SEWAGE SLUDGE EFFECTS ON PRODUCTION OF WILD LEGUME SHRUBS

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1. ABSTRACT

The aim of the present study was to determine sewage sludge effects on growth and production in four species of wild legume shrubs: Colutea arborescens, Dorycnium hirsutum, Dorycnium pentaphyllum, and Medicago strasseri in a greenhouse experiment. The soils treated with sewage sludge had a relatively large amount of organic matter and phosphorus and a high quantity of heavy metals, but these were under the limits for agricultural uses, except for cadmium. In general, the growth of the wild legume shrubs was better on treated soils with sewage sludge than soils not treated or treated with mineral fertiliser. The application of sewage sludge has a great potential for the reclamation of degraded soils in combination with wild legume shrubs, since it improves the growth of plants and thus could contribute to controlling the desertification process. Heavy metals such Cd, Pb, Ni and Cr did not affect shrub growth. The micro nutrients Zn and Cu (very low in calcareous soils) could have been the reason for plant growth enhancement since the macro nutrients seemed to have slight effects.

2. INTRODUCTION

Fire, unsound cultivation practices, inadequate or excessive grazing, urban pressure and public works, can all initiate the process of land degradation, and this is generally followed by soil erosion and decline of vegetation and land productivity. Degraded areas have a serious risk of desertification, which is a difficult phenomenon to reverse (Grainger, 1990; Le Houèrou, 1996). Soil erosion problems and ongoing degradation processes presently affect large parts of the Mediterranean area and because of this, it is essential that action leading to natural resource conservation, and regeneration and improvement of the fragile and semiarid ecosystems is taken.

It is well known that degraded soils are deficient in organic matter. Furthermore, human activity generates a large quantity of urban organic waste which requires disposal. In recent years, research on urban organic wastes and their effects on various soil characteristics have been conducted by several authors (Garcìa et al., 1991; Navas et al., 1998; Walter et al., 2000; White et al., 1997). The use of this organic waste also has the beneficial effect of decreasing the considerable volume of waste, thus contributing to the conservation of the environment. The use of this sort of waste in land reclamation and in agricultural systems has being identified as an important issue for both soil conservation and residual disposal, and has gained considerable importance for research in arid and semiarid environments (Albadalejo et al.,1994; Lax et al., 1994; Navas, 1996; Sabey et al., 1990).

Besides the contribution of organic matter and macro nutrients, sewage sludge provides significant contributions of micro nutrients such as Fe, Zn and Cu in deficient calcareous soils. Undesirable constituents potentially associated with sewage sludge application include elevated levels of heavy metals including Cd and Pb. Sewage sludge can be also a source of slow-release N and P in contrast to mineral fertilisers, thereby it could be used to improve the soil chemical, physical and biological properties and consequently its fertility.

On the other hand, degraded soils restoration requires revegetation with plants which are able to grow and develop in low fertility soils or may even serve to improve the quality of the soil, giving a vegetation cover that protects the soil surface. In this aspect, the legume shrubs play an important role in land reclamation and have a great potential for the regeneration of degraded lands in semiarid climates, due to their high adaptation to arid and semiarid environments, nitrogen-fixing capacity and their ability to grow on poor soils (Van Andel et al., 1993). Recent studies have used different wild legume shrubs to select the most productive and drought tolerant plants for cool semiarid climates (de Andrès et al., 1997, 1998, 1999). From these studies, the shrubs

Colutea arborescens, Dorycnium hirsutum, Dorycnium pentaphyllum and Medicago strasseri were identified as good candidates for land reclamation and erosion control.

The aim of this study was to evaluate the establishment of wild legume shrub species in a degraded soil that had received high rates of sewage sludge application over an 8-year period in a greenhouse environment. The objectives were as follows:

1. to assess the effect of different rates of sewage sludge applications on the growth and production of four wild legume shrub species; and

2. to determine the nutrient and heavy metal concentrations in the shrub tissues.

