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Artichoke, *Cynara scolymus* L. (*Asteraceae*), a Mediterranean culture: plant and soil elementary composition, a comparison

Abstract

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Samples of both *Cynara scolymus* and the relevant agricultural soil, taken along 7 different and successive stages of their growth cycle, have been submitted to AES/ICP, INAA, FRX and Kjeldahl elementary analysis. The results show that of 27 analysed elements the plant accumulates 4 (N, Na, P and W), rejects 21 elements (B, Mg, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta and Th), and accumulates or rejects 2 other (K and Br) depending on developmental stage. Comparisons with similar studies carried out on *Capsicum annuum*, the pepper plant, show that the "compositional plant behaviour" related to that of its soil is common to both plants as regards 21 out of the 27 studied elements (N, Mg, P, Ca, Sc, Ti, V, Cr, Mn, Fe, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta and Th), while it differs by only 6 elements (B, Na, K, Co, Br and W). We may conclude that, for most of the analyzed elements (21 out of 27), both plants accumulate or reject them in the same way, the same non-metals are accumulated and the same metals are rejected in both plants. Moreover, the "rooted plant" is the most physiologically active stage. Such results may be looked at as an example of ecophysiological similarity within the vegetal living matter, in spite of its morphological and taxonomical diversity.

Introduction

The elementary composition of several mediterranean horticultural crops such as *Capsicum annuum,* pepper (Cavero & al. 1992, 1993a) and *Cynara scolymus,* artichoke, (Cavero & al. 1997, Marco & al. 1997), and its evolution along the agricultural cycle have been studied. Similar studies include the soil analysis carried out on samples, simultaneously taken with the plants (Cavero & López 1993, Cavero & al. 1993b). Other researchers appear in some works concerning the elementary composition of horticultural plants in single stages of their agricultural cycle, aiming to know the effects of the fertilization (Zornoza & Arozarena 1986, Fenn & al. 1987, Magnifico 1987, Bar-Tal & al. 1990, Moulinier 1980, Pomares & al. 1991, Prado & al. 1983, and others); or contamination, (Uhnak & Rippel 1990, Pearson 1993, Torija & Martínez 1982); or basic studies, as those of Martínez-Sánchez & al. 1990, Torija & Martinez 1983, Lattanzio 1982, Martínez-Llopis 1990, Ensminger & al. 1994 and Lamand & al. 1996.

In this paper, the elementary concentration of 27 elements in seven plant and soil samples taken along the agricultural cycle of artichoke, is studied. The results will enable us to know where the elements concentrate, either in plant or in soil (Markert 1991), the metal or non-metal character (Frieden 1984) of the elements accumulated in the plant, and the most active stage from the physiological point of view. In the same way, a comparison between artichoke and pepper of "such an elementary compositional behaviour" will be also carried out.

Material and methods

The samples were entire Artichoke plants belonging to "variedad de Tudela". Normal land culture was carried out in two villages of Navarra County, Cadreita and Tudela. Plant and soil sampling took place simultaneously for in seven different and meaningful developmental stages of the agricultural cycle: A, initial "zuecas" (cuttings); B, rooted plant; C, first-sprouting plant; D, rosette stage; E, second-sprouting plant; F, fully yielding plant; G, final "zuecas" (cuttings). Details of plant and soil sampling data and kinds of manipulations are indicated in Cavero & López 1993, Cavero & al. 1997 and Marco & al. 1997. As a whole, 13 plant samples and 12 soil samples have been analysed by Atomic Emission Spectroscopy by Inductive Coupled Plasma (AES/ICP), for B; by Kjeldahl, for N; by X Ray Fluorescence (FRX), for P; and by Instrumental Neutron Activation Analysis (INAA), for Na, Mg, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Zn, Br, Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta, W and Th. in total 27 elements on 25 plant and soil samples. Compared results of the concentrations of each element in plant and soil of both plots showed which elements have a major concentration in plant (the plant accumulates them), which elements have a major concentration in soil (the plant rejects them) and which elements shift their concentration according to each stage of the agricultural cycle. In order to know which elements are mostly accumulated or rejected, the elementary concentration in plant has been divided by the elementary concentration in soil. This has been done for each element and during all the agricultural stages in both plots, obtaining the average value for each element. The metal or non-metal character of the elements that accumulate in plant and in soil has also been indicated. Finally, to know the most active stage from a physiological point of view, the plant and soil concentrations have been divided by each element in each stage in both plots obtaining the average value for each stage and element.

