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Original article

Evolution of ability of remediation heavy metal Cadmium by some of plant species and biochar in drought stress conditions

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Extended abstract

Introduction
Environmental stresses such as drought, temperature, heavy metals and salinity greatly reduce plant growth and development, among non-biological stresses, drought stress is one of the environmental factors which limits crop production and reduces average yield by 50% or more (Wang et al.,2 003). Heavy metals are another environmental stress that in recent years as it has become one of the biggest problems of the agricultural sector. Due to technical and economic limitations of heavy metal removal methods, the search for new methods has received a great deal of attention and in this regard biological absorption as a new method has received special attention(Maleki and Zarasvand, 2008).

Materials and methods
In order to Evolution Ability of Remediation Heavy Metal Cadmium by Some of Plant Species and Biochar in drought stress conditions experimental in years 2017-2018 was carried out for two years in the research farm of the Faculty of Agriculture, Islamic Azad University, Karaj Branch. The experiment was factorial in a completely randomized design with 3 replications. Experimental factors included cadmium chloride salt at four levels (control, 10 mg.kg^{-1}, 20 mg.kg^{-1}, 30 mg.kg^{-1}), Biochar at three levels (control, biochar at the time of first year planting, biochar after first year harvest and at the time of second year planting), 3 crop species (clover, alfalfa, canola) and drought stress (control, 40% available moisture discharge based on gypsum block, 60% available moisture discharge based on gypsum block). One month before planting the soil was contaminated with cadmium chloride at specific levels in the experiment then biochar treatment was added to the soil of the desired pots. After cultivating crops and sufficient vegetative growth shoot and root specimens were carefully removed from the soil of the pots and after washing and drying according to the protocol in this experiment extracts were taken for reading in an atomic absorption apparatus. For analyze the measured data, Mean and Bartlett comparison were performed using MSTATC, SAS and Excel software.

Results and discussion
The results of analysis of variance showed that Triple interactions of cadmium, crop species, drought stress for all studied traits(Dry weight of shoots, dry weight of roots, amount of cadmium in shoots, amount of cadmium in roots, measurement of metal element, accumulation coefficient, extraction coefficient) It became significant with a one percent error probability. The results also showed that the triple interactions of cadmium, crop species, biochar only for traits Translocation factor, Accumulation

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factor, Enrichment cofficient became significant with a probability level of one percent. And for other traits, this triple interaction was not significant. The results of mean comparison showed that the highest mean amount of cadmium in the shoot(2.68 mg.kg^{-1}) And roots(1.78 mg.kg^{-1}) Related to canola treatment at the level of 30 ppm cadmium And under drought stress conditions, 60% of available moisture discharge was based on gypsum block. Most average Translocation factor related to the triple interactions of cadmium, crop species, biochar related to treatment Canola cadmium at the level of 20 ppm and biochar at the time of crop cultivation in the first year(a3b3c2) with average (3.73) and the lowest was related to cadmium control treatments (a1b1c1) with mean (0.1). The most common triple interactions of cadmium, crop species, drought stress are also related treatment of cadmium Canola at 20 ppm level without drought stress (a3b3d1) (3.98) and the lowest mean was related to cadmium control treatment (a1b1d1) with mean (0.1). Most average Accumulation factor corresponding to the triple interactions of cadmium, crop species, biochar related to the treatment of cadmium Canola at the level of 30 ppm and biochar at the time of crop cultivation in the first year(a4b3c2) with average (70.137) and the lowest was related to cadmium control treatments (a1b1c1) with mean (0.0044). Most of the triple interactions of cadmium, crop species, drought stress also related to cadmium Canola treatment at 20 ppm level without drought stress (a3b3d1) (148.87) and the lowest mean was related to cadmium control treatment (a1b1d1) with mean (0.0043). The highest mean of triple interactions of cadmium, crop species, biochar for Enrichment cofficient related to the treatment of cadmium Canola at the level of 30 ppm and without biochar in the first year (a4b3c1) with a mean (0.182) and the lowest was related to cadmium control treatments (a1b1c1) with mean (0.0117).

