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ORGANIC WASTES AS AMENDMENTS FOR LIMESTONE QUARRY RESTORATION IN SEMIARID ENVIRONMENTS

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Abstract

An experimental soil restoration project started in 2008 in a calcareous rock quarry in SE Spain, under Mediterranean semiarid conditions, on two different substrates (marl and topsoil). The substrates were amended with two different organic wastes: a sewage sludge and a compost. Two different mulches, mineral and organic, to mitigate soil water losses, were also tested. Three perennial species from nursery (*Stipa tenacissima*, *Antyllis terniflora* and *Anthyllis cytisoides)* were planted in subplots within every one of 16 experimental plots. A drip irrigation system was implemented to provide support water to every seedling under critical soil water conditions during the first months after plantation. The first results show an average survival rate of 73% in the replanted area. Survival was higher in the plots on marl than in the plots on topsoil, where the role of spontaneous vegetation might have played a negative role. A vigor index which considered plant height, width and number of leaves, has revealed that *Stipa tenacissima* reaches the highest vigor average value, followed in decreasing order by *Anthyllis cytisoides* and *Anthyllis terniflora*. However, when comparing the different treatments, the highest plant vigor corresponds to *Anthyllis cytisoides* in plots which combine the use of organic amendments and mineral mulch. Statistical GLM analyses indicate the significant role of support irrigation, organic amendments and mulches (in this order) for vegetation establishment and growth in this semiarid environment.

Keywords: sewage sludge, compost, solid urban residue, organic ammendment.

INTRODUCTION

Mining and quarrying disturbs aproximately 240.000 km^2 of the Earth surface, though regional, national or federal governments establish regulations that require the operator to restore the land once the extraction activity has ceased (Dollhopf, 2006). Though most quarries in Spain follow the restoration procedures well described in “quarry restoration” manuals, results are not successful in the driest zones of the semiarid Mediterranean region where annual precipitation is well below 300 mm and rainfall patterns favour soil erosion.

Trying to solve this problem is the main goal of this research work, which consists in experimental soil restoration based in the essential principles: revegetate with local plant species assuring minimum soil conditions of water and nutrients while minimizing soil losses by water erosion. Organic wastes will be used as necessary ammendments for both nutrients (N) and soil structure agents.

EXPERIMENTAL

The following points were considered:

1.- Selection of 2 experimental areas: area A (bare marl), and area B (with a topsoil layed down 10 years ago, with opportunistic plant species). 8 plots 15 m x 5 m were set in each area.

2.- Plot preparation consisted in the following operations:

a. ripping following contour lines (2 m apart, 40 cm deep).
b. use of organic residues as amendments: compost of urban refuses were applied directly and then mixed with the substrate with a mechanical spade;

sewage sludge from a urban wastewater treatment plant was mixed with the substrate in a pile and then layed down.

c. Then two types of mulches were layed down, chopped forest residues (or chopped wood) and fine gravel.

d. Drip irrigation was set to assure plant survival during the summer months.

e. Finally, manual planting of 1200 plants from a nursery, consisting in 3 species (among the most representative in the area): *Stipa tenacissima* (alpha grass) and two legume shrubs: *Antyllis terniflora* and *Anthyllis cytisoides*.

3.- Monitoring program. As it was an exploratory project, we had to minimize the number of experimental plots and no control plots were considered for non-ripped soil, no irrigation, and no-plantation based on the assessment made for spots under such conditions in the same quarry area. Consequently, only organic amendments, mulches and planted species were considered as studied factors along with the area factor.

The main variables under test were those related to the planted species and were planned to be measured every 6 months. These variables are either qualitative or quantitative: 1) State of the plant (dead - alive), 2) Height (quantitative), 3) Maximum and minimum width (quantitative), 4) Number of leaves or stems (qualitative, from 1 to 4 depending on the number of leaves-stems), 5) Colour of the leaves (qualitative: 1-green, 2-yellow, 3-brown).

From these variables, *biovolume* (height x average width) and *vigour* (biovolume x Nb leaves) were assessed.

The monitoring program included essential meteorological variables, like magnitude and intensity of rainfall, air temperature and humidity, wind speed and direction. The climate diagram of a nearby station indicate the quite long dry period between March and November (Fig 1).

Also soil moisture at a depth of 10 cm was monitored every week in summer and at a longer interval in winter.

Characterisation of substrates, organic residues and mulches was also done.

