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PLANT COLONIZATION AND BIOMASS PRODUCTION IN A XERIC TORRIORTHENT AMENDED WITH URBAN SOLID REFUSE

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ABSTRACT

A long-term field experiment was conducted in a semiarid Mediterranean site to determine the effect of the application of several doses (6·5, 13, 19·5 and 26 kg m^{-2}) of urban solid refuse (USR) on the plant colonization, plant cover and biomass production. The plant species richness did not increase in all the treated plots with respect to the control except immediately after the treatment was applied. This increase was only maintained after three years in the lowest dose of USR and the control. The addition of USR slowed floristic change and the lowest percentages of change corresponded to those plots receiving the highest doses. The plot receiving the lowest doses behaved in a similar way to the control plot. Plant cover increased substantially in the plots treated with USR compared with the control plot, even the lowest doses increasing the cover by 500 per cent. Plant biomass also significantly increased in all the amended plots compared with the control, although such increases were not directly proportional to the doses of USR added. USR can be considered an effective organic amendment to regenerate the plant cover of degraded soils.

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INTRODUCTION

The natural vegetation of the arid and semiarid areas of the Mediterranean basin are severely depleted. Shortage of water is often considered to be the principal limiting factor (Groves, 1986), but scarcity of nutrients, particularly phosphorus and nitrogen, is likely to be more important (Tilman, 1993). Vegetation has adapted to this situation. Annual species predominate over perennial and bushy species. However, annuals offer scant protection to the soil and, given the torrential nature of what rainfall there is, hydric erosion leads to serious degradation of the soil. Spontaneous recovery of these areas is difficult. To accelerate their regeneration, soils are often amended with materials with a high organic matter content to stimulate biological activity and provide nutrients (Guidi, 1981; Bastian and Ryan, 1986; Logan, 1992). At the same time the soil's water holding and available water capacity are improved (Khaleel, *et al*., 1981).

But what effect has the addition of organic matter on the evolution of plant cover? On occasion the addition of wastes has been found to inhibit plant germination and growth (Hunt, *et al*., 1973; Nogales, *et al*., 1983; Jimenez and Perez-Garcia, 1989; Rodgers and Anderson, 1995). Other studies report beneficial effects with no really important phytotoxic problems (Sopper and McMahon, 1987, 1988a and b; Garcia, *et al*., 1990; Guidi, *et al*., 1990). Glenn, *et al*. (1994) obtained good plant cover and biomass improvement with composted urban solid wastes in natural forested systems. However, studies on plant colonization, changes in biomass and plant production in unforested environments are rare (Schmidt, 1988; Peet, 1992).

Since 1988 we have been carrying out a study of the regeneration of a degraded soil in a semiarid area of S.E. Spain by adding USR. The changes in the performance of physical, chemical, and microbiological properties of this soil have already been reported by Roldan and Albaladejo (1993), Albaladejo, *et al*. (1994),

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and Diaz, *et al*. (1994). In this paper we describe the spontaneous plant colonization processes and biomass production and their correlation with varying doses of USR.

MATERIALS AND METHODS

Field Study Site

The experimental area was located in Abanilla (30 km north of Murcia, S.E. Spain), one of the most degraded areas along the Spanish Mediterranean coast.

The climate is arid to semiarid Mediterranean: annual rainfall averages 200–300 mm, mostly in autumn and spring. The mean annual temperature is 19·2 °C, potential evapotranspiration reaches 900 mm year^{-1} and the drought period can last for 11–12 months.

The low rainfall and high temperatures contributed to xerophytic vegetation which, although adapted to the prevailing conditions, provides little soil cover. The potential vegetation corresponds to the Rhamno-Quercetum series. Due to man-induced degradation, edaphic series predominate where the loamy and/or saline nature of the soil permits only the growth of a specially adapted vegetation (Alcaraz, *et al*., 1991). Plant cover (2–4 per cent) is mainly open matorral (scrub).

The soil is a Xeric Torriorthent (USDA-SCS, 1975) formed from marls, with only an ochric epipedon as diagnostic horizon. Soil degradation is very high because of the lack of vegetal cover and the nature of the parent material (Albaladejo, *et al*., 1988). More detailed soil characteristics can be found in Diaz, *et al*. (1994) and Albaladejo, *et al*. (1994).