Conclusions

Most of the triple interactions of cadmium, crop species, drought stress are also related Treatment of cadmium Canola at 30 ppm level and drought stress 60% available moisture discharge based on gypsum block (a4b3d3) (0.180) the lowest mean was related to cadmium control treatment (a1b1d1) with mean (0.0011). The results of this study showed that Canola had a higher uptake and transport of cadmium metal than clover and alfalfa.

***Keywords*:** Biochar, Cadmium, Crop rotation, Drought stress

Table 1. Soil analysis used in the experiment

Sample	(SP)	EC	pH	calcium carbonate	organic matter	N*	K	P	Sand	silt	clay	Texture
	%	ds m^{-1}		-----------%----------		Kg.ha^{-1}	-------ppm-----		----------%-----------			
Soil	50.31	4.1	7.58	19.49	4.61	199.82	600	32	28	44	28	C.L
Optimal range	>40	<1.5	8-6	…	>0.2	…	220-200	20-15	…	…	…	…

* Estimation of nitrogen released during the growing season

Table 2. biochar features used in this experiment

Specifications	iodine number	Area	amount of humidity	pH	Percentage of ash	Grading	Foundation
	mg.g^{-1}	m^{2}g^{-1}	%		%	μ	Cellulose materials from the woods of Mazandaran forest
Biochar	160-180	170	3-4	8	4-5	180	