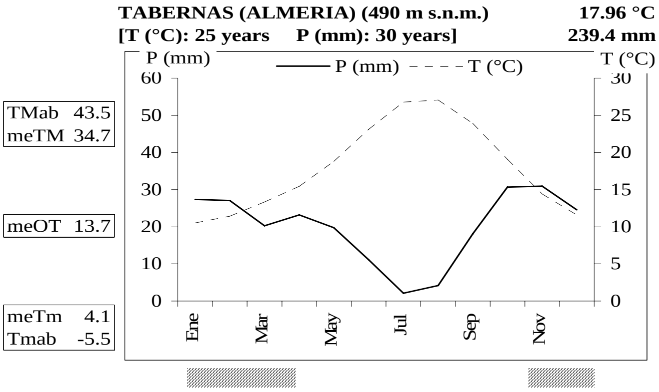

Figure 1. Climatic diagram of Tabernas station.

RESULTS AND DISCUSSION

The contents of organic carbon (OC) and N was heterogeneous among plots due to the irregular mode of laying down the organic amendments. However OC and N were higher in the control plots of area B than in those of area A, because B had a previous topsoil.

The measurements of all plants six months after the plantation allowed to know the main effects of the factors *plant species*, *area*, *amendment* and *mulch*) on either quantitative or qualitative variables. Kruskall-Wallis tests were used for quantitative variables and the chi-square test for the qualitative ones.

Six months after the plantation *Stipa tenacissima* showed the highest survival rate followed by *Anthyllis cytisoides*. But the vigour of living plants was highest in this latter species, followed by *Stipa*. Though no many differences in the survival rate according the area, vigour was clearly higher in A.

The role of organic amendments was significant with regards biovolume and plant vigour only in area A. In Area B the theoretical better quality of the topsoil might have had some influence. Sewage sludge performed better than compost.

The role of mulches was significant in maintaining a higher soil moisture. Vigour follows the following order with regard to mulches: Gravel > Control > Chopped wood. There were significant differences between gravel and control and between gravel and chopped wood, but not significant differences between chopped wood and the control.

To know the main effects of the factors area, amendment, mulch and plant species and the interactions among them, in quantitative normal variables, like height of the plants, a General Linear Model was tested. However, as the control plot no-amendment + no-mulch was missing in both areas, we had to remove all data with no-mulch, loosing, therefore, the combination amendment & no-mulch. This GLM had an $r^2 = 0.55$, $p < 0.00$ (table 1).

Table 1. Interactions among factors.

Height Univariate Tests of Significance
Sigma-restricted parameterization
Effective hypothesis decomposition
Exclude condition: mulch = 'no'

Effects	SS	Degr. Freed.	MS	F	p
Intercept	553884.3	1	553884.3	7191.309	0.000000
area	27404.2	1	27404.2	355.800	0.000000
amendment	177.3	2	88.6	1.151	0.316840
mulch	6522.8	1	6522.8	84.689	0.000000
species	16172.6	2	8086.3	104.988	0.000000
area*amendment	491.7	2	245.9	3.192	0.041571
area*mulch	8276.5	1	8276.5	107.457	0.000000
amendment*mulch	303.1	2	151.5	1.967	0.140447
area*species	2681.3	2	1340.7	17.406	0.000000
amendment*species	676.8	4	169.2	2.197	0.067571
mulch*species	3737.0	2	1868.5	24.259	0.000000
area*amendment*mulch	410.7	2	205.3	2.666	0.070108
area*amendment*species	227.7	4	56.9	0.739	0.565449
Area*acolcha*especie	6072.9	2	3036.4	39.423	0.000000
amendment*mulch*species	4882.1	4	1220.5	15.846	0.000000
area*amendment*mulch*species	2464.8	4	616.2	8.000	0.000002
error	66546.4	864	77.0		

	Multiple R	Multiple R^2	Adjusted R^2	SS Model	df Model	MS Model	SS Residual	df Residual	MS Residual	F	p
height	0.741990	0.550549	0.532343	81515.31	35	2329.009	66546.45	864	77.02135	30.23849	0.00

CONCLUSIONS

- The four tested factors (area, species, amendment, mulch) have had significant responses: 1) *Stipa tenacissima* had the highest survival rate but *Anthyllis cytosoides* had the highest vigour. 2) Organic residues were more effective on a marly substrate than on a typical soil substrate. 3) Sewage sludge had a better effect than compost. 4) Gravel-mulch enhanced plant vigour.
- Medium depth riping had a positive effect in controlling runoff and erosion.
- Interactions with spontaneous species not yet evaluated.

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