	0	0.154^{dB}	0.213^{cdAB}	0.150^{cB}	0.171^{bAB}	0.228^{bcdA}	**
	20	0.178^{cdAB}	0.267^{abcA}	0.133^{cB}	0.188^{bAB}	0.272^{bcB}	**
SL		NS	**	**	NS	*	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.17 Cadmium content in root exposed to 0 and 5 ppm Cd treatment

Root Cd (ppm)	Cd (ppm)	Exposure time		Duration after exposure	SL
		2d	20d	14d (34)	
1. *I. aquatica*	0	0.163^{dA}	0.747^{dA}	0.917^{cA}	NS
	5	331.700^{cB}	1254.077^{bA}	446.660^{bB}	**
2. *B. oleracea*	0	0.417^{dAB}	0.008^{dB}	0.663^{cA}	*
	5	1031.503^{aB}	3472.937^{aA}	2499.96^{aA}	**
3. *E. prostrata*	0	0.830^{dA}	0.457^{dA}	0.413^{cA}	NS
	5	351.200^{cB}	1124.003^{bA}	341.897^{bB}	**
4. *C. barbata*	0	0.373^{dA}	0.573^{dA}	0.290^{cA}	NS
	5	476.203^{bB}	772.000^{cA}	303.330^{bC}	**
SL		**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.18 Cadmium content in root exposed to 0 and 20 ppm Cd treatment

Root Cd (ppm)	Cd (ppm)	Exposure time		Duration after exposure	SL
		2d	8d	14d (22)	
1. *I. aqu0atica*	0	0.163^{cB}	0.773^{dAB}	1.080^{dA}	*
	20	1116.260^{bAB}	1638.237^{cA}	607.700^{cB}	**
2. *B. oleracea*	0	0.417^{cA}	0.248^{dA}	0.417^{dA}	NS
	20	3418.147^{aB}	4500.090^{aA}	2494.550^{aC}	**
3. *E. prostrata*	0	0.830^{cA}	0.247^{dB}	0.790^{dA}	*
	20	1043.730^{bB}	2144.557^{bA}	977.697^{bB}	**
4. *C. barbata*	0	0.373^{cA}	0.883^{dA}	0.490^{dA}	NS
	20	1151.603^{bAB}	1804.983^{cA}	589.967^{cB}	**
SL		**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