Table 3. Analysis of variance traits studied in clover, alfalfa, canola

Source of variations	DF	Dry weight of shoot	Dry weight of root	The amount of cadmium in shoot	The amount of cadmium in root	Translocation factor	Accumulation factor	Enrichment coefficient
Year (Y)	1	0.064^{ns}	0.019^{ns}	0.239**	0.0000001^{ns}	0.982**	6374**	0.061**
Rep*year	4	6138.73**	265.154**	0.419**	0.517**	0.982**	1391**	0.002**
Cadmium (C)	3	6492.81**	482.163**	38.886**	25.154**	75.794**	98169**	0.085**
C × Y	3	0.008^{ns}	0.00006^{ns}	0.040**	0.0000001^{ns}	0.137**	977**	0.023**
Crop species (S)	2	37829.52**	5064.73**	98.485**	17.835**	100.345**	36858**	0.620**
S * Y	2	0.006^{ns}	0.00021^{ns}	0.102**	0.0000001^{ns}	0.160**	3668.**	0.041**
Biochar (B)	2	5191.341**	62.436**	0.370**	0.408**	0.147**	328**	0.002**
B *Y	2	0.061^{ns}	0.0193^{ns}	0.0003^{ns}	0.0000001^{ns}	0.0002^{ns}	3.110^{ns}	0.0001^{ns}
Drought stress (D)	2	2306.675**	34.308**	0.250**	0.259**	0.083**	534.**	0.001**
D * Y	2	0.00063^{ns}	0.00001^{ns}	0.0002^{ns}	0.0000001^{ns}	0.0001^{ns}	5.2^{ns}	0.00003^{ns}
S * C	6	163.115**	7.346**	17.957**	6.051**	27.472**	59681**	0.086**
Y * C * S	6	0.00578^{ns}	0.0001^{ns}	0.018*	0.00000001^{ns}	0.0439**	594**	0.019**
C * B	6	2.513^{ns}	0.165^{ns}	0.112**	0.088**	0.187**	215**	0.0006**
Y * C * B	6	0.009^{ns}	0.00006^{ns}	0.0001**	0.000001^{ns}	0.0003^{ns}	2^{ns}	0.0001**
C * D	6	26.182**	10.264**	0.059**	0.058**	0.081**	164**	0.0002**
Y* C *D	6	0.0003^{ns}	0.00001^{ns}	0.00006^{ns}	0.00000001^{ns}	0.0001^{na}	1.6^{ns}	0.00004^{ns}
S * B	4	169.703**	0.699^{ns}	0.124**	0.008^{ns}	0.0002^{ns}	232**	0.0014**
Y * S * B	4	0.006^{ns}	0.0002^{ns}	0.0001^{ns}	0.0000001^{ns}	0.000004^{ns}	2.2^{ns}	0.0002**
S * D	4	117.021**	1.9431**	0.018*	0.022**	0.276**	809**	0.0001*
Y * S * D	4	0.00012^{ns}	0.00004^{ns}	0.00001^{ns}	0.00000001^{ns}	0.0004^{ns}	8.01^{ns}	0.00002^{ns}
B* D	4	7.632^{ns}	0.28994^{ns}	0.008^{ns}	0.005^{ns}	0.0007^{ns}	2.28^{ns}	0.00003^{ns}
B * D	4	0.0004^{ns}	0.00001^{ns}	0.000009^{ns}	0.0000001^{ns}	0.000001^{ns}	0.02^{ns}	0.00004^{ns}
C * S * B	12	5.868^{ns}	0.417^{ns}	0.068**	0.008^{ns}	0.076**	167**	0.0004**
Y * C * S * B	12	0.005^{ns}	0.0001^{ns}	0.00007^{ns}	0.0000001^{ns}	0.0001^{ns}	1.6^{ns}	0.0001**
C * S * D	12	24.903**	3.21455**	0.015*	0.012*	0.102**	207**	0.0001**
Y * C * S * D	12	0.00024^{ns}	0.00004^{ns}	0.00001^{ns}	0.000001^{ns}	0.0001^{ns}	2.06^{ns}	0.00005^{ns}
S * B * D	8	4.863^{ns}	0.456^{ns}	0.004^{ns}	0.003^{ns}	0.005^{ns}	4.45^{ns}	0.00002^{ns}
Y * S * B * D	8	0.0002^{ns}	0.00004^{ns}	0.000004^{ns}	0.0000001^{ns}	0.000008^{ns}	0.04^{ns}	0.00004^{ns}
C * S * B * D	36	1.65046^{ns}	0.09230^{ns}	0.003^{ns}	0.003^{ns}	0.0048^{ns}	3.39^{ns}	0.00003^{ns}
Y * C * S * B * D	36	0.0002^{ns}	0.00003^{ns}	0.000003^{ns}	0.0000001^{ns}	0.000007^{ns}	0.03^{ns}	0.00002^{ns}
Error	428	4.398	0.46488	0.0072	0.0058	0.009	28.4	0.00004
CV%		*4.39*	*6.87*	*14.26*	*17.47*	*9.71*	*16.98*	*10.10*

**: Significant in $p<0.01$, *: Significant in $p<0.05$, ns: Non-Significant

Table 4. Interaction of cadmium, crop species, and drought stress traits studied in clover, alfalfa, and canola