Experimental Design

In October 1988 a set of experimental plots consisting of five 90 m^2 rectangles was established on a hillside with a 10 per cent slope and north-westerly orientation in a homogeneous area.

To improve soil quality different doses of USR were added to the top 30 cm layer with a rotovator. A control plot was also tilled by rotovator. The amounts of USR added (kg m^{-2}) were as follows. Plot C = control; plot 1 = 6·5; plot 2 = 13·0; plot 3 = 19·5 and plot 4 = 26·0. The USR amendment levels were designed to raise the soil's organic matter content of 0·5, 1·0, 1·5 and 2 the percentage in the control. The USR used in this experiment was fresh material, which had been allowed to mature naturally for 10–15 days, after technical removal of the larger inorganic components (plastic, glass, etc.). Some relevant parameters of the USR are shown in Table I; for more detailed analytical characteristics see Albaladejo, *et al*. (1994) and Roldan and Albaladejo (1993).

Table I. Physical–chemical characteristics of the USR used in this experiment

Water content (%)	45·42
Ash (%)	40·70
pH (1:20 aq. extr.)	6·50
Conductivity (1:20) mScm^{-1}	4·22
Organic carbon (%)	23·0
Total N (%)	1·2
Total P (%)	0·6

Data were subjected to one-way analysis of variance and significant differences were determined by Tukey's test.

Measurements

Physical–chemical characteristics. Soil analyses were made from October 1988 to March 1992 to characterize the physical and chemical differences between plots. The percentage of stable aggregates was determined according to Benito, *et al*. (1986) with some modifications as shown in Diaz, *et al*. (1994). Porosity was determined from the equation $100(1 - D_b/D_p)$, D_b being the bulk density of an undisturbed soil sample of known volume weighed after drying at 105 degC, and D_p the particle density obtained by measuring the kerosene needed to make up the volume of a 25 ml volumetric flask containing 10 g of soil. The infiltration rate was calculated by double ring infiltrometer. Exchangeable K was determined by ammonium acetate extraction and using a flame photometer according to Schollemberger and Simon (1954). Available phosphorus was estimated by sodium bicarbonate extraction (Olsen, *et al.*, 1954) and colorimetric determination (Murphy and Riley, 1962). The saturation extract was an extraction of the soil solution obtained from a saturated paste by pressure pump (Bower and Wilcox, 1965), and from this extract, electrical conductivity was determined potentiometrically. The total organic carbon content was determined after pretreatment with HCl to eliminate carbonates (Colombo and Baccanti, 1989) followed by combustion at 1020 degC and determination in an automatic carbon analyser. Total N was determined in an automatic N analyser.

Plant characteristics. Inventories were made in spring of 1989, 1991, 1992 and 1993. A percentage of cover was assigned to each of the species found. Aerial biomass was determined by the destructive method, cutting all the vegetation in three plots (1 m^2) and calculating the dry weight after heating in an oven at 70 degC for 24 hours.

RESULTS AND DISCUSSION

Changes in the Floristic Composition

The incorporation of the waste by rotovator left the soil completely bare, but due to its increased fertility and improved physical properties (Table II), and, following the first rains (see Figure 1), the vegetation began to appear. The year 1989 saw an explosion of annual plants mainly belonging to the families Cruciferae and Compositae (Table III). Annuals behave as pioneering and invading species, which take advantage of the added easily assimilable nutrients. The presence of annuals declined with time, as did the number of individuals. More slowly growing perennial species (Leguminosae and Thymelaceae) began to dominate and these increased in size and diversity according to the theories of Montalvo, *et al.* (1993) and McCook (1994). This succession occurred in all the treated plots, but was more rapid in plots 1 and 2 (lower doses) than in 3 and 4 (higher doses).

One year after incorporation of the USR, species richness was higher in all treated plots than in the control plot (Figure 2), 31 per cent of the variety of species being *de novo* colonizing annual leguminous plants. They play an important role in the nitrogen cycle. While the diversity or number of species increased in plot 1 (the lowest doses of USR) it decreased in the other plots compared with the control. The fifth year after treatment was about the same, except that perennials appeared in the plots which had received the highest doses of USR (plots 3 and 4).