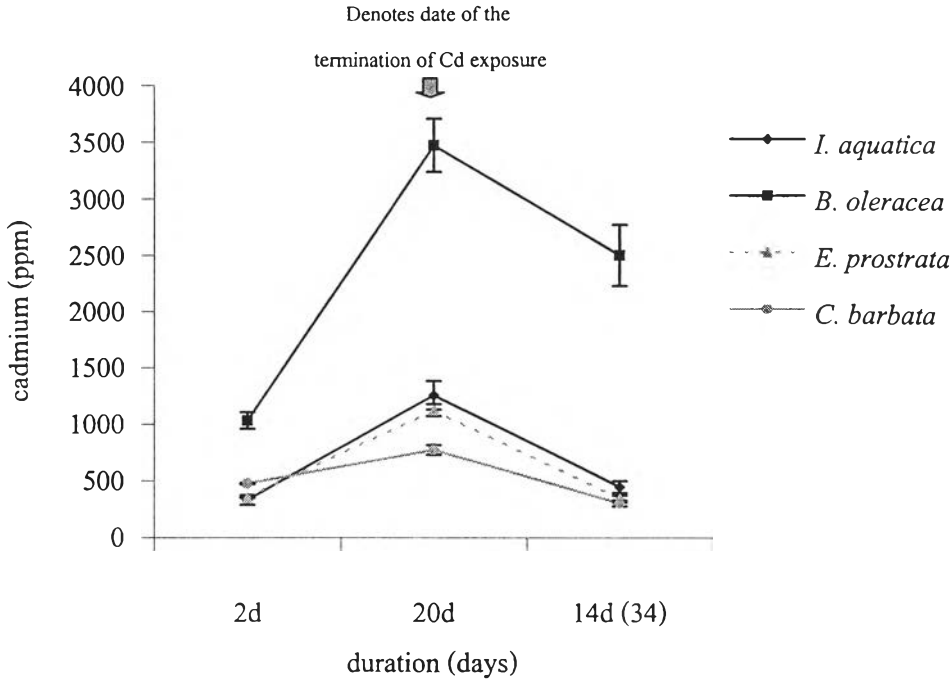

Fig 4.7 Cadmium accumulation in roots of four plants species exposed to 5 ppm Cd; vertical bars indicate SE.

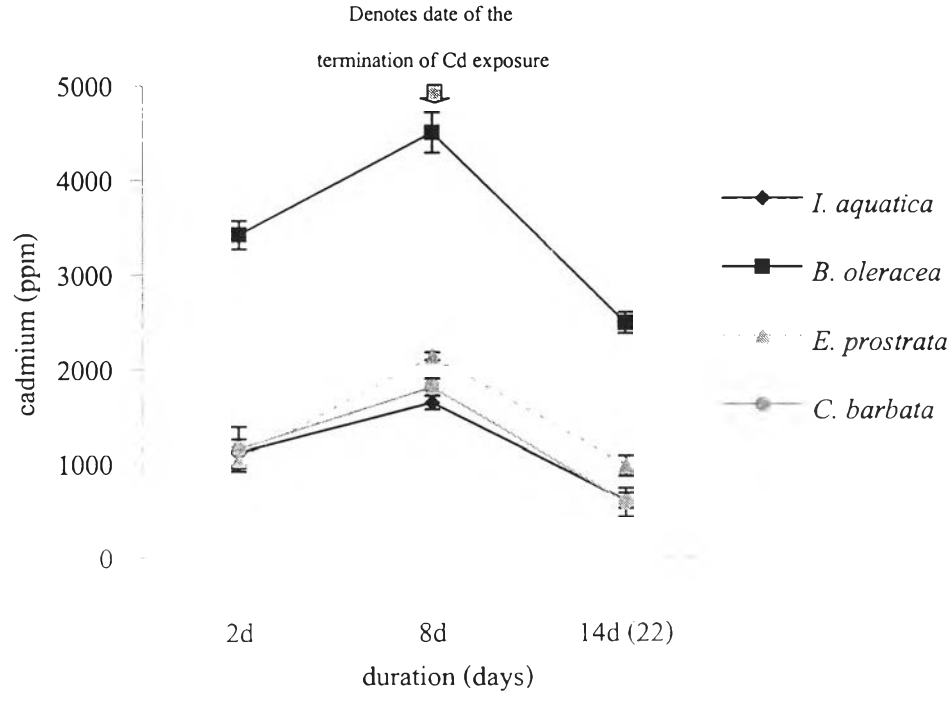

Fig 4.8 Cadmium accumulation in roots of four plant species exposed to 20 ppm Cd; vertical bars indicate SE.

After the plants had been transferred to Cd-free culture solution, the root Cd content rapidly dropped. The reduction of 60% or more was found in root samples of *I. aquatica*, *E. prostrata* and *C. barbata*. Elimination of Cd in solution also lowered the Cd content in root of *B. oleracea*, but a slight decrease was observed. Exposure to 5ppm Cd resulted in a 28% reduction of root Cd content compared with the 42% reduction when plant were grown in 20 ppm Cd containing nutrient solution.

Cadmium content in shoot

Tables 4.19 and 4.20 indicate that *E. prostrata* being exposed to Cd to some extent had insignificant difference of shoot Cd relative to *B. oleracea*. Shoot Cd content in *B. oleracea* and *C. barbata* lowered after elimination of Cd in solution. However, contrary results were obtained from *I. aquatica* (at both levels of Cd) and *E. prostrata* (at 20 ppm Cd). 2.8- and 1.4-fold increases in shoot Cd content were found at 20 ppm Cd concentration (Figs 4.9 and 4.10). Considering the proportion of shoot Cd and root Cd content, *E. prostrata*, unlike the other species, markedly increased its shoot Cd content when the stress proceeded.