Cadmium	Crop species	Drought stress	Dry weight of shoot	Dry weight of root	cadmium in shoot	cadmium in root
			g		mg/kg	
		control	47.89666^{i}	6.215 ^{i}	0.0001 ^{z}	0.001 ^{z}
	Clover	40% evaporation	47.1383^{i}	6.23 ^{i}	0.0001 ^{z}	0.001 ^{z}
		60% evaporation	43.0383^{k}	6.286 ^{i}	0.0001 ^{z}	0.001 ^{z}
		control	49.3766^{i}	14.9616 ^{c}	0.0001 ^{z}	0.001 ^{z}
control	Alfalfa	40% evaporation	47.1833^{i}	15.0633 ^{b}	0.0001 ^{z}	0.001 ^{z}
		60% evaporation	43.0666^{k}	15.4783 ^{a}	0.0001 ^{z}	0.001 ^{z}
		control	75.1183 ^{a}	14.4533 ^{c}	0.0001 ^{z}	0.001 ^{z}
	Canola	40% evaporation	73.3833 ^{b}	14.6416 ^{c}	0.0001 ^{z}	0.001 ^{z}
		60% evaporation	69.975 ^{d}	15.105 ^{b}	0.0001 ^{z}	0.001 ^{z}
		control	43.895^{k}	5.21 ^{j}	0.1446 ^{y}	0.19 ^{y}
	Clover	40% evaporation	42.495^{k}	4.705 ^{k}	0.155 ^{x}	0.2 ^{x}
		60% evaporation	39.8716^{l}	4.1716 ^{k}	0.1825 ^{v}	0.2266 ^{u}
		control	45.8083^{j}	13.811^{d}	0.155 ^{x}	0.2 ^{x}
10 ppm	Alfalfa	40% evaporation	42.905^{k}	13.968 ^{d}	0.1722 ^{w}	0.2166 ^{v}
		60% evaporation	40.535^{l}	14.4066 ^{c}	0.1928 ^{u}	0.2366 ^{t}
		control	70.0816 ^{c}	13.46 ^{d}	0.8438 ^{i}	0.2133 ^{w}
	Canola	40% evaporation	67.4083 ^{d}	13.0066 ^{d}	0.868 ^{h}	0.2366 ^{t}
		60% evaporation	62.8716 ^{e}	11.6116 ^{f}	0.8955 ^{g}	0.2633 ^{s}
		control	38.56^{m}	3.84 ^{l}	0.279 ^{t}	0.3866 ^{r}
	Clover	40% evaporation	36.4933^{n}	3.505 ^{l}	0.2962 ^{r}	0.4033 ^{p}
		60% evaporation	33.8733^{p}	3.1383 ^{l}	0.3478 ^{n}	0.4533 ^{k}
		control	39.8083^{l}	12.64 ^{e}	0.2824 ^{s}	0.393 ^{q}
20 ppm	Alfalfa	40% evaporation	36.9083^{m}	12.1066 ^{e}	0.2996 ^{q}	0.41 ^{n}
		60% evaporation	34.5416^{o}	10.74 ^{g}	0.3513 ^{m}	0.46 ^{j}
		control	63.14 ^{e}	12.44 ^{e}	2.0804 ^{f}	1.17 ^{f}
	Canola	40% evaporation	56.94^{f}	11.806 ^{f}	2.108 ^{e}	1.2 ^{e}
		60% evaporation	50.9066^{i}	10.7733 ^{g}	2.156 d	1.2733 ^{d}
		control	36.565^{n}	3.2383 ^{l}	0.2996 ^{q}	0.4066 ^{o}
	Clover	40% evaporation	34.4883^{o}	2.9183 ^{m}	0.341 ^{o}	0.4466 ^{L}
		60% evaporation	31.205^{q}	2.505 ^{n}	0.3857 ^{k}	0.49 ^{h}
		control	37.8066^{m}	11.64 ^{f}	0.31 ^{p}	0.4166 ^{m}
30 ppm	Alfalfa	40% evaporation	34.906^{o}	10.9066 ^{g}	0.3547 ^{l}	0.4666 ^{i}
		60% evaporation	32.8733^{p}	9.94 ^{h}	0.4064 ^{j}	0.52 ^{g}
		control	61.87166^{e}	11.4383 ^{f}	2.4111 ^{c}	1.52 ^{c}
	Canola	40% evaporation	54.9383^{f}	10.805 ^{g}	2.4627 ^{b}	1.57 ^{b}
		60% evaporation	48.905^{i}	9.705 ^{h}	2.6866 ^{a}	1.7866 ^{a}