The species richness (Figure 2), increased in all the treated plots relative to the control immediately after the treatment was applied. In 1991 the species richness increased sharply in all plots compared with the 1989 values. This increase was only maintained after three years in plot 1 and the control plot. Grime (1979) and Tilman (1982) suggested that habitats with a high production capacity show less diversity due to the intense competition. Van Hecke, *et al.* (1978) using NK treatments also found that diversity diminished with increased fertilization, while Tilman (1993) showed that species richness was highest at the start of the experiment and declined from the first to the sixth year in nitrogen fertilization treatments, the greatest decline in species richness in his experiment occurring in the highest nitrogen treatment.

Plant Cover

Plant cover increased substantially in the plots treated with USR relative to the control plot (Figure 3), even the minimum doses (plot 1) increasing the cover by 500 per cent. Plot 1 showed intermediate values between the control and the rest of the plots. The differences between plots 2, 3 and 4 were small although still

Table II. Soil physical–chemical changes in response to different amounts of urban solid refuse applied to the test plots

	Oct. 88	Mar. 89	Mar. 90	Mar. 91	Mar. 92
Stable aggregates (%)					
Control	50	45	51	48	
1	62	63	67	62	
2	69	68	68	68	
3	79	73	67	72	
4	77	78	75	78	
Porosity (%)					
Control	35·59	41·84			
1	40·27	45·53			
2	42·74	49·18			
3	45·19	46·95			
4	46·39	45·54			
Infiltration rate (cm h^{-1})					
Control		8	8	6	9
1		16	17	13	16
2		22	40	14	14
3		42	33	23	39
4		48	51	52	31
K available (cmol kg^{-1})					
Control	0·44	0·47	0·39	0·29	0·65
1	0·77	0·45	0·51	0·64	0·62
2	1·12	1·38	0·61	0·84	0·90
3	2·00	1·43	0·77	0·95	1·02
4	2·30	1·64	0·92	1·15	1·48
P available (mg kg^{-1})					
Control	5	6	3	3	2
1	13	10	6	6	11
2	7	12	11	9	9
3	8	10	19	13	31
4	19	24	22	27	25
EC (S m^{-1})					
Control	0·069	0·050	0·053	0·061	0·055
1	0·355	0·259	0·066	0·071	0·101
2	0·748	0·588	0·293	0·252	0·284
3	1·080	0·575	0·307	0·288	0·257
4	0·940	0·875	0·362	0·330	0·278
N t (%)					
Control	0·037	0·022	0·039	0·052	0·042
1	0·062	0·045	0·072	0·062	0·080
2	0·070	0·078	0·106	0·066	0·086
3	0·090	0·140	0·137	0·110	0·159
4	0·057	0·114	0·190	0·181	0·162
C org. (%)					
Control	0·36	0·59	0·40	0·49	0·56
1	1·26	1·13	0·78	0·84	0·96
2	1·27	1·24	1·20	1·31	1·23
3	1·75	1·25	2·00	1·08	1·50
4	1·37	1·75	2·20	1·78	2·23

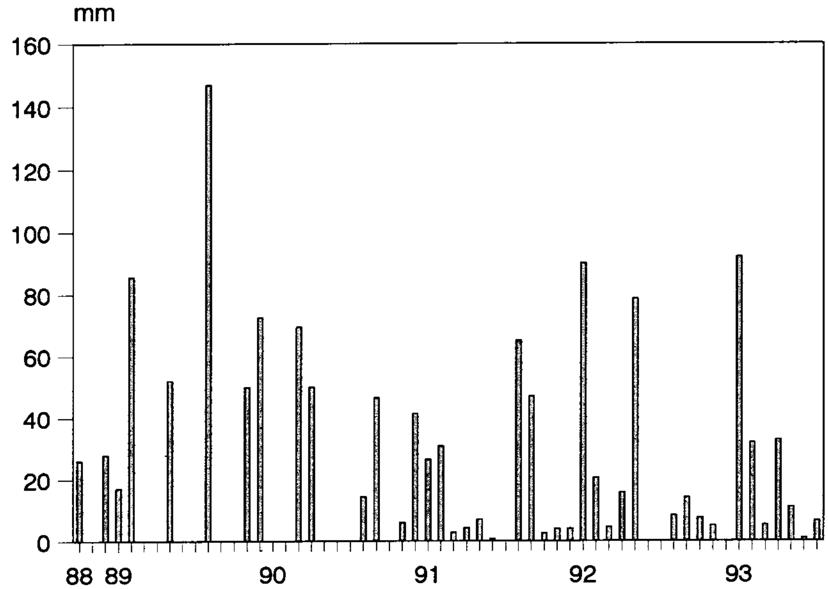

Figure 1. Monthly rainfall recorded during the experiment.