Results

The elementary concentrations in each of the samples, both plant and soil, and for each of the experimental plots, are given in Table 1, which shows amazing differences between elementary composition of artichoke plant and its soil. In each one of the seven samples, no element has the same concentration in both materials: each element has either higher or lower concentration in plant than in soil. The artichoke plant accumulates (Fig.1): N, Na, P and W, that is, 4 out of 27 elements, 2 metals (Na, W) and 2 non-metals (N, P); rejects (Fig. 2): B, Mg, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta and Th, that is, 21 out of 27 elements, that is, 20 metals and 1 non-metal (B); and, according to its developmental stage, accumulates or rejects K and Br, that is, 2 out of 27 elements, 1 metal (K) and 1 non-metal (B).

Table 1. Elements concentrations (ppm. or %) in Phenological stages of the Artichoke plant and in different soil samples for each locality.

PLANT / SOIL		Locality	A	B	C	D	E	F	G
ppm	B	Cadreita	1	8	17	13	12	10	1
		Tudela	1	7	27	20	14	15	5
	B	Cadreita	——	120	170	110	120	150	120
		Tudela	——	70	90	90	100	70	120
%	N	Cadreita	1,20	1,70	2,86	2,67	2,49	2,07	1,28
		Tudela	1,20	1,64	3,01	2,71	2,51	1,60	1,33
	N	Cadreita	——	0,121	0,120	0,121	0,102	0,114	0,111
		Tudela	——	0,117	0,109	0,106	0,105	0,117	0,104
	Na	Cadreita	0,241	0,402	0,578	0,393	0,44	0,409	0,182
		Tudela	0,241	0,387	0,323	0,416	0,414	0,366	0,313
	Na	Cadreita	——	0,365	0,357	0,359	0,398	0,394	0,399
		Tudela	——	0,28	0,288	0,275	0,304	0,307	0,306
	Mg	Cadreita	0,166	0,286	0,398	0,367	0,236	0,237	0,137
		Tudela	0,166	0,216	0,238	0,24	0,25	0,173	0,168
	Mg	Cadreita	——	0,87	0,78	0,83	1,05	1,1	0,987
		Tudela	——	0,64	0,69	0,61	0,608	0,798	0,714
	P	Cadreita	0,19	0,21	0,34	0,27	0,24	0,21	0,21
		Tudela	0,19	0,22	0,42	0,35	0,3	0,22	0,22
	P	Cadreita	——	0,057	0,059	0,055	0,044	0,052	0,055
		Tudela	——	0,048	0,046	0,044	0,044	0,059	0,055
	K	Cadreita	1,73	1,72	5,3	3,23	3,14	3,32	1,32
		Tudela	1,73	1,19	4,53	3,09	2,92	2,56	1,08
	K	Cadreita	——	1,2	1,34	1,17	1,28	1,38	1,29
		Tudela	——	1,33	1,27	1,13	1,36	1,35	1,35
	Ca	Cadreita	0,897	1,71	1,96	1,71	1,37	1,38	0,642
		Tudela	0,897	1,31	1,63	1,69	1,42	1,3	0,844
	Ca	Cadreita	——	13	13,3	12,1	13,5	13,8	14,1
		Tudela	——	6,6	7,6	6,9	7,75	7,98	8,2
ppm	Sc	Cadreita	0,224	0,535	0,197	0,29	0,229	0,116	0,112
		Tudela	0,224	0,344	0,223	0,267	0,176	0,111	0,152
	Sc	Cadreita	——	7,33	7,25	7,24	6,93	7,11	7,16
		Tudela	——	6,73	6,05	5,67	5,97	6,25	5,64
	Ti	Cadreita	88,1	214	106	124	88,8	87	57
		Tudela	88,1	141	78,9	160	88,2	77,4	68,2
	Ti	Cadreita	——	3000	2800	2900	2790	3120	2830
		Tudela	——	2980	3300	3100	3170	3640	3190
	V	Cadreita	2,18	5,57	1,83	3,18	2,77	1,3	1,09

