Response of Clover *Trifolium fragiferum* L. cv. 'Salina' To a Heavy Urban Compost Application

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The clover, *T. fragiferum* L. cv. 'Salina' was grown for two years in a greenhouse under a heavy rate of urban compost application at sowing ($100 \text{ t ha}^{-1} \text{ year}^{-1}$). An inorganic fertilizer was also applied for comparison ($8\text{N}-15\text{K}_2\text{O}-15\text{P}_2\text{O}_5$, $1.2 \text{ t ha}^{-1} \text{ year}^{-1}$). The legumes *Medicago rugosa* Des. cv. 'Paragosa', *Trifolium subterraneum* L. ssp. *subterraneum*, *T. subterraneum* L. ssp. *brachycalycinum* were also grown for comparison. The combined N applied with the inorganic fertilizer did not impair either seedling emergence or growth of any of the legumes. Seedling emergence of legumes was in general higher under the urban compost treatment than under the inorganic and control treatments, with that of *T. fragiferum* being the highest. This latter species was the only one with a higher dry matter production under the urban compost treatment than under the other treatments. Urban compost application significantly increased N, P, Cu and Zn concentration and export of *T. fragiferum*, in relation to the inorganic and control treatments. A similar trend was observed for K, but without significant differences, with clover also showing a reasonable capacity to absorb Na (natrophilic character). Significant increases in Ni and Cr concentrations, in relation to the control, were also observed in the last cut carried out in the second year, although phytotoxic or toxic levels for cattle were never registered for any metal analyzed in *T. fragiferum*.

Introduction

The presence of certain elements, particularly Mn, Cu, Cr, Cd, Ni and Pb, in soils is important for clover production, as they can affect growth of plants and grazing animals (Kendall and Stringer 1985). Most grasses are reasonably tolerant to excess of trace metals, although clovers are rather sensitive. Therefore, it is important to study clover response to industrial or sewage waste products, and urban composts, in order to avoid excessive amounts of trace metals in soils, not only for clover growth, but also for fodder crop quality (Gambus 1994).

Plant tolerance to compost application, especially at heavy application rates, can also imply a certain level of salt tolerance, as urban composts may possess high total Na content in some cases. Most clovers do not tolerate high salinity, although some reasonably tolerant subspecies and cultivars exist, including strawberry clover (*T. fragiferum*), which is especially noted for its ability to grow on wet saline or alkaline soils (Townsend 1985). Assuming that this cultivar could also possess a parallel heavy metal tolerance, then it could be a very suitable species for reclamation of saline areas using urban composts (Avnimelech *et al.* 1990). The present paper reports the response of *T. fragiferum* cv. 'Salina', a cultivar developed in the USA by selection from the Australian cultivar 'Palestine' (Townsend 1985), to a heavy urban compost application.

Materials and Methods

The experiment was performed for two years in a greenhouse, using pots with a capacity of about 0.2 m^3 (40 cm depth, 250 kg soil). The first horizon of a light yellow-

ish-brown sandy clay loam soil, typical of SW Spain, was used as a substrate. Table 1 shows some properties of this substrate. Urban compost from the city of Seville (fraction < 30 mm) was used as organic fertilizer. Table 2 shows some properties of the < 2 mm fraction of this compost. A commercial 8-15-15 inorganic fertilizer was also used for comparison.

TABLE 1.
Physical and chemical parameters of the soil used

pH	7.8	K (ammonium acetate) mg kg ⁻¹	210
CaCO ₃ %	23	sand (>200 µm) %	33
Cation exchange capacity cmol _c kg ⁻¹	16.0	sand (200 - 20 µm) %	18
Organic matter %	1.0	silt (20 - 2 µm) %	22
C/N	9.0	clay (< 2 µm) %	24
N %	0.08	Illite %	50
P (Olsen) mg kg ⁻¹	14.0	Montmorillonite %	34