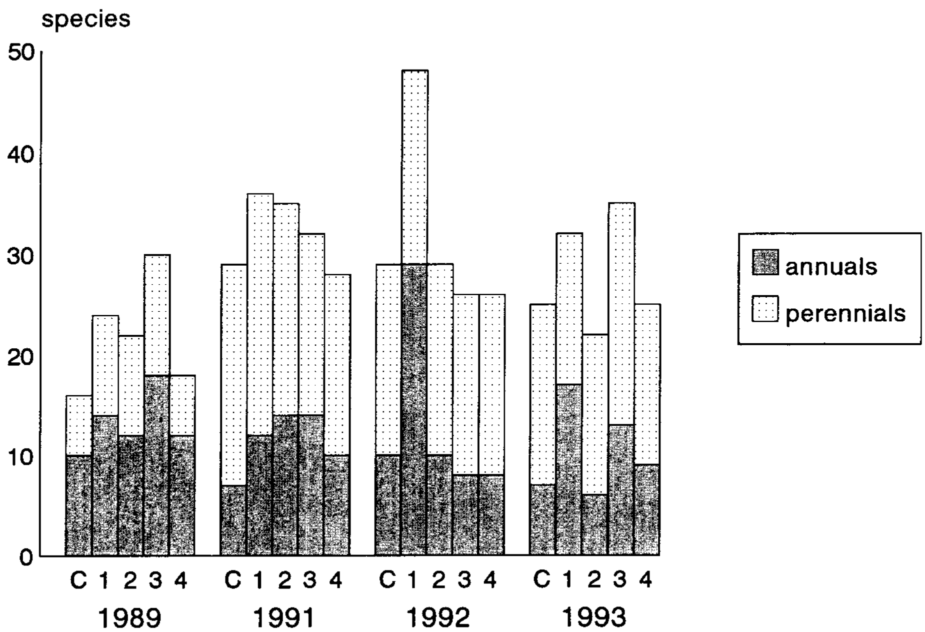

Figure 2. Species richness for perennial and annual plants in response to different amounts of USR applied to the test plots.

significant with respect to the control in all cases. However, in no case was the trend proportional to the doses. As time passed the plant cover values persisted even after long periods of drought. Similar results were obtained by Pichtel, *et al.* (1994) adding different organic compounds in an experiment to regenerate mining areas.

Table III. (part one). Changes in floristic composition and relative per cent of cover in response to different amounts of USR applied to the test plots. For species authors see Garcia-Rollan (1981, 1983) and Mateo and Crespo (1990)