Table 4. Continued

Cadmium	Crop species	Drought stress	Translocation factor	Accumulation factor(mg/kg)	Enrichment cofficient
control	Clover	control	0.1 s	0.0047 p	0.1 e
		40% evaporation	0.1 s	0.0047 p	0.1 e
		60% evaporation	0.1 s	0.0043 p	0.1 e
	Alfalfa	control	0.1 s	0.00495 p	0.1 e
		40% evaporation	0.1 s	0.00471 p	0.1 e
		60% evaporation	0.1 s	0.00430 p	0.1 e
	Canola	control	0.1 s	0.00752 p	0.1 e
		40% evaporation	0.1 s	0.00736 p	0.1 e
		60% evaporation	0.1 s	0.00701 p	0.1 e
10 ppm	Clover	control	0.7659 p	6.3253 o	0.0146 k-n
		40% evaporation	0.7798 n	6.5587 o	0.0157 i-m
		60% evaporation	0.8102 k	7.2287 no	0.0185 h-k
	Alfalfa	control	0.7798 n	7.0715 no	0.0166 h-n
		40% evaporation	0.7993 l	7.3385 no	0.0185 h-k
		60% evaporation	0.8201 j	7.7795 no	0.02084 g-i
	Canola	control	3.9851 a	59.0273 g	0.0920 f
		40% evaporation	3.7010 b	58.3685 g	0.0989 e
		60% evaporation	3.4344 c	56.15797 h	0.1029 e
20 ppm	Clover	control	0.7342r	10.7547 m	0.0173 h-m
		40% evaporation	0.7470 q	10.7793 m	0.0179 h-l
		60% evaporation	0.77930 n	11.74877 j-l	0.0210 gh
	Alfalfa	control	0.7343 r	11.24565 k-m	0.0201 g-j
		40% evaporation	0.7470 q	11.04024 lm	0.0212 gh
		60% evaporation	0.7785 n	12.1267 jk	0.0253 g
	Canola	control	1.8091 d	131.6990 c	0.1567 d
		40% evaporation	1.786 e	120.3052 e	0.1540 d
		60% evaporation	1.71784 f	109.9427 f	0.1576 cd
30 ppm	Clover	control	0.74920 q	10.9547 lm	0.0116 n
		40% evaporation	0.77576 n	11.6999 j-m	0.0132 l-n
		60% evaporation	0.7992 l	11.9115 j-l	0.0150 j-n
	Alfalfa	control	0.7561 q	11.70631 j-m	0.0127 mn
		40% evaporation	0.7691o op	12.3311 ij	0.0147 k-n
		60% evaporation	0.78943 m	13.3125 i	0.01690 h-m
	Canola	control	1.5981 g	148.8723 a	0.16445 b
		40% evaporation	1.5804 h	134.8604 b	0.1621 bc
		60% evaporation	1.51173 i	130.2834 d	0.1805 a

Table 5. The main effects of biochar on the studied traits in clover, alfalfa and canola

Biochar treatments	Dry weight of shoot	Dry weight of root	The amount of cadmium in shoot	The amount of cadmium in root	Translocation factor	Accumulation factor	Enrichment cofficient
	--------g--------		-------mg/kg-------			mg/kg	
Control	44.84^{b}	9.59^{b}	0.6203^{a}	0.4630^{a}	0.983^{b}	30.71^{b}	0.070^{ab}
Biochar at the time of cultivation of the first year	53.34^{a}	10.53^{a}	0.5485^{b}	0.3877^{b}	1.028^{a}	32.85^{a}	0.065^{b}
Biochar after the first year harvest and at the time of the second year cultivation	44.87^{b}	9.61^{b}	0.6203^{a}	0.4630^{a}	0.983^{b}	30.72^{b}	0.0713^{a}

In each column, the means with at least one common letter based on Duncan's test at the level of 5% probability have no significant difference.