TABLE 2.
Urban compost analyses on a dry matter basis (ranges of the different batches used in both years, fraction less than 2mm)

pH-H ₂ O (compost/water 1/5)	7.0 - 7.5	Ca %	6.8 - 7.5
Moisture %	27 - 29	Mg	% 0.43 - 0.55
Total organic matter %	48 - 51	Na %	1.2 - 2.0
C/N	9 - 11	Fe %	1.3 - 1.4
Cation exchange capacity cmol _c kg ⁻¹	85 - 97	Mn mg kg ⁻¹	700 - 850
Water soluble sugars mg kg ⁻¹	2.3 - 3.7	Zn mg kg ⁻¹	920 - 1200
(C _{reducing sugars} /C _{total}) · 100	22 - 27	Cu mg kg ⁻¹	90 - 125
Ether extract %	0.50 - 0.56	Pb mg kg ⁻¹	325 - 450
Total lipid extract %	0.78 - 0.83	Cr mg kg ⁻¹	65 - 90
N (Kjeldahl) %	1.5 - 1.7	Ni mg kg ⁻¹	65 - 78
P %	0.42 - 0.50	Co mg kg ⁻¹	8 - 10
K %	0.69 - 0.85	Cd mg kg ⁻¹	< 5
S %	0.25 - 0.30	B mg kg ⁻¹	26 - 33

Seedling Emergence of Legumes

Compost sensitivity of emerging seedling of *Medicago rugosa* Des. cv. 'Paragosa', *Trifolium subterraneum* L. ssp. *subterraneum* (ecotype ENMP 2011), *T. subterraneum* L. ssp. *brachycalycinum* (ecotype ENMP 2557) and *T. fragiferum* L. cv. 'Salina' was monitored during three week each year, using the big pots described above, by sowing four lots of seeds per pot, with 25 seeds per lot and two pots per species and treatment (urban compost, UC; inorganic fertilizer, IF, and control, C, without any fertilization). Fertilizers were previously spread on the surface of each pot, at a rate of 100 t ha⁻¹ per year in the case of the urban compost and 1,2 t ha⁻¹ per year for the inorganic fertilizer. Both fertilizers were incorporated into the first 5 cm of the substrate each year.

Dry Matter Production of Legumes

This experiment was conducted for two years, with a planting density of 40 plants per pot. There were three randomized replicates (pots) per species and treat-

ment (urban compost, inorganic fertilizer and control without any fertilization). The fertilizers were spread on the surface of each pot at a rate of 100 t ha⁻¹ year⁻¹ in the case of the urban compost and 1,2 t ha⁻¹ year⁻¹ for the inorganic fertilizer. At harvest, plant fresh and dry weight (drying at 70°C for 48 h) were recorded for each species.

Plant Analysis

In the case of *T. fragiferum* L. cv. Salina, after decontamination by washing, the plant material was dried at 70°C and then grounded. Nitrogen was determined by Kjeldahl digestion and mineral elements following dry ashing and dissolution in HCl (Jones *et al.* 1991). Potassium and Na were determined by flame emission, P by colorimetry using the phospho-vanadomolybdic complex, and Ca, Mg, Fe, Mn, Zn and Cu by atomic absorption spectrophotometry. In addition, plant material (leaves and petioles) from the last cut of the second year (urban compost and control treatments) was analyzed for Fe, Mn, Zn, Cu, Ni, Cr, Cd and Pb by wet oxidation with concentrated HNO₃ under pressure in a Parr bomb (Jones and Case 1990) using a graphite furnace for element determination. Boron was also determined according to Barbier and Chabannes (1953).

Statistical Analyses

Data analysis was conducted performing analysis of variance. Mean separations were determined by the Tukey test ($P < 0.05$).

Results and Discussion

Seedling Emergence of Legumes

The results in Table 3 show that the heavy urban compost applications did not damage *T. fragiferum* seedling emergence, compared to the other two treatments, despite possessing lighter seeds (1.2 g, 1000 seeds weight, as compared, for example, with about 7.5 g for *T. subterraneum*). Despite the fact that large seeds generally produce more vigorous seedlings, which in turn could increase their tolerance to soil constraints, e.g. salinity (Marañón *et al.* 1989; Grieve and Francois 1992), small seeds can

TABLE 3.