	1989					1991					1992					1993				
	C	1	2	3	4	C	1	2	3	4	C	1	2	3	4	C	1	2	3	4
Aizoon hispanicum	0	0·1	0·1	0	2	0	0	0	0	0	0	0	0	0·1	0·1	0	0·1	0	0	0
Allium ampeloprasum	0	0·1	0·1	0·1	0·1	0	0·1	3	0·5	0·1	0	0	0	0	0	0	0	0	0·1	0
Ajuga iva	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis arvensis	5	7	7	3	5	0	0·1	4	3	6·5	1	3	0·1	0	0	0·5	4	0·1	0	5
Artemisia herba-alba	0	0	0	0	0	0·1	5	0	0	0	0·1	0·1	0	0·5	0	0·1	0	0	0·1	0
Asparagus horridus	0	0	0	0	0	0	0·1	0·8	0	0	0	1	0·1	0	0	0	1·5	0·4	0·1	0·1
Aster squamatus	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus sesameus	0	0	0	0	0	0	0	0	0	0	0	0·7	0	0	0	0	0	0	0	0
Atractylis cancellata	0	0·1	0	0·1	0·1	0·1	0·1	0	0	0	0	0·8	0	0	0	0	0·8	0	0	0
Atractylis humilis	0	0	0	0	0	4	3	0·5	0·2	0·2	6	0·1	0·1	0·1	0·5	1	0·5	0·5	0·5	0·5
Avena barbata	0	0	0	0·1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Beta maritima	0	0·1	4	0·1	0	0	0·1	13	7	11	0	0·8	1	0	0·1	0	1	0·1	0·2	0
Brachypodium retusum	0	0	0	0	0	18	0	0	0	0	14	0	0	0	0	8	0	0	0	0·1
Bromus fasciculatus	0·2	0	0	0·1	0	0	0	0·1	0	0	0	1	0	0	0	0	0	0·1	0	0
Calendula arvensis	0	0	0	0·1	0	0	0	0	0·1	0	0	0	0	0	0	0	0	0	1	0
Carduus bourgeanus	0	0·1	0·1	0·1	0	0	1	1	0	0·1	0	0·1	0·1	0	6	0	0	0	0	2
Carlina corymbosa	0	0	0	0	0	0	0	0	0	0·1	0	0	0	0	0	0	0	0	0	0
Centaurea melitensis	0	0·1	0·1	0·1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cichorium intybus	0	0	0	0	0	0	0	0	0	0	0	0	0	0·1	0	0	0	0	0	0
Convolvulus althaeoides	8	5	5	7	4	0·5	0·1	5	4	3	7	6	0	0·1	0·1	0·5	0·1	0	0·1	0
Conyza bonariensis	0	0	0	0	0	0	2	0·1	1	0·1	0	0·1	0	0	0	0	0	0	0	0
Coronilla scorpioides	0	0	0	0	0	2	0·1	0	0	0	0	0·4	0	0	0	0	0	0	0	0
Crepis taraxacifolia	0	0	0	0	0	3	5	5	9	9	1	3	7	10	0·3	0·7	2	0	11·5	5
Cynodon dactylon	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dactylis hispanica	0	0	0	0	0	0	0	0	0	0	0	1·1	0·1	0·5	0	0	0	0·1	0·1	0
Diplotaxis muralis	7	3	6	8	9	0·1	0	0·1	0	0·1	0	0·3	0	0	0	4	0·8	0	0·8	0·1
Dittrichia viscosa	0	0	0	0	0	1	0·1	0·4	0	0·1	0	0	0·1	0	0·1	0·6	0·1	0	0	0·1
Dorycnium pentaphyllum	0	0	0	0	0	0	3	0	0	0·1	0	0·1	0	0	0·3	0	0·6	0	0	0·3
Eryngium campestre	3	0·2	0·1	6	0·1	0	0·2	0	0·6	0·1	0·1	0	0·5	0·1	0·1	0·1	0	0	0·1	0
Eruca vesicaria	0	0	0	0·1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbia exigua	0	0	0	0	0	0	0	0·1	1	0	0	0·7	0·1	0	0	0	0	0·2	0	0
Euphorbia helioscopia	0·1	0·1	0·1	0·1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbia serrata	0	0	0	0·1	0	0·1	7	5	5	5	1·5	0	0	0·1	0·6	0·6	0	0·1	0·5	5
Filago pyramidata	0	0	0	0	0	0	0	0	0·1	0	0·1	0·1	0	0	0	0	0·1	0	0	0
Glaucium corniculatum	0	0·1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hammada articulata	0	0	0	0	0	1·5	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Hedypnois cretica	0	0	0	0	0	0	0	0	0·6	0	0	0·6	0	4·5	0	0	1	0	0	0
Hedysarum spinosissimum	0	0	0	0	0	8	0	0	0	0	9	0·8	0·1	0	0	0·8	1·2	0	0	0
Hordeum leporinum	0	0	0·1	0·1	0·1	0	7	12	11	9	0	5	0	5	15	0	0·1	0·5	0·2	0·1
Lactuca serriola	0	0	0	0	0	0	0·1	0	0	0	0	0	0	0	0·1	0	0	0	0	0

Table III. (part two)

