

THE USE OF TEPHRA MULCH INCREASES SOIL FERTILITY (LANZAROTE, SPAIN)

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Abstract

Few references exist with respect to the fertility of rock-covered soils. On the island of Lanzarote (Canary Islands, Spain) a dry farming system has been developed in very arid conditions on land artificially covered with tephra. For the present work, three sites were selected and the soil fertility status of the soils under the tephra was compared with that of the adjacent natural soils. Soil samples were taken from the first 25 cm both in the mulched soils and the uncovered soils. Each sample was analysed for pH, EC, carbonates, exchangeable cations, organic C, total N, Olsen P and micronutrients (Fe, Mn, Cu, Zn and B). Non-parametric tests were carried out with the SPSS package for statistical analysis. No significant differences ($p < 0.05$) were found in the various parameters with the exception of B, which was always lower in the mulched soils. Soil pH was high, slightly alkaline in the mulched soils and alkaline in the natural soils. The EC and ESP values were also found to be lower in the mulched soils, where Ca was more important in the exchange complex. Average levels of organic C, N and P were higher in the mulched soils, a circumstance explained by the layer of organic matter (manure) placed on the soil prior to covering with mulch. Nonetheless, N was still the element that most restricted crop development. The percentage of carbonates was lower in the mulched soils. The above considerations, along with the greater humidity year-round, allow us to conclude that the mulch agrosystem improves soil fertility.

Additional Keywords: Canary Islands, arid soils, dry farming, volcanic materials

Introduction

On the volcanic island of Tenerife (Canary Islands, Spain) under extremely arid conditions ($P < 150$ mm; ETP > 2000 mm in an evaporimetric tank, annual temperature of approximately 20° C, and strong trade winds), a traditional farming system has evolved, based on the use of a covering of basaltic tephra on the soil. The tephra acts as mulch and has permitted the development of a form of dry farming highly effective for soil and water conservation. Onions are the main crop grown, along with potatoes and grapes, including a number of local varieties. No cultivation is possible in the unmulched soils.

For decades authors have discussed the possibility of using crushed rocks added to soil as fertilisers (Hartwell and Pember 1908; Keller 1948; Coleman 1977; Kronberg and Nesbitt, 1981; Chesworth *et al.* 1983). The fertility of soils covered with layers of basaltic tephra has received little attention in the literature (Tejedor *et al.* 1999), more focus having been placed on the water conservation aspects of the soils (Groenevelt *et al.* 1989; Pérez 2000; Tejedor *et al.* 2002a, 2002b, 2003a) and the role played by the mulch in rehabilitating saline-sodic soils (Tejedor *et al.* 2002b, 2003b).

In the present paper mulched soils are compared to uncovered adjacent natural soils in order to study the influence on fertility of the tephra covering.

Materials and Methods

Three sites representative of the different situations present on Lanzarote were chosen. The natural soils are Haplocambids (Soil Survey Staff 1999). Around 30 years ago, the three soils were covered with a 12-13 cm layer of tephra, which was of medium grain size ($4 \text{ mm} < D_{50} \leq 2 \text{ mm}$) in the first two soils and coarse in the third ($D_{50} \geq 4 \text{ mm}$). On each site, in addition to the covered plots there are others which were not covered.

In order to compare the fertility of the mulched soils with that of the uncovered adjacent soils, 10 samples of arable layer (0-25 cm) were taken from each of the systems, 5 from under the mulch and 5 from the uncovered soil. Routine methods were used to determine pH in saturated extract (pHs), electrical conductivity in saturated extract (ECs), carbonates, organic C, N, available P, exchange complex and micronutrients (USDA-NRCS 1996). Results were analysed statistically using the Mann-Whitney U test and SPSS programme, version 11.0.1 (SPSS Inc. 2001).

Results and Discussion

Tables 1, 2 and 3 give the average values for the different parameters. Two different letters in a column indicate significant differences ($p < 0.05$) while two letters the same indicate that the differences were non-significant ($p > 0.05$).

Table 1. Relevant chemical properties

Site	Land use	pHs	ECs	O.C.	N	P	CaCO ₃
			dS m ⁻¹	%	%	mg kg ⁻¹	%
1	Mulched soil	8.2 a	0.8 a	0.44 a	0.07 a	12.3 a	7.9 a
	Bare soil	8.1 a	1.0 a	0.48 a	0.07 a	12.4 a	7.1 a
2	Mulched soil	8.1 a	1.0 a	0.33 a	0.05 a	15.5 a	16.4 a
	Bare soil	8.4 b	0.9 a	0.32 a	0.05 a	11.0 b	17.3 b
3	Mulched soil	8.0 a	2.1 a	0.62 a	0.08 a	26.5 a	10.4 a
	Bare soil	8.1 b	1.0 a	0.55 a	0.07 a	10.4 a	14.2 b

The soils are basic in the three systems, with significant differences in the last two. Salinity results indicate that the mulched soils, with the exception of site 3 (slightly saline), are non-saline. The average value -above 2 dS m⁻¹ - obtained in site 3 is not representative of the sample group, given the high standard deviation (1.3). Salinity is therefore not a problem for crop growth in the studied systems, and only the yield of very sensitive crops would be restricted.