3. MATERIALS AND METHODS

Municipal sewage sludge from the two Madrid treatment plants, were applied from 1983 to 1991 on plots of soil located in "La Canaleja", an experimental farm in Alcal· de Henares, Madrid. This soil had low organic matter and high carbonate concentration, being classified by Soil Taxonomy as Typic Haploxeralf Calciorthid. The experimental field design was established as a randomised complete block, having an untreated plot (control), a mineral fertiliser (MF) plot, equivalent in N, P, K to a low rate of sewage sludge application, and four sludge treatments (Table 1), each replicated three times. Wheat (Triticum aestivum L. Ansa) was grown in each plot during and after sludge application. After the 8^{th} year of the last sludge application the surface soils from the different treatments were collected (0-15 cm depth) from the middle of each plot for the greenhouse experiments.

Soil subsamples from each treatment were collected, air-dried, ground and passed through a 2 mm sieve for analysis (Table 3). The main chemical and physical properties were determined by standard methods (pish Ministry of Agriculture, Fisheries and Food, 1994). The total content of heavy metals in the applied sludges (Table 2) and soil sample (Table 4) were determined by Plasma Emission Spectrometry after acid digestion with HNO_3-HCl (McGrath and Cunliffe, 1985). The soil available heavy metals were extracted using the DTPA (diethylenetriaminepentaacetic acid) method (Lindsay and Norvell, 1978). (Table 4).

The wild legume shrubs used in this study were Colutea arborescens, Dorycnium hirsutum, Dorycnium pentaphyllum, and Medicago strasseri. The plant material was obtained by cutting propagation from an experimental plantation of wild leguminous shrubs at "La Canaleja". The shrubs were grown in 30 l plastic pots under glasshouse conditions. At the commencement of the study when the shrubs were transplanted into the pots the plants were 20 to 25 cm in height. Following planting the pots were randomly placed on the greenhouse bench and water was added as needed throughout the study.

After 12 months the legume shrubs were measured for height and then harvested. Shrubs were separated into roots, stems, leaves and flowers. Flowers, leaves, and stems were washed with distilled water, and roots were washed in tap water until free of soil, then washed with distilled water. The washed plant tissue samples were dried in an oven at 70†C, and weighed. After this, dried plant samples were ground to pass through a 0,85 mm diameter screen for chemical analyses. Shrub roots, stems and leaves were analyse for micro elements and heavy metals by ICP plasma after dry combustion (500 †C). Macro nutrients for leaves were also analysed for C and N by dry combustion with a LECO HCN analyser, and P, Ca, Mg and K by ICP plasma after nitric-perchloric acid mixture digestion. There were not enough samples of shrub flowers to performance the analyses.

	Treatments	Total amounts Mg ha^{-1}
C	Control	-
MF	Mineral fertiliser	-
T 1	Sur d1	400
T 2	Sur d2	800
T 3	Vivero d1	400
T 4	Vivero d2	800

Table 1. Treatments applied from 1983 to 1991.
Sur and Vivero: Sewage sludges. d1 and d2: 50 and 100 Mg. ha^{-1} $year^{-1}$, respectively.

	Zn	Pb	Cd	Ni	Cr	Cu
ÝÝ mg Kg^{-1}						
Sur	2250±535	665±180	82±54	100±65	272±163	1640±577
Vivero	1250±344	450±110	30±22	94±74	490±85	540±234

Table 2. Total heavy metal contents in the applied sludges (mean µ SD, n=8)

Data were analysed using GLM procedures included in the SAS statistical package (SAS Institute Inc; 1988). Significant differences between means were estimated using Duncan's Multiple Range Test, P = 5%, (Duncan, 1955).

4. RESULTS AND DISCUSSION

The main physical and chemical soil characteristics of the different treatments are shown in Table 3. Organic matter, $N(NO_3)$, CEC, available P and EC in the sewage sludge treatments were higher than in the control and mineral fertiliser plots. The soil pH values were slightly lower than the control. Significant increases in soil organic matter were expected due to the addition of relatively large amounts of sewage sludge to soil, these results support that. Sewage sludge metals applied are mainly associated with the organic matter in the soil. Mineralisation of sewage sludge organic matter may release metals in available forms even in the long term following the cessation of sludge application, (Mc Bride, 1995).