		Locality	A	B	C	D	E	F	G
	Co	Cadreita	——	7,81	7,64	7,6	7,4	7,53	7,75
		Tudela	——	7,84	6,8	6,57	6,78	7,19	6,43
	Zn	Cadreita	24,2	26,9	23,2	26,8	19,4	15	19,8
		Tudela	24,2	23,2	25,7	20,8	21	12,7	12,8
	Zn	Cadreita	——	57	56	60	57,6	63,1	66,9
		Tudela	——	50	46	49	53,7	60,6	50,9
	Br	Cadreita	2,22	8,47	22,2	15,9	16,1	20	5,66
		Tudela	2,22	4,87	24,2	12,3	32,7	27,8	7,67
	Br	Cadreita	——	6,1	6,1	6,6	5,74	5,79	6,39
		Tudela	——	6,9	7,7	7,5	7,46	7,52	6,81
	Rb	Cadreita	3,37	9,66	6,09	5,39	5,16	4,23	2,86
		Tudela	3,37	6,79	4,86	6,3	4,04	2,61	3,08
	Rb	Cadreita	——	85	76	82	72,6	74,3	75,7
		Tudela	——	84	83	73	78,5	82,2	71,7
	Sr	Cadreita	70,4	95	127	100	79,9	93,7	46,9
		Tudela	70,4	99,1	96,2	80,2	72,5	73,1	55,4
	Sr	Cadreita	——	440	370	430	370	385	372
		Tudela	——	210	190	170	104	105	194
	Cs	Cadreita	0,199	0,427	0,146	0,234	0,172	0,087	0,097
		Tudela	0,199	0,308	0,153	0,252	0,166	0,09	0,137
	Cs	Cadreita	——	5,5	5,2	5,6	5,12	5,12	5,64
		Tudela	——	6,2	5,34	5,5	5,14	5,32	4,86
	La	Cadreita	0,765	1,59	0,579	1,13	0,706	0,503	0,349
		Tudela	0,765	1,03	0,698	0,868	0,595	0,432	0,589
	La	Cadreita	——	22,0	22,0	20,8	21,4	21,6	23,3
ppm		Tudela	——	26,7	29,2	29,1	26,4	28,3	33,3
	Ce	Cadreita	1,1	3,2	1,53	2,22	1,52	0,934	0,369
		Tudela	1,1	2,33	1,64	1,87	1,24	1,1	1,42
	Ce	Cadreita	——	47,4	47,1	45,0	45,7	44,5	46,4
		Tudela	——	59	66	65,4	54,5	58,9	70,9
	Sm	Cadreita	0,424	0,438	0,173	0,178	0,153	0,074	0,094
		Tudela	0,424	0,351	0,283	0,369	0,122	0,43	1,26
	Sm	Cadreita	——	3,89	3,9	3,68	3,78	3,92	4,11
		Tudela	——	4,84	5,7	5,4	4,77	5,12	5,55
	Eu	Cadreita	0,02	0,056	0,021	0,036	0,025	0,014	0,013
		Tudela	0,02	0,049	0,031	0,037	0,03	0,023	0,027
	Eu	Cadreita	——	0,86	0,81	0,83	1,04	1,05	1,03

Table 1. (condinued)