Organic C and total N levels are as low in the mulched soils as in their uncovered neighbours, less than 2 % and 1 % respectively. These values are, however, normal for soils in arid regions with a little of plant cover and low biological activity. Although the differences are not significant, the values tend to be slightly higher in the mulched soils, a circumstance probably due to the layer of manure placed during preparation of the system prior to the covering with tephra and also to the small amounts of ammonium nitrate and ammonium sulphate added annually. The low N levels are compensated by the use of crops with low nitrogen requirements. Although the studied soils show high carbonate and pH levels, available P is relatively high, a situation accounted for by the dust frequently carried to the island by the winds from the Sahara. According to Torres (1995) the dust particles in suspension can contain as much as 85 mg kg⁻¹ of available P. Goosens (1995) notes that rock fragments act as a dust trap, favouring accumulation. Of the mulched plots studied, only those of site 1 would need additional P. However, it may be assumed that the local crop varieties grown have lower requirements, given that there are no reports of P deficiencies. Significant differences are seen in the carbonate content of sites 2 and 3. In both cases content is lower in the mulched soils, due perhaps to the higher moisture content which results in the carbonates partly dissolving and leaching.

Table 2. Exchange complex

Site	Land use	Ca	Mg	K	Na	ESP
		(cmol _c kg ⁻¹)				%
1	Mulched soil	21.7 a	6.1 a	3.0 a	0.5 a	1.0 a
	Bare soil	20.1 a	7.5 a	4.1 b	1.2 b	4.4 b
2	Mulched soil	22.2 a	8.1 a	3.0 a	0.5 a	0.8 a
	Bare soil	17.5 b	11.6 b	2.9 a	2.2 b	10.5 b
3	Mulched soil	20.1 a	7.1 a	3.9 a	1.1 a	3.1 a
	Bare soil	22.9 b	10.7 b	2.8 b	1.4 a	7.0 a

Calcium is the dominant cation in the exchange complex, and Mg and K content is high –in all cases, above 0.5 cmol_c kg⁻¹ and 0.6 cmol_c kg⁻¹ respectively, the limits set by MAFF (1967). In view of the K levels, no K fertilisers are required. The uncovered soils in the three selected systems have exchangeable Na levels in excess of 1 cmol_c kg⁻¹ and can therefore be considered potentially sodic (Landon 1991). However, the mulched soils -with the exception of site 3- show lower values. It would appear therefore that there is a reduction of this cation in the covered soils. In terms of the exchangeable sodium percentage (ESP), the soils of sites 2 and 3 can be considered slightly sodic ($7 \leq \text{ESP} \leq 15$). Although judging by the data no serious sodicity problems appear to exist, compared to the uncovered soils levels have fallen considerably since the soils were covered 30 years ago.

Table 3. Micronutrients

Site	Land use	Fe	Mn	Cu	Zn	B
		mg kg ⁻¹				
1	Mulched soil	93.2 a	62.2 a	4.8 a	2.2 a	1.6 a
	Bare soil	73.3 b	109.1 b	4.6 a	2.1 a	2.1 b
2	Mulched soil	45.3 a	21.5 a	3.5 a	3.6 a	3.3 a
	Bare soil	50.7 b	21.6 a	3.6 a	3.7 a	5.9 b
3	Mulched soil	53.6 a	60.6 a	3.6 a	2.6 a	3.0 a
	Bare soil	48.2 a	43.9 b	3.9 a	2.4 a	3.8 b

Regarding micronutrients, in sites 2 and 3 the Fe levels can be considered to be low, below 60 mg kg⁻¹ (FAO 1982). No common pattern is seen between the mulched and unmulched soils in terms of Mn, Cu and Zn content and no deficiencies are evident in any case. Boron levels are always higher in the uncovered soils, with significant differences in the soils of all three selected sites.

Conclusions

The results obtained highlight the better fertility conditions in the soils covered with basaltic tephra than in the uncovered soils. This is due largely to the former soils' higher moisture (Tejedor *et al.* 2003a) and is reflected in the lower salinity, sodicity and B content.

Considered alongside results from previous studies (Tejedor *et al.* 2002a, 2002b, 2003a, 2003b) these findings evidence the sustainable nature of the agrosystem, which is highly adapted to the environment. The positive effects of a surface covering of tephra have permitted the development of a form of dry farming, which would otherwise have been impossible. The system requires very little investment and technical knowledge and the crops grown can be considered ecological, with high value added, given that virtually no plant health products are used.

Average production between 1997-2000 for the three main crops was as follows: 8,043 kg ha⁻¹ for onions, 6,030 kg ha⁻¹ for potatoes and 907 kg ha⁻¹ for grapes. It is worth noting that the yields obtained with the system, which uses no irrigation, in extremely dry years such as 2000 (69 mm rainfall in the year) were 2,361 kg ha⁻¹ for onions, 6,063 kg ha⁻¹ for potatoes and 1,775 kg ha⁻¹ for grapes. The wine produced from the grapes -over 2 million litres per year- is of top quality.

In addition to the aforementioned conservationist and yield aspects, the practice is also of great cultural importance, having contributed greatly to the island's recent economic and social development. The system is not merely a means of combating desertification but represents also a cultural heritage that, with the appropriate modifications, could serve as a model for less favoured regions elsewhere.

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