Table 4.19 Cadmium content in shoot of the plants exposed to 0 and 5 ppm Cd treatment

Shoot Cd (ppm)	Cd (ppm)	Exposure time		Duration after exposure	SL
		2d	20d	14d (34)	
1. *I. aquatica*	0	0.183^{dA}	0.513^{cA}	0.307^{dA}	NS
	5	24.623^{cB}	51.527^{bA}	52.170^{bA}	*
2. *B. oleracea*	0	0.25^{dA}	0.08^{cA}	0.060^{dA}	NS
	5	112.823^{aB}	214.263^{aA}	129.913^{aB}	**
3. *E. prostrata*	0	0.277^{dA}	0.457^{cA}	0.457^{dA}	NS
	5	32.290^{bC}	206.387^{aA}	114.657^{aB}	**
4. *C. barbata*	0	0.250^{dAB}	0.500^{cA}	0^{dB}	*
	5	22.050^{cB}	36.130^{bA}	26.487^{cB}	**
SL		**	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

Table 4.20 Cadmium content in shoot of the plants exposed to 0 and 20 ppm Cd treatment

Shoot Cd (ppm)	Cd (ppm)	Exposure time		Duration after exposure	SL
		2d	8d	14d (22)	
1. *I. aquatica*	0	0.183^{dB}	0.693^{cA}	0.393^{cAB}	*
	20	18.717^{cB}	16.837^{cB}	47.957^{bA}	**
2. *B. oleracea*	0	0.25^{dA}	0.040^{cA}	0.060^{cA}	NS
	20	57.957^{aB}	138.390^{aA}	126.900^{aA}	*
3. *E. prostrata*	0	0.277^{dB}	0.040^{cB}	1.017^{cA}	**
	20	35.883^{bB}	87.967^{bAB}	125.213^{aA}	**
4. *C. barbata*	0	0.250^{dA}	0^{cA}	0^{cA}	NS
	20	37.027^{bB}	129.843^{abA}	63.730^{bB}	*
SL		*	**	**	

** = significant at $P \leq 0.01$

* = significant at $P \leq 0.05$

NS = not significant

The superscript letter following the number indicate similar or different mean in the same column (common letter) or in the same row (capital letter).

Duration after exposure is the duration after the plants had been transferred to Cd-free nutrient solution.