Soil parameter	C	MF	T1	T2	T3	T4
pH	8.8± 0.10	8.7± 0.10	8.3± 0.15	8.3± 0.20	7.8± 0.10	7.9± 0.20
$CaCO_3$ g Kg^{-1}	118± 15	135± 17	143± 11	121± 11	97..2± 7.5	156± 12
CEC Cmol Kg^{-1}	4.99± 1..2	5.68± 1..5	7.81± 0.23	9.06± 0.52	9.12± 1.52	9.56± 0.64
E.CÝ dS m^{-1}	0.19± 0.02	0.20± 0.02	0.26± 0.03	0.23± 0.02	0.28± 0.03	0.28± 0.03
$N(NO_3)$ mg kg^{-1}	2.69± 0.22	2.78± 0.14	4.41± 0.31	5.94± 0.32	10.7± 1.2	11.7± 1.1
$N(NH_4)$ mg kg^{-1}	10.4 ± 1.2	9.35± 0.35	8.36± 1.12	9.33± 1.00	7.90± 0.75	11.3± 0.92
APÝ mg kg^{-1}	13.8 ± 1.4	54.2 ± 2.2	80.4 ± 5.2	119 ± 7.6	146 ± 9.2	191± 10..2
AK mg kg^{-1}	289 ± 12	330 ± 15	242 ± 21	234 ± 16	300 ± 11	273 ± 10
O M.g kg^{-1}	0.81± 0.21	1.18± 0.32	2.00± 0.20	2.75± 0.62	2.42±0.2.2	3.19± 0.52
Texture	Clay loam					

Table 3. Chemical and physical properties of the soil used in the study. (mean µ SD, n=3).
AP: available P, AK: available K. OM: oxidable organic matter. CEC: cation exchange capacity.

		Zn	Pb	Cd	Ni	Cr	Cr
	mg kg-1						
Control	totalAvail.	25.1 b1.15	30.5 c2.39	0.25 d0.06	10.6 c0.12	29.2 cND	8.76 c1.52
MF	TotalAvail.	20.8 b2.12	25.9 c2.13	0.64 d0.04	7.65 c0.21	39.5 cND	15.6 c1.82
Treatment	TotalAvail	125	62.0	4.52	24.2	56.5	85.1 a28.1

1		a25.3	a7.10	b1.64	b0.58	bND	
Treatment 2	TotalAvail	174 a28.8	92.3 a8.89	6.97 a1.85	27.5 ab0.83	80.5 aND	131 a32.3
Treatment 3	TotalAvail	113 a18.0	65.3 b6.37	2.68 c0.89	34.6 a0.71	62.0 abND	62.1 b12.9
Treatment 4	TotalAvail	164 a24.4	91.7 a6.37	3.99 bc1.09	35.9 a0.85	79.5 aND	92.4 a18.8

Table 4. Total and available heavy metal contents of the soil used in the study. (mean of three replicates).
Mean values within a column followed by the same letter are not significantly different at the 0.05 level by Duncan`s multiple range test. Avail: available by DTPA. ND: not detectable (below the detection limit).

The high sewage sludge application rates increased all the soil total heavy metals, as shown in Table 4. The effect of the application of sewage sludge on the total heavy metal contents in soil after the last application was statistically significant in all the cases. The increment of soil metal contents was due to the load of metals in the sludge treatments and generally, depended on the rate of application. But with the exception of soil total Cd all the heavy metal contents were below those established by the pish guidelines (RD 1310/1990) relating to the maximum allowed for heavy metals in soils. An increase of soil available heavy metals in the sewage sludge treatments was also observed (with the exception of Cr).