Percentages of seedling emergence of legumes (relative to the control) as affected by different treatments; Inorganic Fertilizer (IF) and Urban Compost (UC) (control percentages set at 100%)

Species	Treatment	Percentages of emergence	
		First Year	Second Year
<i>M. rugosa</i>	IF	117 a	105 a
	UC	122 a	121 a
<i>T. subterraneum</i> ssp. <i>subterraneum</i>	IF	88 a	87 a
	UC	103 a	107 a
<i>T. subterraneum</i> ssp. <i>brachycalycinum</i>	IF	102 a	96 a
	UC	92 a	107 a
<i>T. fragiferum</i>	IF	108 a	110 a
	UC	141 a	144 a

Values followed by the same letter in the same column, for each species, do not differ significantly ($P < 0.05$).

also have an important inherent capacity for germination and emergence under potentially negative conditions of the substrate.

This was shown by Rogers *et al.* (1995) for *T. repens* cv. 'Haifa' in relation to salinity, and it seems also the case of *T. fragiferum* cv. 'Salina' in relation to the urban compost presence, a product which usually has a high NaCl concentration, besides other possible constraints, as it was the case of the compost used in these experiments (Table 2). The absolute germination percentage of *T. fragiferum* under the heavy urban compost application was around 50 percent in both years, only slightly lower than that of *T. subterraneum* (ca. 60 percent) and clearly larger than that of *M. rugosa* (ca. 20 percent). The results in Table 3 also seem to confirm the idea that, if the compost was mature enough, heavy applications of such product, even at sowing, do not necessarily have a negative effect on germination and seedling emergence for many plants (Murillo *et al.* 1989; Murillo *et al.* 1995a).

Dry Matter Production

Except for *T. fragiferum*, the highest total dry matter production (two years) was recorded for the inorganic fertilizer treatment, with a significant difference in relation to the remaining treatments in the case of *T. subterraneum* (both subspecies) and in relation to the control treatment for *M. rugosa* (Table 4).

Although N fertilization of legumes is not generally required, the addition of N can be beneficial when nodulation is poor and N₂ fixation is reduced because of the lack of proper strains of Rhizobia. In addition, the N status may shift rapidly if environmental factors such as overirrigation, lack of O₂, high temperatures or extreme drought become unfavorable for the N₂-fixing bacteria (Kelling and Matocha 1990).

In order to avoid the appearance of possible phenomena which could negatively affect N₂ fixation, or early growth of legumes, a N amount roughly equivalent to 96 kg ha⁻¹ year⁻¹ was applied at sowing with the inorganic fertilizer treatment, amount which did not damage plant growth, according to the obtained results. Furthermore,

TABLE 4.

Mean values of total dry matter production (g m⁻²) obtained for each legume for the different treatments; Control (C), Inorganic Fertilizer (IF) and Urban Compost (UC)
(the number of cuts is indicated in brackets)

Species	Treatment	Dry matter		Total Two Years
		First Year	Second Year	
<i>M. rugosa</i>	C	169 b (1)	85 b (1)	254 b
	IF	234 a (1)	185 a (1)	419 a
	UC	218 ab (1)	120 b (1)	338 a
<i>T. subterraneum</i>	C	439 b (2)	763 a (2)	1202 b
ssp. <i>subterraneum</i>	IF	728 a (2)	885 a (2)	1613 a
	UC	571 b (2)	358 b (2)	929 b
<i>T. subterraneum</i>	C	343 a (2)	1012 a (2)	1355 b
ssp. <i>brachycalycinum</i>	IF	913 b (2)	1200 a (2)	2113 a
	UC	373 a (2)	1140 a (2)	1513 b
<i>T. fragiferum</i>	C	1546 a (4)	1158 a (5)	2704 a
	IF	1423 a (4)	1317 a (5)	2740 a
	UC	1569 a (4)	1395 a (5)	2964 a

Values followed by the same letter in the same column, for each species, do not differ significantly (P<0.05).

100 t ha⁻¹ of the urban compost applied represents an addition of readily utilizable N (NO₃-N and NH₄-N) up to 40-50 kg ha⁻¹, and even more in other cases (Murillo *et al.* 1995a).

In general, legume responses to the heavy urban compost application were moderate, although significant increases in dry matter (30 percent to 40 percent, $P < 0.05$) were observed for *M. rugosa* in relation to the control (which could be due to a comparatively poor response of this species to the substrate used, Table 4).