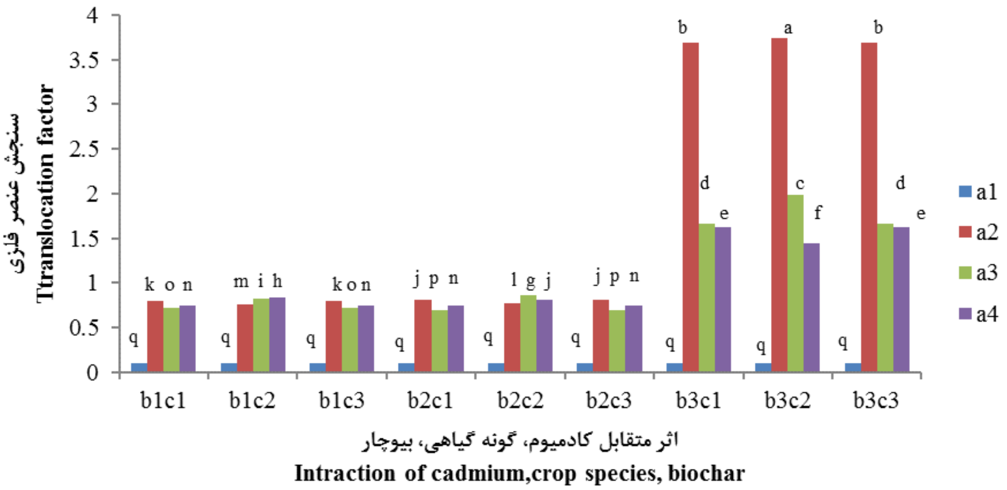

Fig. 1. Triple interactions of cadmium chloride salt [control (a1), 10 (a2; 10 mg.kg^{-1}), (a3; 20 mg.kg^{-1}), (a4; 30 mg.kg^{-1})], biochar [control (c1) , Biochar at the time of cultivation of the first year (c2), biochar after the harvest of the first year and at the time of cultivation of the second year (c3)], crop species [clover (b1), alfalfa (b2), rapeseed (b3)]on Translocation factor

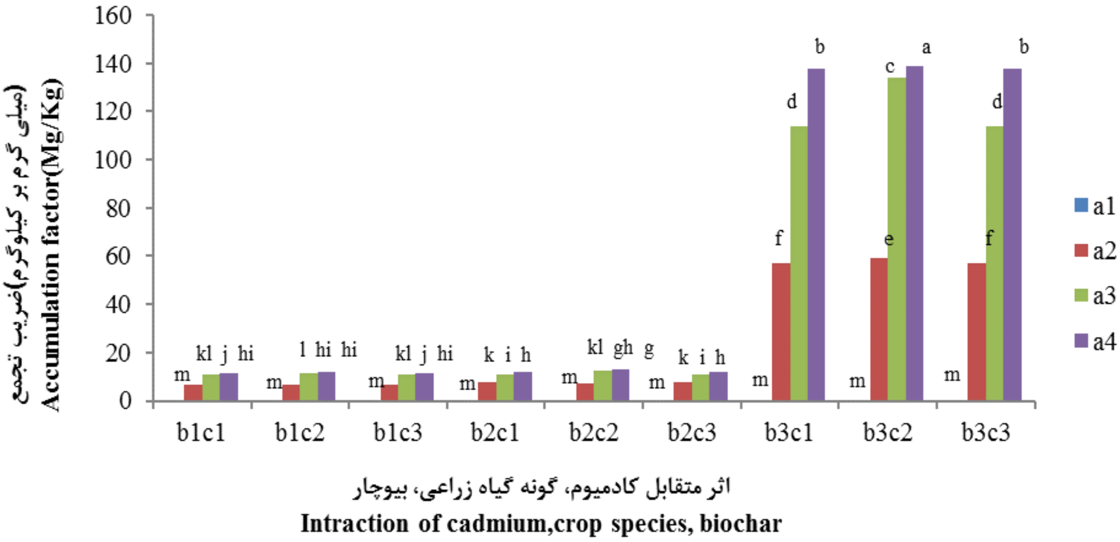

Fig. 2. Triple interactions of cadmium chloride salt [control (a1), 10 (a2; 10 mg.kg^{-1}), (a3; 20 mg.kg^{-1}), (a4; 30 mg.kg^{-1})], biochar [control (c1) , Biochar at the time of cultivation of the first year (c2), biochar after the harvest of the first year and at the time of cultivation of the second year (c3)], crop species [clover (b1), alfalfa (b2), rapeseed (b3)]on Accumulation factor