Shrub	Soil Treatments	Height (cm)	Root (g)	Stem (g)	Leaf (g)	Total Biomass (g)
Dorycnium pentaphyllum	C	77.7 a	6.82 b	10.37 b	4.11 b	21.30 b
	MF	86.0 a	13.19 ab	15.07 b	6.96 ab	35.22 ab
	T1	96.0 a	13.26 ab	41.27 a	13.86 a	68.39 a
	T2	88.3 a	17.58 ab	27.97 ab	10.72 ab	56.28 ab
	T3	89.0 a	21.44 a	27.76 ab	9.34 ab	58.53 ab
	T4	77.0 a	8.24 ab	17.78 ab	4.96 b	30.98 ab
Dorycnium hirsutum	C	84.7 a	9.16 a	21.25 a	12.74 b	43.88 a
	MF	79.7 a	11.34 a	29.49 a	17.76 ab	58.50 a
	T1	81.7 a	17.80 a	40.98 a	27.33 ab	86.11 a
	T2	81.0 a	14.72 a	43.10 a	27.99 ab	85.81 a
	T3	83.3 a	17.58 a	44.81 a	30.40 ab	93.22 a
	T4	75.0 a	13.95 a	43.96 a	34.45 a	92.49 a
Medicago strasseri	C	90.7 a	13.30 a	27.83 b	11.48 a	53.65 a
	MF	88.7 a	18.78 a	41.98 ab	12.88 a	75.18 a
	T1	88.0 a	17.34 a	45.43 ab	13.59 a	79.25 a
	T2	100.0 a	23.14 a	56.93 ab	14.61 a	97.73 a
	T3	104.3 a	25.94 a	62.62 a	17.28 a	108.66 a

	T4	104.0 a	22.33 a	57.35 ab	19.65 a	103.54 a
Colutea arborescens	C	102.7 a	4.84 b	10.70 b	4.28 b	20.68 c
	MF	101.0 a	11.37 ab	12.64 b	5.22 b	30.68 bc
	T1	99.0 a	13.01 a	14.31 b	7.33 ab	36.90 bc
	T2	113.7 a	16.77 a	20.94 b	9.93 a	49.86 ab
	T3	97.3 a	13.06 a	21.97 b	6.87 ab	44.71 b
	T4	127.7 a	19.01 a	35.48 a	11.40 a	68.39 a
OVERALL	C	88.9 a	8.53 b	17.54 b	8.15 b	34.88 b
	MF	87.7 a	13.88 ab	25.90 ab	11.18 ab	51.64 ab
	T1	91.2 a	15.35 a	35.50 a	15.53 ab	67.66 a
	T2	98.3 a	18.05 a	37.24 a	15.81 ab	72.42 a
	T3	93.5 a	19.51 a	38.29 a	15.97 ab	76.28 a
	T4	95.9 a	15.88 a	38.64 a	17.62 a	73.85 a

Table 5. Effects of different soil treatments on the growth and dry mass production of shrubs. (mean of three replications).
Mean values within a column followed with by the same letter are not significantly different at the 0.05 level by Duncan`s multiple range test.

In general, a slightly positive growth response was observed when the shrubs were grown in sludge-amended soil (Table 5). The mean height of the control and MF were approximately 88.3 cm whereas the mean height of plants with sewage sludges was 94.7 cm but there were no significant differences between these values. To evaluate the effect of sludge on the shrubs, the weights of harvested shrub tissues were determined (Table 5). Harvested root weights showed a significant difference for all sludge treatments and harvested steam weights show a similar pattern when compared to the controls. Harvested leaf weights manifested significant difference only with the T4 treatment. Leaf weights were significantly higher for T4 than all treatments. Harvested total biomass of all the wild legume shrubs study was significantly higher in sludge amended soil than in the control. The sewage sludge addition significantly increased the root, stem, leaf and total biomass dry weights of Dorycnium pentaphyllum and Colutea arborescens. Medicago strasseri and Dorycnium hirsutum showed significant differences in stem and leaf dry weights respectively among soil treatments, and the growth of these shrubs was greater in biosolid amended soils, although these differences were not statistically different. It was concluded that sewage sludge treated soils substantially increased the growth of wild legume shrubs. The sewage sludge application enhanced the soil characteristics for plant growth, and these effects were more important for shrub growth than the possible detrimental effects of the heavy metals present.