In general, both *T. subterraneum* subspecies gave higher dry matter productions than that of *M. rugosa*, but with a moderate response to the urban compost application in the case of ssp. *brachycalycinum* and with a not definite response for ssp. *subterraneum*, since its dry matter production was higher than that of the control in the first year (without significant difference, $P < 0.05$) but lower in the second, showing a significant difference ($P < 0.05$). Dry matter productions of *T. subterraneum* with urban compost application were always lower than those obtained for the inorganic fertilizer treatment, similarly to *M. rugosa*.

Comparatively, the best response in dry matter production to the urban compost application was that of *T. fragiferum* (Table 4). Thus, *T. fragiferum*, a suitable clover for calcareous soils, seems to respond well to urban compost loadings in this kind of soils. This could be an interesting practice for reclamation or revegetation of calcareous saline areas, since this species is also considered a salt-tolerant plant (Townsend 1985; Salo *et al.* 1996).

Concentration and Export of Nutrients

Except for K and Ca (Table 5), the concentrations of most nutrients of *T. fragiferum* cv. 'Salina', were within the normal range reported for most clovers growing in the field, whichever treatment was considered (Fleming 1973; Kelling and Matocha 1990; Jones *et al.* 1991). Considering that 'critical levels', and sufficiency ranges for clovers are often somewhat higher in field experiments than in greenhouse studies, it is likely that the nutritional and physiological requirements of cv. 'Salina' could be adequately covered under the conditions used in this assay.

Combined N applied with the IF treatment was not detrimental for clover growth although applications of N at seedling may sometimes reduce both the stand and subsequent yield of clovers (Knight 1967; Taylor 1985). 'Salina' strawberry showed both normal establishment and growth for the IF treatment, with a N concentration similar to those obtained with the other two treatments in the first year and significantly higher than that of the control in the second year (Table 5). Total above-ground N export (two years) for the IF treatment was slightly higher than that of the control, although the difference was not significant (Table 6). However, the application of N did not result in a profitable return as expected. The apparent recovery fraction was negative for N, as well as for P, when comparing the N export with that of the control without N application (data not shown).

The response of 'Salina' clover to a heavy urban compost application was clear in relation to the N uptake, especially in the second year, with a N concentration significantly higher than those of the remaining treatments (Table 5). Total N export (Table 6) was also significantly higher than those of the other two treatments. Urban compost also had a moderate, positive effect on both concentration and export of P (Tables 5 and 6), with the effect on P concentration being apparent in the second year of the assay, with a significant increase compared to the remaining treatments. There exist variable results in the literature on the effect of urban compost on soil P availability and

TABLE 5.
Mean values and range of N, P, Ca, Mg, K and Na concentrations (%) in *T. fragiferum* dry matter (above ground part) after different treatments; Control (C), Inorganic Fertilizer (IF) and Urban Compost (UC)

Element	Treatment	First year		Second year	
		Mean	Range	Mean	Range
N	C	3.40 a	2.77 - 3.74	3.38 a	3.03 - 3.69
	IF	3.22 a	2.64 - 3.48	3.70 b	3.50 - 3.88
	UC	3.40 a	2.68 - 3.85	4.12 c	4.02 - 4.28
P	C	0.32 a	0.34 - 0.37	0.27 a	0.26 - 0.28
	IF	0.28 a	0.22 - 0.32	0.27 a	0.25 - 0.30
	UC	0.32 a	0.27 - 0.35	0.31 b	0.29 - 0.34
Ca	C	2.43 a	2.05 - 2.86	2.67 a	2.31 - 3.05
	IF	2.50 a	2.10 - 2.74	2.67 a	2.27 - 2.87
	UC	2.38 a	2.00 - 2.60	2.49 a	1.98 - 2.87
Mg	C	0.37 a	0.29 - 0.50	0.34 a	0.23 - 0.50
	IF	0.37 a	0.30 - 0.45	0.43 a	0.32 - 0.54
	UC	0.34 a	0.30 - 0.37	0.40 a	0.31 - 0.49
K	C	4.85 a	3.94 - 5.57	4.43 b	2.96 - 5.30
	IF	4.78 a	4.32 - 5.20	3.59 a	2.94 - 4.75
	UC	4.97 a	4.57 - 5.32	4.03 b	3.44 - 4.50
Na	C	0.76 a	0.68 - 0.80	0.57 a	0.30 - 0.78
	IF	0.72 a	0.65 - 0.78	0.89 b	0.78 - 1.00
	UC	0.72 a	0.66 - 0.76	0.84 b	0.60 - 1.06

Values followed by the same letter in the same column, for each element, do not differ significantly ($P < 0.05$).

plant uptake. Some authors have reported decreases in P contents of crops as consequence of compost application, while others have registered increases on soil P availability and plant uptake (Gallardo-Lara and Nogales 1987).