	1989					1991					1992					1993				
	C	1	2	3	4	C	1	2	3	4	C	1	2	3	4	C	1	2	3	4
Lathyrus cicera	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Launaea fragilis	0	0	0	0	0	0·1	0	0·1	0·1	0·1	5	3	0·7	0	0·2	0	0	1	0·1	0·2
Launaea nudicaulis	0	0	0	0	0	2	0·1	0	0	0	0·1	1·1	0	0·1	0	0·1	0·1	10	0	0
Lavatera cretica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0·1	0	0	0	0	0
Leontodon longirostris	0	0	0	0	0	0	0	7	9	7	0	0·1	0·1	0	0	0	0	0	0	0
Lolium rigidum	15	10	8	6	13	0	0	0	0·1	5	0	2	0·8	0	6	0	0·5	0	0·1	0
Lygeum spartum	0	0	0	0	0	0·1	0·1	0·1	2	0	0	0	0·1	0·1	0	0	0	0·1	0·1	0
Malva parviflora	0	0	0	0·1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medicago littoralis	0	0	0	0	0	0	0	0	0	0	0	0·7	0·1	0	0	0	0·1	0	0	0
Melilotus sulcata	0	0	0	0	0	0	0	0·1	0	0	0	0·8	0	0	0	0	0·1	0	1	0
Moricandia arvensis	36	41	34	38	46	3	8	9	15	19	0·1	0·1	0·9	0·1	13	16	7	16	13	30
Onobrychis stenorrhiza	0	0	0	0	0	0·1	0	0	0	0	3	0	0	0	0	0·7	0	0	0	0
Ononis mollis	0	0	0	0	0	0	0	0	0	0	0	0·5	0	0	0	0	0	0	0	0
Ononis tridentata	0	0	0	0	0	0	0	0·1	1	0	0	0	0·1	0·1	0	0	0	0·1	0·1	0
Onopordum macracanthum	0	0	0	0	0	0	0	0	0·1	0	0	0	0	0	0	0	0	0	0	0
Pallenis spinosa	0·1	9	7	4	0	0·1	5	8	4	4	3	7	10	5	0·3	0·1	6	15	10	0·1
Papaver hybridum	0·3	0·1	0·1	0	0	0	0	0	0	0	0	0·3	0	0	0	0	0	0	0	0
Papaver rhoeas	0	0	0	0·1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phagnalon rupestre	14	11	10	8	7	17	11	5	5	6	20	11	19	19	18	15	29	29	28	2
Plantago albicans	0	0	0	0·1	0	0	4	0	0·1	0	0	0·1	0	0	0	0	0·1	0	0·1	0·1
Plantago afra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0·2	0	0	0	0	0
Plantago lagopus	0	0	0	0	0	6	0	0·1	0	0	8	0·8	0·1	0	0	9	1	0·1	0·8	0
Piptatherum miliaceum	0	0	0	0·1	0·1	0	0·1	0·1	2	0·1	0	0	13	6	6	0	0	0·5	0·1	7
Rapistrum rugosum	0·1	3	6·4	0·1	0·1	2	0·1	0	0	0	0	0·1	0	0	0	0	0	0	0	0
Reichardia picroides	0	0	0	0	0	0	0·1	0·1	2	0	0	0	0	0	0	0	0·8	0·1	3	0
Reichardia tingitana	0	0	0	0	0	0	0	0·1	0	0·1	0	1	3	5	0	0	0	0	0	0·5
Reseda lutea	0	0	0	0	0	0	0	0	0	0	0·1	0	0	0	0	0	0	0	0	0
Reseda undata	0	0	0	0	0	0	0	0	0	0	0·5	0	0	0	0	0·8	0	0	0	0
Salsola genistoides	0	0	0	0	0	2	0	0	0	0	0·1	0	0	0	0	1	0	0	0	0
Scabiosa stellata	0	0	0	0	0	0	0	0	0	0	0	0·2	0	0	0	0	0·5	0	0	0
Scorpiurus sulcatus	0	0·1	0	0	0	0	0	0	0	0	0·8	0·2	0	0	0	0	0	0	0	0
Scorzonera angustifolia	0	0	0	0	0	0·2	0·1	0·1	0	0	0·1	0·1	0·1	9	0·4	0·1	1	0	0·1	0·1
Scorzonera laciniata	0	0·1	0·1	0·1	0·1	0	0·1	0·1	0·1	3	0	0·5	0·6	0·4	0·1	0	1·2	0	0·1	0·5
Sonchus asper	3	3	4	7	2	0	0·1	10	6	5	0	0·6	0	4	11	0	0	0	10	6
Sonchus tenerrimus	8	6·5	7	11	7	0	4	9	8	6	2	5	10	5	0	1·2	1·6	0·1	0·5	1
Stipa parviflora	0	0	0	0	0	7	17	0·1	1·5	0·1	9	12	25	23	21	13	25	25	17	34
Suaeda vera	0	0	0	0	0	0	0	0	0	0·1	0	0	0	0	0·3	0	0	0	0	0·2
Teucrium gracillimum	0	0	0	0	0	0	0	0	0	0	0·1	0	0	0	0	0·1	0	0	0	0
Thymelaea hirsuta	0	0	0	0·1	0	10	11	0·6	0·1	0	0·5	9	0·1	0·1	0	7	8	0	0·1	0
Thymus hyemalis	0·1	0·1	0·1	0	0	7	4	0·1	0·8	0	5	8	7	1	0	19	4	0·5	0·4	0
Trachynia distachya	0	0	0	0	0	0	0	0	0	0	0·8	7	0	0	0	0	0	0	0·1	0
Vicia peregrina	0·1	0·1	0·1	0·1	0·1	0	0·1	0·1	0	0	0	0	0	0	0	0	0·1	0	0	0