Shrub	Treatments	C (g kg^{-1})	N(g kg^{-1})	P(g kg^{-1})	K(g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})
Dorycnium pentaphyllum	C	534	23.9	1.69	11.3	12.2	1.51
	MF	536	26.0	2.11	14.7	12.9	1.52
	T1	531	22.6	1.90	12.7	11.3	1.43
	T2	533	23.5	1.81	12.8	11.3	1.51
	T3	534	22.9	1.64	12.2	11.8	1.48
	T4	536	22.7	1.71	12.3	12.0	1.49
Dorycnium hirsutum	C	514	17.3	1.14	9.79	13.8	2.32
	MF	505	21.1	1.65	11.7	17.7	2.67
	T1	511	23.8	1.52Ý	9.79	18.1	2.71
	T2	514	21.5	1.46	10.6	17.7	2.62
	T3	513	25.8	1.99	10.5	18.7	2.78
	T4	506	23.0	1.64	10.2	21.5	3.25
Medicago strasseri	C	484	28.2	1.64	18.4	16.2	2.34
	MF	487	25.4	3.09	16.3	15.0	2.01
	T1	487	23.0	2.76	15.8	14.0	2.13

	T2	488	23.2	2.79	18.4	14.5	2.05
	T3	483	21.0	2.42	15.1	14.9	2.16
	T4	483	27.5	2.56	18.6	13.6	2.20
Colutea arborescens	C	462	24.8	1.60	12.7	17.4	2.68
	MF	501	21.0	2.01	7.49	15.2	2.40
	T1	488	23.1	1.77	8.36	19.7	2.85
	T2	493	22.0	2.39	9.82	15.7	2.55
	T3	485	25.8	2.72	9.36	18.1	3.26
	T4	490	25.2	2.78	9.95	23.0	2.88
OVERALL	C	499 a	23.6 a	1.52 b	13.1 a	14.9 b	2.21 b
	MF	507 a	23.4 a	2.22 a	12.6 a	15.2 b	2.15 b
	T1	504 a	23.1 a	1.99 a	11.7 a	15.8 a	2.28 ab
	T2	507 a	22.6 a	2.11 a	12.9 a	14.8 b	2.18 b
	T3	504 a	23.9 a	2.19 a	11.9 a	15.9 a	2.42 a
	T4	504 a	24.6 a	2.17 a	12.8 a	17.5 a	2.46 a

Table 6. Macro nutrient contents of shrub leaves for the different treatments.

Several factors may have contributed to the positive sludge effect. The major factors that the sludge addition could have enhanced are the supply of N and P; micro nutrients such as Zn and Cu; biological properties and physical properties. Organic matter added in the sludge would increase waterholding capacity, decrease bulk density, and increase aeration and root penetrability. Each of these factors could foster plant growth.

Shrub	element	Tissue	C	MF	T1	T2	T3	T4
Dorycnium pentaphyllum		Root	20.2c	28.6c	50.76 a	60.53a	45.1ab	73.6 a
	Zn	Stem	24.7b	36.6ab	46.99 a	49.6a	48.9a	47.5 a
		Leaf	25.6b	26.7b	34.8b	38.4ab	38.0ab	51.6 a
		Root	5.33b	5.49b	9.97 a	10.1a	8.66a	9.21 a
	Pb	Stem	2.93b	3.61ab	4.34 a	4.11ab	4.46a	4.54 a
		Leaf	0.46a	0.33a	0.43 a	0.48a	0.48a	0.51 a
		Root	0.41b	0.62b	2.28 a	2.46a	1.29a	2.67 a
	Cd	Stem	0.15 c	0.41b	0.75 a	0.96a	0.41b	0.68ab
		Leaf	ND	0.14c	0.45ab	0.62a	0.40b	0.57 a
		Root	1.22c	1.47bc	1.75ab	2.67a	1.80ab	2.17ab
	Ni	Stem	1.07b	1.16b	1.56 a	1.61a	1.38a	1.40 a
		Leaf	0.18b	0.23b	1.16 a	1.09a	1.16a	1.57 a
		Root	1.10c	1.41bc	2.06ab	2.40a	2.36a	2.21 a
	Cr	Stem	0.19a	0.23a	0.51 a	0.50a	0.55a	0.56 a
		Leaf	ND	ND	ND	ND	ND	ND
		Root	9.42c	10.6c	28.8 a	30.7a	18.1ab	25.1 a
	Cu	Stem	3.89b	3.69b	6.07 a	5.88a	6.41a	6.70 a
		Leaf	4.25b	5.15b	11.5 a	11.3a	9.33a	11.2 a
Dorycnium hirsutum		Root	40.2c	37.8c	127b	208a	122b	142b
	Zn	Stem	40.7b	32.5 b	81.2 a	71.8a	81.4a	92.6 a