It is possible that, under similar conditions, different results could arise from pot and field experiments. As for metals, it is possible that pot studies overestimate the nutrient availability found under field conditions, although the reason for this discrepancy has not been clearly established (Mc Bride 1995). Using this same urban compost at field, Cabrera *et al.* (1989) did not find increases in soil P availability.

The addition of urban compost caused a moderate positive response on K plant uptake (Tables 5 and 6). It is well established that K is present in urban composts in an easily available form (Gallardo-Lara and Nogales 1987) and can cause a 'luxurious' K plant uptake. This circumstance has been reported for lettuce (Hernández *et al.* 1992) using similar urban compost and type of soil to those used in this assay. However, for 'Salina' strawberry the response was only moderate, showing some increases in total above-ground export, although not significant in relation to those produced by C and IF treatments (Table 7). The apparent recovery fraction for K caused by IF and UC treatments was very similar in the first year, approximately 18 percent in both cases (data not shown).

The inorganic fertilization did not increase either K concentration nor K plant export (Tables 5 and 6). Potassium concentration was even significantly lower than that of the control in the second year (Table 5). Despite the addition of K, it is possible that soil K availability was insufficient in the second year to cope with the increased growth resulting from the application of the inorganic fertilizer (Table 4). If this was the case, this could explain the significant increases in Na concentration and export in the plants

with IF treatment in the second year (Tables 5 and 6). A possibly insufficient K supply could be partially alleviated by Na uptake, which could have substituted K, particularly in its biophysical role. To a certain extent, this could also be the case in the second year for the urban compost treatment. This effect of replacing K by Na has been frequently described in the literature (Griffith *et al.* 1965; Nowakowski *et al.* 1974; Smith *et al.* 1980; Barraclough and Leigh 1993).

These results show that this clover appears to have a reasonable capacity to absorb and transport Na, a capacity not shown by all plants, despite Ca and Mg being universal substitutes (Barraclough and Leigh 1993) and despite the fact that dicotyledonous species (as clovers) have a larger demand for Ca than monocotyledonous (as grasses), as it has been well demonstrated by Loneragan and Snowball (1969). Both concentration and total above ground export of Ca and Mg did not indicate any noticeable variation whichever treatment was considered (Tables 5 and 6). Thus, a potential immediate salinization derived from the urban compost utilization does not seem to be a problem for 'Salina' clover, due to its natrophilic character.

TABLE 6.
Above ground N, P, Ca, Mg, K and Na export (g m⁻²) of *T. fragiferum* dry matter following the treatments Control (C), Inorganic Fertilizer (IF) and Urban Compost (UC)

Element	Treatment	First Year	Second Year	Total Two Years
N	C	46.5 a	39.2 b	85.7 b
	IF	41.4 a	49.0 ab	90.4 b
	UC	54.7 a	57.0 a	112.0 a
P	C	4.2 ab	3.2 a	7.4 b
	IF	3.4 b	3.6 a	7.1 b
	UC	4.5 a	4.3 a	8.8 a
Ca	C	41.4 a	31.1 a	72.5 a
	IF	37.2 a	36.0 a	73.2 a
	UC	39.9 a	35.3 a	75.2 a
Mg	C	6.8 a	3.9 b	10.7 a
	IF	6.0 a	5.9 b	11.8 a
	UC	5.2 a	5.8 a	11.0 a
K	C	60.9 a	53.1 a	114 a
	IF	64.4 a	46.7 a	111 a
	UC	74.1 a	57.3 a	131 a
Na	C	11.0 a	7.0 b	18.0 b
	IF	10.0 a	11.5 a	21.5 a
	UC	10.6 a	10.7 a	21.3 a

Values followed by the same letter in the same column, for each element, do not differ significantly ($P < 0.05$).