	Tudela	2,18	3,57	1,64	2,99	1,97	1,27	1,59
V	Cadreita	——	61	56	63	60,2	72	67,8
	Tudela	——	50	51	48	52	55,7	44,9
Cr	Cadreita	2,12	5,49	1,75	2,53	1,61	1,27	1,18
	Tudela	2,12	2,39	1,84	1,91	1,79	1,00	3,18
Cr	Cadreita	——	44,9	43,6	43,0	41	43	41,7
	Tudela	——	38,0	35,3	32,8	33,7	33,7	36,4
Mn	Cadreita	25,5	53,1	44,5	51,3	47,2	31,1	22,7
	Tudela	25,5	42,5	51,8	53,3	41,8	26,2	24,3
Mn	Cadreita	——	480	449	452	493	529	513
	Tudela	——	357	376	342	369	416	352
Fe	Cadreita	622	1450	597	878	669	380	372
	Tudela	622	964	708	849	570	338	472
Fe	Cadreita	——	2000 0	2000 0	2010 0	1830 0	1900 0	1900 0
	Tudela	——	2190 0	2000 0	2020 0	1810 0	1980 0	1790 0
Co	Cadreita	4,62	3,17	3,85	6,32	3,19	3,64	3,87
	Tudela	4,62	2,01	3,19	3,28	2,83	5,21	3,29

	Tudela	——	0,98	1,06	0,953	1,13	1,15	1,09
Hf	Cadreita	0,128	0,246	0,127	0,238	0,175	0,141	0,044
	Tudela	0,128	0,204	0,157	0,248	0,157	0,158	0,165
Hf	Cadreita	——	5,3	4,86	5,3	5,05	4,99	5,24
	Tudela	——	8,94	10,0	10,9	11,1	11,2	10,1
Ta	Cadreita	0,045	0,065	0,059	0,074	0,053	0,035	0,062
	Tudela	0,045	0,036	0,026	0,058	0,054	0,018	0,034
Ta	Cadreita	——	0,90	0,87	0,79	0,864	0,765	0,11
	Tudela	——	0,89	0,96	0,94	0,927	0,894	0,841
W	Cadreita	13,2	25,3	22	31,7	22,6	16,5	19,4
	Tudela	13,2	16,1	15	27,5	17,6	10,6	11,4
W	Cadreita	——	1,2	1,7	1,6			
	Tudela	——	1,6	1,7	1,4			
Th	Cadreita	0,214	0,515	0,21	0,3	0,265	0,125	0,121
	Tudela	0,214	0,329	0,247	0,332	0,2	0,159	0,206
Th	Cadreita	——	7,68	7,47	7,4	6,88	6,68	6,98
	Tudela	——	9,18	9,17	9,56	9,23	9,24	10,6

* A stage: initial cuttings were the same for both localities

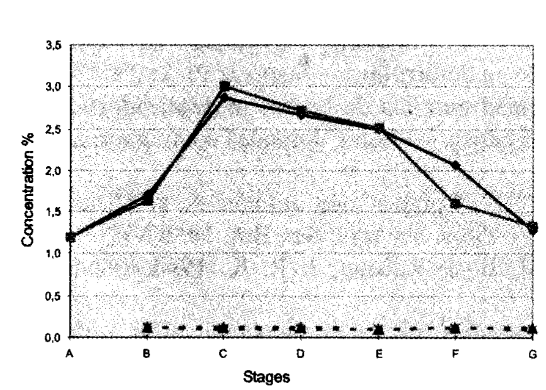
The following elements are arranged in decreasing order according to the magnitude of the accumulation in the artichoke: N, W, P, Br, K, Na, Co, Sr, Zn, Mg, Ca, B, Mn, Sm, Rb, Cr, Ta, V, Ti, Fe, Cs, Sc, Eu, La, Th, Ce and Hf. N and W are the most accumulated elements; while the most rejected are Ce and Hf. The stage B, "rooted plant", is physiologically the most active because it has its maximum accumulation in 12 out of 27 elements. The same type of analysis on pepper cultures (Cavero & López 1993) shows the following results: pepper accumulates (Fig. 3): B, N, P, K and Br, that is, 5 out of 27, 1 metal (K) and 4 non-metals; it rejects (Fig. 4) Na, Mg, Ca, Sc, Ti, V, Cr, Mn, Fe, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta and Th, that is, 20 out of 27, all of them are metals; and, according to its developmental stage, accumulates or rejects Co and W that is, 2 out of 27 elements, both metal elements.

The following elements are arranged in decreasing order according to the magnitude of the accumulation in the pepper plant: N, B, P, K, W, Br, Mg, Co, Zn, Sr, Na, Ca, Mn, Rb, Ta, La, Cr, V, Fe, Sc, Cs, Eu, Ce, Ti, Hf, Th and Sm. That is, N and B are the most accumulated elements while the most rejected are Th and Sm. The stage C, "rooted plant", is physiologically the most active because it has its maximum accumulation in 16 out of 27 elements.