		Leaf	43.9b	48.1b	63.0a	75.5a	67.8a	83.3 a
		Root	6.17b	7.44b	9.53ab	9.94ab	11.75a	12.32 a
	Pb	Stem	2.95a	2.68a	3.38 a	3.16a	3.50a	3.19 a
		Leaf	0.34a	0.37a	0.92 a	0.96a	0.69a	0.89 a
		Root	0.95b	0.97b	10.7 a	10.6a	10.5a	11.8 a
	Cd	Stem	0.53c	0.51c	0.96b	1.22ab	2.33a	1.44ab
		Leaf	0.31c	0.37c	0.99b	1.31a	0.88b	1.11ab
		Root	2.09a	2.14a	2.52 a	2.99a	3.32a	3.21 a
	Ni	Stem	1.57b	1.60b	2.70ab	2.30ab	3.24a	2.68ab
		Leaf	1.53b	1.65b	2.22 a	2.34a	2.26a	2.93 a
		Root	1.31a	1.52a	2.98 a	2.58a	3.87a	2.17 a
	Cr	Stem	0.37a	0.47a	0.61 a	0.60a	0.60a	0.57 a
		Leaf	ND	ND	ND	ND	ND	ND
		Root	19.4b	15.6b	67.1 a	65.2a	60.0a	63.3 a
	Cu	Stem	7.32a	7.31a	11.0a	9.4a	9.76a	10.3 a
		Leaf	4.47b	4.95b	10.8 a	10.4a	15.1a	12.9 a

Table 7. Micro nutrient and heavy metal contents of the shrub tissues in the different treatments. (Dorycnium pentaphyllum and Dorycnium hirsutum). Mean values within the same line followed by the same letter are not significantly different at the 0.05 level by Duncan`s multiple range test. ND: not detectable (below the detection limit).

The N, P, K, Ca, and Mg contents of the leaf tissue were generally within the normal range (Table 6). The P content of the leaf tissue from sludge amended soil was the only value that was significantly greater than the control.

Shrub	element	Tissue	C	MF	T1	T2	T3	T4
Medicago strasseri		Root	51.9e	56.1de	109cd	239a	155bc	193b
	Zn	Stem	53.1b	52.8b	72.2b	115a	121a	140a
		Leaf	77.2b	60.9b	114a	110a	140a	112a
		Root	7.07b	10.8ab	16.4a	17.5a	15.3a	15.3 a
	Pb	Stem	3.44b	3.66b	6.87ab	6.76ab	5.00ab	8.31 a
		Leaf	1.18a	2.43a	2.62 a	3.06a	2.71a	3.41 a
		Root	0.63c	0.70c	7.08b	7.51b	5.54a	8.19 b
	Cd	Stem	0.12d	0.21cd	0.38b	0.82a	0.36bc	0.44b
		Leaf	0.10c	0.12c	0.35a	0.34a	0.19b	0.25b
		Root	1.76b	2.55c	3.42b	5.34a	3.93b	5.57 a
	Ni	Stem	0.50bc	0.25c	1.17abc	1.64a	1.43ab	1.76 a
		Leaf	0.76b	1.04ab	1.88ab	2.21ab	1.55ab	2.32a
		Root	0.84a	0.58a	0.58a	0.63a	0.80ab	0.85 a
	Cr	Stem	0.22a	0.36a	0.47a	0.49a	0.57a	0.57