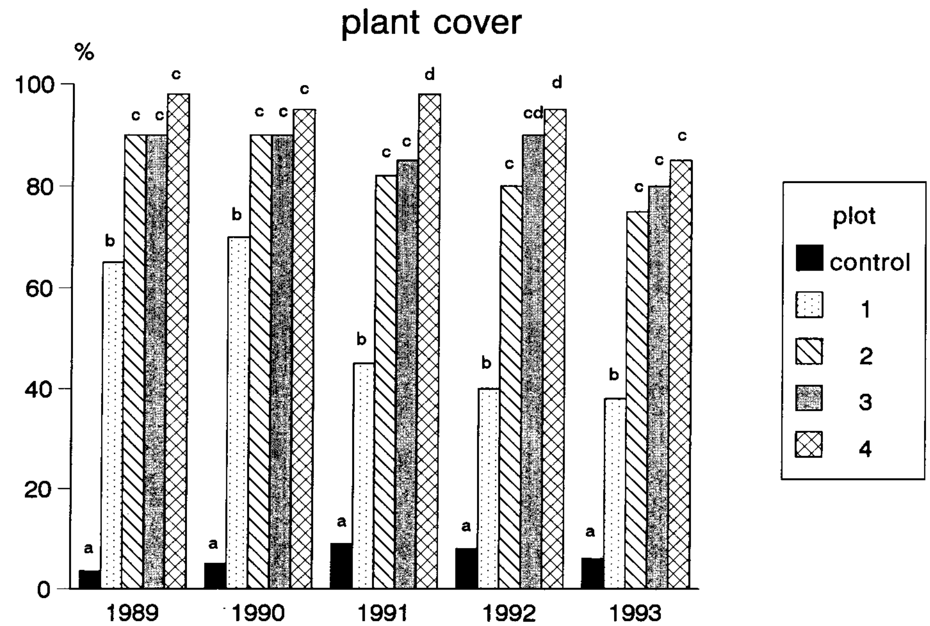

Figure 3. Percentage plant cover change in response to different amounts of USR applied to the test plots. Values are mean of four replicates. For each sampling date, bars sharing one letter do not differ significantly ($P < 0.05$) as determined by Tukey's test.