TABLE 7.

Mean values and range of Fe, Mn, Zn and Cu concentrations (mg kg⁻¹) in *T. fragiferum* dry matter (above-ground part) after different treatments; Control (C), Inorganic Fertilizer (IF) and Urban Compost (UC)

Element	Treatment	First Year		Second Year	
		Mean	Range	Mean	Range
Fe	C	102 a	83 - 124	152 a	67 - 239
	IF	118 a	83 - 173	153 a	67 - 280
	UC	89 a	77 - 102	154 a	80 - 275
Mn	C	110 a	98 - 134	106 a	74 - 141
	IF	103 a	65 - 129	116 a	79 - 154
	UC	106 a	99 - 115	106 b	82 - 140
Zn	C	50 a	42 - 59	52 a	48 - 60
	IF	59 a	34 - 85	79 b	57 - 92
	UC	124 b	88 - 163	191 c	161 - 258
Cu	C	15 a	11 - 19	15 a	12 - 18
	IF	18 a	17 - 21	16 a	12 - 18
	UC	21 a	18 - 22	20 a	16 - 23

Values followed by the same letter in the same column, for each element, do not differ significantly ($P < 0.05$).

On the contrary, the heavy urban compost application did not increase either Fe and Mn concentrations (Table 7) nor their above ground plant export (Table 8), which agree with data in the literature for Fe (Gallardo-Lara and Nogales 1987). Data in relation to Mn were more interesting, since toxicity can occur in forage crops by this metal and the strawberry clover being only moderately tolerant to Mn excess as compared to other more tolerant clovers, e.g. red and white clover (Kendall and Stringer 1985). However, it is also well known that in plants Mn can decrease as consequence of compost application (Gallardo-Lara and Nogales 1987), possibly due to the presence of different complexing agents in the organic matter (Wallace and Wallace 1983). Nevertheless, factors such as organic matter characteristics and dose, plant species, soil

type and management may influence Mn plant uptake (Murillo *et al.* 1995a,b). In this study, the application of urban compost did not reduce either the Mn concentration (Table 7) nor the above ground Mn export (Table 8), although its export was slightly lower than those observed with the control and inorganic fertilizer treatments.

The increases in heavy metal concentrations were comparatively low. As an example, Table 9 shows the heavy metal and B concentrations from leaves and petioles of the last cut of clover (second year). These values were always clearly lower than those phytotoxic concentrations or toxic levels for cattle, although the heavy dose of urban compost loaded significantly increased the concentration of Zn, Cu, Ni and Cr

TABLE 8.
Above ground Fe, Mn, Zn and Cu export
(mg m⁻²) of *T. fragiferum* dry matter
following the treatments Control (C),
Inorganic Fertilizer (IF) and
Urban Compost (UC)

Element	Treatment	First Year	Second Year	Total Two Years
Fe	C	161 ab	170 a	330 b
	IF	217 a	208 a	425 a
	UC	128 b	217 a	345 b
Mn	C	192 a	145 a	337 a
	IF	170 a	158 a	328 a
	UC	161 a	151 a	312 a
Zn	C	80.7 b	86.3 b	167 b
	IF	88.7 b	109 b	198 b
	UC	156 a	243 a	399 a
Cu	C	22.0 a	18.4 b	40.4 b
	IF	24.0 a	21.6 a	45.6 b
	UC	28.7 a	32.1 a	60.7a

Values followed by the same letter in the same column, for each element, do not differ significantly ($P < 0.05$).

TABLE 9.

Mean values of Fe, Mn, Zn, Cu, Ni, Cr, Cd, Pb and B concentrations (mg kg⁻¹) of *T. fragiferum* leaves and petioles dry matter as affected by treatments Control (C) and urban compost (UC).

Phytotoxic concentrations and toxic levels for cattle are also depicted for some cases.