Discussion & conclusions

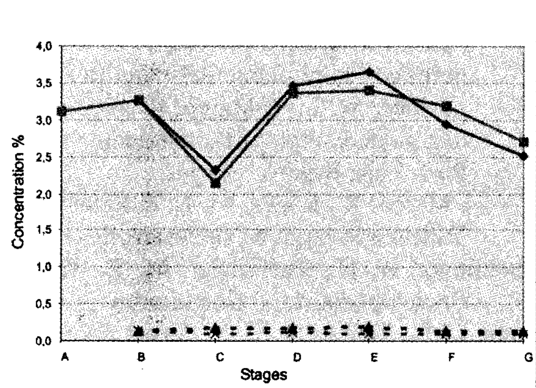
Several surprising coincidences appear comparing the elementary compositional behaviour of both Artichoke and Pepper plant-soil cultural systems. Both plants accumulate the same 2 elements, N and P; both plants reject the same 19 elements, Mg, Ca, Sc, Ti, V, Cr, Mn, Fe, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta and Th. In sum, in such plant-soil systems, the "elementary composition behaviour" of Artichoke and Pepper is coincident for 21 out

Fig. 1: N evolution in Artichoke



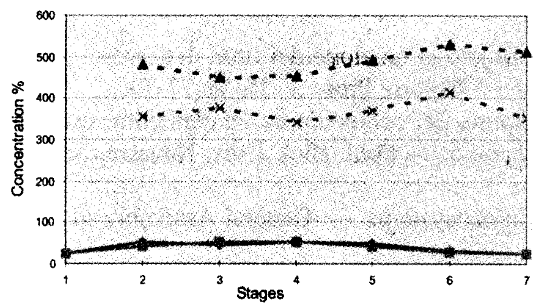
Other similary behaviouring elements: Na, P and W

Fig. 3: N evolution in Pepper



Other similary behaviouring elements: B, P, K and Br

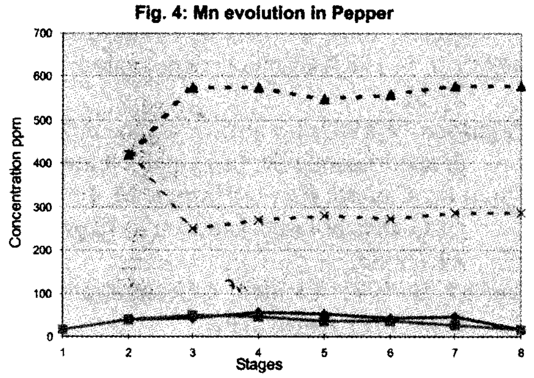
Fig. 2: Mn evolution in Artichoke



Other similary behaviouring elements: B, Mg, Ca, Sc, Ti, V, Cr, Fe, Co, Zn, Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta and Th

Leyend: Cadreita Plant; Tudela Plant; Cadreita Soil; Tudela Soil

Fig. 4: Mn evolution in Pepper



Other similary behaviouring elements: Na, Mg, Ca, Sc, Ti, V, Cr, Fe, Zn Rb, Sr, Cs, La, Ce, Sm, Eu, Hf, Ta and Th

Leyend: Cadreita Plant; Sartaguda Plant; Cadreita Soil; Sartaguda Soil

of the 27 studied elements, as well as for their metal or non-metal character, that is to say for the 21 coincident elements, both plants accumulate 2 non-metals and reject 19 metals.

Moreover N and P, the two elements accumulated by the plant, are ordinary added by fertilization.

The "rooted plant", some 4 weeks after transplantation, is physiologically the most active, as it is the stage with the highest number of elements at their highest accumulation in the whole agricultural cycle.

The study of the elementary composition of the plant-soil systems for both Artichoke and Pepper cultures shows that, in spite of their morphological and taxonomical diversity, the vegetal living matter has astonishing ecophysiological similarities.

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