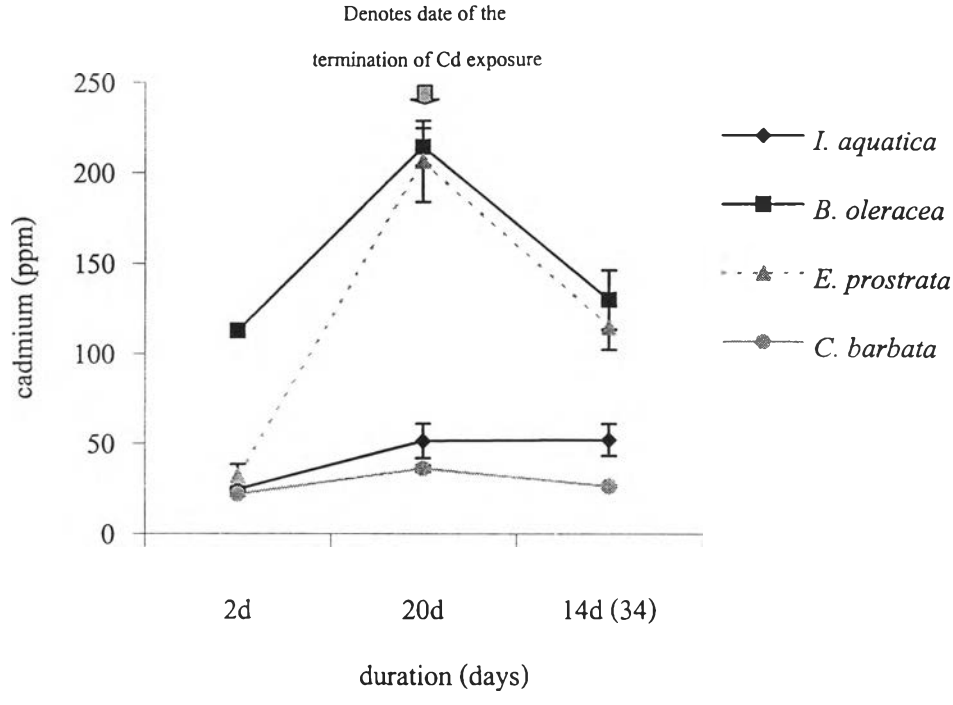

Fig 4.9 Cadmium accumulation in shoots of four plant species exposed to 5 ppm Cd; vertical bars indicate SE.

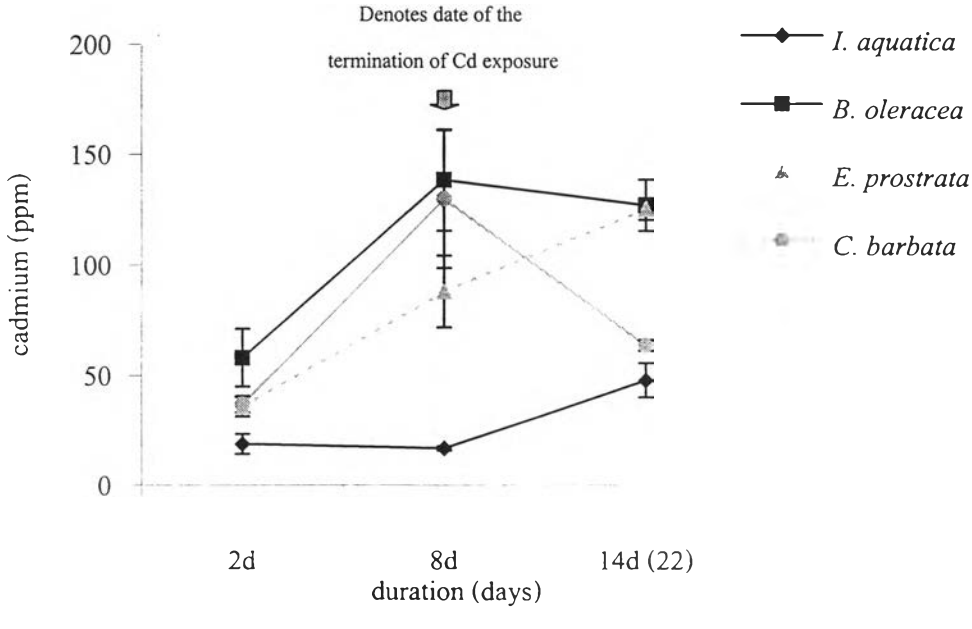

Fig 4.10 Cadmium accumulation in shoots of four plant species exposed to 20 ppm Cd; vertical bars indicate SE.

4.2 Relationship of treatments and parameters

Tables 4.21 and 4.22 show the correlation between all parameters and each treatment (0 and 5 ppm Cd and 0 and 20 ppm Cd). Cadmium content in root and shoot were highly correlated with each treatment at every stages of Cd exposure, whereas leaf area only correlated to the treatment after exposure for some periods. Similar results were found in the chlorophyll contents. In contrast, RWC only correlated with the treatments when the Cd was maintained in the culture solution, while proline showed significant correlation when plant reached the maximum stress at day 20 and day 8 for 5 and 20 ppm treatment, respectively.