Plant Part	Treatment	Fe	Mn	Zn	Cu	Ni	Cr	Cd	Pb	B
Leaves	C	150 a	80 a	55 b	16 b	4.3 b	0.8 b	< 1	7.5 a	22 a
	UC	170 a	90 a	180 a	22 a	6.0 a	1.1 a	< 1	8.0 a	22 a
Petioles	C	100 a	36 a	30 b	9 b	2.5 b	-	-	-	19a
	UC	115 a	40 a	75 a	13 a	3.5 a	-	-	-	20 a
Phytotoxic concentrations ^z		-	400 - 2000	500 - 1500	25 - 40	50 - 100	-	5 - 700	-	> 100 ^y
Toxic levels for cattle ^x		2400	1000 ^w	900	115	50 ^v	-	0.5 ^v	30 ^v	-

^z According to Chaney (1989)

^y According to Adriano (1986)

^x According to Georgievskii *et al.* (1982)

^w According to Jarrige (1981)

^v Maximum concentration chronically tolerated by cattle according to Chaney (1989)

in leaves and Zn, Cu and Ni in petioles, with the increase being more conspicuous for Zn, 225 percent in leaves and 150 percent in petioles, in relation to the control. The remaining trace elements were increased around 40 percent compared to the control.

However, a Zn concentration of 180 mg kg⁻¹ (range of 161 - 258 mg kg⁻¹ in plants the second year, Table 7) was far from being phytotoxic for most plants and from toxic levels for cattle and other grazing animals. Most plants tolerate Zn concentrations in leaves much larger than 100 mg kg⁻¹ without any visual toxicity symptoms (in a pot experiment carried out with alfalfa, Zn concentration of 702 mg kg⁻¹ was associated with yield depression, Adriano 1986). In this case, it seems convenient to pay more attention to soil contamination and quality than to the risk of plant or animal toxicity, which could only be present after repeated compost application for a large number of years.

In the case of Cu, the risk of plant or animal toxicity can be more immediate, since a concentration of 25 mg kg⁻¹ can be toxic for plants, as well as for some animals, such as sheep (Georgievskii *et al.* 1982). However, it is important to point out that the herbage intaked by ruminants includes a lot of grasses, where Cu concentration is much lower than that of legumes. As pointed out by Kubota (1983), the median concentration of Cu for US grasses was 4 mg kg⁻¹ (range of 1 - 16 mg kg⁻¹), much lower than that of legumes, 8.4 mg kg⁻¹ (range of 1 - 28 mg kg⁻¹). In this study, a range of Cu concentrations of 16 - 23 mg kg⁻¹ in the second year (Table 7) was not harmful to *T. fragiferum*. It seems obvious that the more moderate compost doses applied in current agriculture will not imply any risk of toxicity for plants or animals, although, as in the case of Zn, periodical soil quality monitorization must be carried out.

Data of Cr and Pb phytotoxicity are comparatively scarce. As pointed out by Adriano (1986), toxicity of Cr is essentially nonexistent, except possibly in soils derived from ultrabasic or serpentic rocks. Concentrations in plant tissues definitely associated with toxicity symptoms are usually in the several hundreds ppm range (Adriano 1986), which obviously was not the case of *T. fragiferum* in this study. Lead phytotoxicity is relatively low compared with other trace metals, and the concentration in *T. fragiferum* was much lower than the maximum concentration chronically tolerated by cattle, as also recorded for Ni, which showed concentrations in the clover always in the normal range for vascular plants (Table 9; Adriano 1986).

The concentration of Cd did not show any important increase in the clover tissues after the heavy dose of urban compost applied, with its level being less than 1 mg kg⁻¹ in both treated and untreated (control) plants, far from the phytotoxic level for most species (Table 9). However, it was not possible to determine if the concentration of Cd was higher than 0.5 mg kg⁻¹, the maximum chronically tolerated by cattle.

Conclusions

The results obtained suggest that *T. fragiferum* cv. 'Salina' could be a suitable plant for using urban composts, even when applied at a heavy rate. Seedling emergence was enhanced, by the large amount of urban compost applied at sowing. Further growth was fairly high, surpassing that obtained with an inorganic fertilizer application. Nitrogen and P concentration and export in the plant were increased by the urban compost presence. Although some heavy metals, Zn, Cu, Cr, Ni, increased by the compost presence, phytotoxic or toxic levels for cattle were never registered. The urban compost tolerance by *T. fragiferum* cv. 'Salina' could be a positive characteris-

tic for using this plant under situations where urban composts applied at a heavy rate was profitable, e.g. recuperation and utilization of saline areas or using brackish water for irrigation.

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