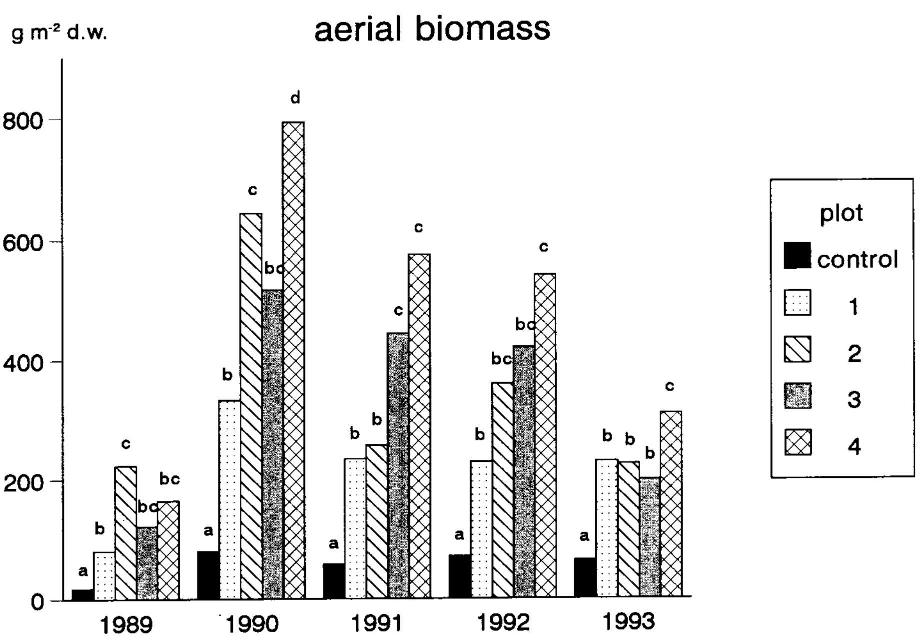

Figure 4. Aerial biomass changes in response to different amounts of USR applied to the test plots. Values are mean of four replicates. For each sampling date, bars sharing one letter do not differ significantly ($P < 0.05$) as determined by Tukey's test.

Plant Biomass

Biomass increased in all the plots relative to the control (Figure 4), although not proportional to the doses of USR added and with maxima coinciding with the moments of rainfall (Figure 1).

During the period 1988–89 (immediately after addition of USR) 209 mm of rain fell between October and May. Relative to the very low biomass values of the control (17·2 $g m^{-2}$) biomass increased by a minimum of 400 per cent in the treated plots. At this early stage the differences between plots are difficult to explain, especially the fact that plot 2 showed the highest biomass production. It seems that the higher doses of waste (plots 3 and 4) has an inhibitory effect immediately after application perhaps because electrical conductivity in the soil increased (see Table II) or due to the presence of toxic volatile compounds (Garcia, *et al.*, 1992). Whatever the case, the dose received by plot 2 was the most balanced as regards plant growth promotion/inhibition. These data referring to the first period showed that the soil had a seed potential sufficiently high to promote the development of plant cover, although this potential only manifested itself when the conditions improved through an increase in the available nutrients and an improvement in the physical properties of the soil (Table II), and/or increased water availability (Lavorel, *et al.*, 1993).

From October 1989 to May 1990 the rainfall was unusually high (293 mm) and the highest aerial biomass values were obtained at this time. Silvertown, *et al.* (1994) obtained similar results in an experiment involving mineral and organic fertilization, biomass increasing significantly with increased precipitation. The significant differences relative to the control remained and the differences between doses also remained proportionally similar.

In contrast, the rainfall between October 1990 and May 1991 was low (118 mm), a normal occurrence in the area. This probably explains the overall fall in biomass production in all the plots, including the control, although purely temporal and successional changes may also have intervened. For the first time differences between plots were related with the different doses of USR added and the differences between the plots and the control remained significant until the end of the experiment.

Between October 1991 and May 1992 134 mm of rain fell, representing another dry spell and one with a very irregular distribution, 85·5 mm falling on 18 and 19 February and almost the whole of the rest in October. Although the vegetation was exposed to a long drought period, the plant cover still managed to recover. Biomass production was similar to the previous years, although the increases in the control and plot 2 are of note. The significant differences between the amended plots and the control continued to be correlated with doses of USR added.

CONCLUSIONS

The addition of USR led to (a) increased fertility and water availability and (b) increased vegetal biomass and plant cover relative to the control.

The dose was a very important factor and influenced the ability of the diversity values to recover. Above 13 $kg m^{-2}$ doses the increases in biomass and plant cover ceased to be significant, while the decrease in diversity and the higher proportion of annuals compared to perennials were significant. These differences were maintained throughout the experiment, although they were more significant between the control and the lowest dose than between the rest of doses.

The stabilization process was more rapid in plot 1 (least doses of USR), where the species diversity and composition were the most similar to the unamended nearby areas, showing a mature vegetation with a strong perennial component and tending to reach the actual plant composition of the area, but exceeding by far the actual percentage of plant cover.

Organic amendment, especially with USR, may be considered an effective way of regenerating the plant cover of degraded soils under semiarid Mediterranean conditions. However, if one of the aims is to maintain an equilibrium between the species composition and diversity and that of the surroundings, the dose to be applied is a critical factor. The above results suggest that a rather low dose is effective and remains so for a prolonged period.

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