								a
		Leaf	ND	ND	ND	ND	ND	ND
		Root	26.1c	38.1c	209a	240a	179ab	191b
	Cu	Stem	8.78b	8.74b	9.13b	11.5ab	11.7ab	12.9 a
		Leaf	2.96b	2.86b	16.4a	19.9a	20.9a	19.3 a
Colutea arborescens		Root	41.5a	36.5a	49.0a	48.3a	43.4a	52.6 a
	Zn	Stem	37.1a	35.0a	34.8a	38.8a	41.4a	36.8 a
		Leaf	28.1b	29.7b	58.7a	56.0a	56.4a	50.5 a
		Root	4.13a	4.15a	6.24a	8.23a	6.18a	5.85 a
	Pb	Stem	6.77a	6.01a	5.23a	5.93a	7.67a	6.47 a
		Leaf	0.70a	0.73 a	0.94a	0.93a	0.67a	0.72 a
		Root	0.29c	0.27 c	1.21a	1.39a	0.46bc	0.96b
	Cd	Stem	0.15a	0.13a	0.24a	0.27a	0.24a	0.24 a
		Leaf	0.11a	0.12a	0.13a	0.21a	0.12a	0.15 a
		Root	1.28a	1.32a	1.65a	2.22a	1.52 a	1.60 a
	Ni	Stem	1.03a	1.08a	1.14a	0.87a	1.01a	1.17 a
		Leaf	1.55a	1.23a	1.31a	1.55a	1.99a	1.57 a
		Root	0.26a	0.31a	0.56a	0.59a	0.61a	0.58 a
	Cr	Stem	0.23a	0.22a	0.35a	0.41a	0.38a	0.45 a
		Leaf	ND	ND	ND	ND	ND	ND
		Root	9.37b	8.27b	21.6a	21.1a	21.5a	20.6 a
	Cu	Stem	2.28a	6.18a	7.29a	8.97a	7.98a	6.79 a
		Leaf	4.71b	6.72a	6.68a	6.32a	7.26a	8.05 a

Table 8. Micro nutrient and heavy metal contents of the shrub tissues in the different treatments. (Medicago strasseri and Colutea arborescens).
Mean values within the same line followed by the same letter are not significantly different at the 0.05 level by Duncan`s multiple range test. ND: not detectable (below the detection limit).

The micro nutrient and heavy metal contents of the shrub tissues in the different treatments are shown in Tables 7 and 8. The Zn content was quite high in the shrub tissues especially in Medicago strasseri and Dorycnium hirsutum and slightly high in Dorycnium pentaphyllum and Colutea arborescecens.

The Cu and Cd contents of root and steam tissues showed a similar pattern to Zn, with higher values in Medicago strasseri and Dorycnium hirsutum and slightly high in Dorycnium pentaphyllum and Colutea arborescecens.But Cd contents in leaf tissues in Medicago strasseri show similar values toDorycnium pentaphyllum and Colutea arborescecens.

Nickel as a mobile element, showed similar values in the three tissues studied and presented the same pattern in the four shrubs. The Pb contents in the shrub tissues remained low in all the species studies and it was hardly absorbed by the plants at all. Even the shrub roots contained by far, less Pb than the corresponding treatments did. The Cr is well known to have a low availability, this explained why this element was undetectable in the leaf of the shrubs and Cr content in the stems was also low. The values were near the sensitivity limits of the plasma ICP measurement and therefore were hardly reproducible. As already shown for Pb, all the absorbed Cr also remained in the roots.

In general, Pb and Cr did not significantly increase with application of sludge. Cd and Ni increased depending on the species, and Zn and Cu increased significantly with sludge applications in all the species studied.

5. CONCLUSIONS

The application of sewage sludge has a great potential for the reclamation of degraded soils in combination with wild legume shrubs, since it improves the growth of plants and thus could contribute to controlling the desertification process. Heavy metals such Cd, Pb, Ni and Cr did not affect shrub growth. The micro nutrients Zn and Cu (very low in calcareous soils) could be the reason of plant growth enhancement since the macro nutrients seemed to have only slight effects. The effects of sewage sludge on production of wild legume shrubs should be studied in a further long-term field experiment to confirm the results obtained in the greenhouse experiment.

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