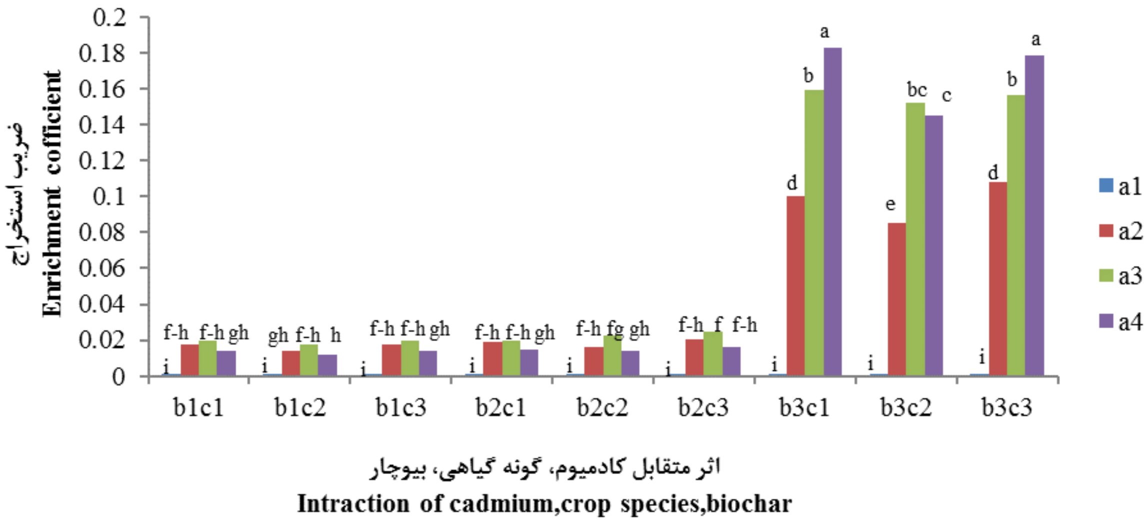

Fig. 3. Triple interactions of cadmium chloride salt [control (a1), 10 (a2; 10 mg.kg^{-1}), (a3; 20 mg.kg^{-1}), (a4; 30 mg.kg^{-1})], biochar [control (c1) , Biochar at the time of cultivation of the first year (c2), biochar after the harvest of the first year and at the time of cultivation of the second year (c3)], crop species [clover (b1), alfalfa (b2), rapeseed (b3)]on Enrichment coefficient

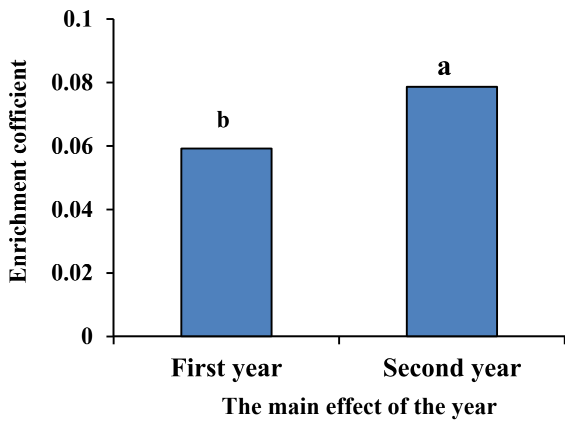

Fig. 4. Effects of year on on Enrichment coefficient