As for the correlation pairs among individual parameters, the selected pairs were Cd content in plant tissues related to all parameters as shown in Tables 4.23 to 4.26, and RWC related to proline as presented in Table 4.27. All parameters, except proline, were inversely related to Cd contents in plants. Root Cd content was highly correlated with proline almost all of the studied period. Insignificant was found in 20 ppm Cd treatment at day 22. RWC followed the same trend like proline, but was only significant at $P \leq 0.05$ of the 5 ppm Cd treatment. Shoot Cd content was highly correlated only at the final day of Cd exposure. However, the correlation between shoot Cd and RWC was not observed. Leaf area, chlorophyll a and chlorophyll a+b were correlated with the plant Cd content when the stress had developed for a long time. The high concentration treatment was more likely to correlate with these parameters. Obviously, root Cd content was highly correlated with shoot Cd content.

Proline was highly correlated with RWC when *I. aquatica*, *B. oleracea* and *E. prostrata* exposed to 20 ppm Cd in nutrient solution (Table 4.27). At 5 ppm Cd in the nutrient solution, only *I. aquatica* showed significant relationship between these two parameters. In contrast, no significant relationship of these parameters was observed in *C. barbata*.

Table 4.21 Correlation of each parameter with the 0 and 5 ppm Cd treatment

Parameters	Treatment (0 and 5 ppm Cd)				
	2d	11d	20d	7d (27)	14d (34)
Proline (μmol/gFW)	0.378	0.422*	0.430*	0.301	0.220
Chlrophyll a (mg/gFW)	-0.075	-0.345	-0.489*	-0.435*	-0.531**
Chlorophyll b (mg/gFW)	-0.016	-0.045	-0.443*	-0.257	-0.475*
Chlorophyll a+b (mg/gFW)	-0.059	-0.257	-0.479*	-0.392	-0.524**
RWC (%)	-0.388	-0.523**	-0.425*	-0.105	-0.040
No. of leaves	0.115	-0.216	-0.383	-0.355	-0.302
Leaf area (cm^2)	-0.274	-0.344	-0.656**	-0.805**	-0.713**
R/S ratio	0.272	0.160	-0.022	0.081	0.192
Root Cd (ppm)	0.799**	-	0.734**	-	0.557**
Shoot Cd (ppm)	0.664**	-	0.723**	-	0.781**

** = Significant at $P \leq 0.01$

* = Significant at $P \leq 0.05$

Table 4.22 Correlation of each parameter with the 0 and 20 ppm Cd treatment

Parameters	Treatment (0 and 20ppm Cd)				
	2d	5d	8d	7d (15)	14d (22)
Proline (μmol/gFW)	0.379	0.390	0.451*	0.330	0.150
Chlrophyll a (mg/gFW)	-0.162	-0.165	-0.506*	-0.445*	-0.531**
Chlorophyll b (mg/gFW)	-0.133	-0.084	-0.451*	-0.409*	-0.404*
Chlorophyll a+b (mg/gFW)	-0.155	-0.147	-0.493*	-0.439*	-0.502**
RWC (%)	-0.462*	-0.706**	-0.769**	-0.349	-0.024
No. of leaves	0.030	-0.152	-0.232	-0.240	-0.273
Leaf area (cm^2)	-0.338	-0.532**	-0.600**	-0.768**	-0.857**
R/S ratio	0.166	0.540**	0.224	0.279	0.037
Root Cd (ppm)	0.757**	-	0.836**	-	0.718**
Shoot Cd (ppm)	0.833**	-	0.759**	-	0.878**

** = Significant at $P \leq 0.01$

* = Significant at $P \leq 0.05$

Table 4.23 Correlation between each parameter and root Cd content of the 0 and 5 ppm Cd treatment

Parameters	Cd content in root (0 and 5 ppm Cd treatment)		
	2d	20d	14d (34)
Proline (μmol/gFW)	0.429*	0.789**	0.611**
Chlrophyll a(mg/gFW)	-0.321	-0.333	0.379
Chlorophyll b(mg/gFW)	-0.281	-0.283	-0.332
Chlorophyll a+b (mg/gFW)	-0.311	-0.322	-0.371
RWC (%)	-0.497*	-0.477*	-0.476*
No. of leaves	-0.151	-0.382	-0.394
Leaf area (cm^2)	-0.189	-0.459*	-0.335
R/S ratio	-0.023	-0.063	-0.151

** = Significant at $P \leq 0.01$ * = Significant at $P \leq 0.05$

Table 4.24 Correlation between each parameter and root Cd content of the 0 and 20 ppm Cd treatment

Parameters	Cd content in root (0 and 20 ppm Cd treatment)		
	2d	8d	14d (22)
Proline (μmol/gFW)	0.688**	0.806**	0.237
Chlrophyll a(mg/gFW)	-0.251	-0.298	-0.499*
Chlorophyll b(mg/gFW)	-0.165	-0.189	-0.378
Chlorophyll a+b (mg/gFW)	-0.229	-0.270	-0.472*
RWC (%)	-0.710**	-0.666**	-0.343
No. of leaves	-0.227	-0.266	-0.325
Leaf area (cm^2)	-0.268	-0.464*	-0.532**
R/S ratio	-0.055	0.296	-0.067

** = Significant at $P \leq 0.01$ * = Significant at $P \leq 0.05$

Table 4.25 Correlation between each parameter and shoot Cd content of the 0 and 5 ppm treatment

Parameters	Cd content in root (0 and 5 ppm Cd treatment)		
	2d	20d	14d (34)
Proline (μmol/gFW)	0.447*	0.617**	0.384
Chlrophyll a(mg/gFW)	-0.260	-0.356	-0.496*
Chlorophyll b(mg/gFW)	-0.220	-0.203	-0.372
Chlorophyll a+b (mg/gFW)	-0.250	-0.317	-0.466*
RWC (%)	-0.460*	-0.386	-0.257
No. of leaves	-0.194	-0.234	-0.214
Leaf area (cm^2)	-0.069	-0.362	-0.442*
R/S ratio	-0.084	0.076	-0.295
Root Cd (ppm)	0.952**	0.826**	0.749**

** = Significant at $P \leq 0.01$ * = Significant at $P \leq 0.05$

Table 4.26 Correlation between each parameter and root Cd content of the 0 and 20 ppm treatment

Parameters	Cd content in root (0 and 20 ppm Cd treatment)		
	2d	8d	14d (22)
Proline (μmol/gFW)	0.396	0.569**	0.306
Chlrophyll a(mg/gFW)	-0.348	-0.287	-0.515**
Chlorophyll b(mg/gFW)	-0.283	-0.191	-0.315
Chlorophyll a+b (mg/gFW)	-0.332	-0.262	-0.465*
RWC (%)	-0.389	-0.356	-0.217
No. of leaves	-0.034	-0.205	-0.147
Leaf area (cm^2)	-0.281	-0.486*	-0.603**
R/S ratio	0.066	-0.007	0.052
Root Cd (ppm)	0.889**	0.826**	0.868**

** = Significant at $P \leq 0.01$ * = Significant at $P \leq 0.05$

Table 4.27 Correlation between RWC and proline accumulation at each studied period

Treatment	*I. aquatica*	*B. oleracea*	*E. prostrata*	*C. barbata*
0 and 5 ppm Cd				
2d	0.520	0.289	-0.262	0.176
11d	-0.979**	-0.547	-0.192	-0.230
20d	-0.876*	-0.473	-0.430	-0.437
7d (27)	-0.245	-0.134	-0.513	0.042
14d (34)	0.585	-0.873*	0.418	-0.188
0 and 20 ppm Cd				
2d	-0.555	-0.958**	-0.921**	0.444
5d	-0.787	-0.904*	-0.972**	-0.798
8d	-0.913**	-0.978**	-0.926**	-0.780
7d (15)	-0.840*	-0.974**	-0.700	0.006
14d (22)	0.193	0.412	-0.045	0.447

** = Significant at $P \leq 0.01$

* = Significant at $P \leq 0.05$