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ORGANIC WASTES AS AMENDMENTS FOR LIMESTONE QUARRY RESTORATION IN SEMIARID ENVIRONMENTS

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Abstract

The impact in using organic wastes as amendments and mulches on the success of quarry restoration projects in arid and semiarid Mediterranean regions is not well understood. We used two types of organic wastes (a sewage sludge from urban water treatment plant and a compost derived from urban solid wastes) and mulches (chopped forest waste and gravel) in an experimental limestone-quarry restoration project started in 2008 in SE Spain. Eight plots on two different substrates, a marl and a topsoil, were previously conditioned before adding the organic amendments and the mulches. In each plot (n=16), 3 perennial species from nursery (*Stipa tenacissima*, *Antyllis terniflora* and *Anthyllis cytisoides)* were planted in subplots (n=48). To avoid soil dryness during the initial growth stage, water was frequently supplied by a drip irrigation system. Six months after the plantation 73% of the plants survived being the survival higher in those plots on marly soils than in the plots on a topsoil where abundant opportunistic vegetation might have had a negative impact. Survival was the highest for *Stipa tenacissima* and the lowest for *Anthyllis terniflora*. A General Linear Model (GLM) analysis indicated that the addition of organic amendments and the use of mulches were the main factors in explaining the success in the vegetation establishment and growth in this semiarid environment.

Keywords: quarry restoration, sewage sludge, compost, urban wastes, vegetation vigor index, GLM analysis.

INTRODUCTION

Mining and quarrying disturbs ~240.000 km^2 of the Earth surface. To minimize the environmental impacts of these activities, regional, national or federal governments establish regulations that require the operator to restore the land once the extraction activity has ceased (Dollhopf, 2006). At present, most of the quarry restoration projects in Spain follow criteria and procedures well described in “quarry restoration” manuals (e.g. Gobierno de la Rioja, 2006; ITGE, 1989). However, the application of these guidelines is questionable in semiarid regions with precipitation values below 300 mm y^{-1} and heavy rainfall events which promote soil erosion (Fig 1).

Figure 1. Soil Restoration with many rills (water erosion) and vegetation of opportunistic species.

The main objectives of this research work are: 1) to know how the essential principles of ecological soil restoration, i.e. revegetate with local plant species assuring minimum soil conditions of water and nutrients (Jorba and Vallejo, 2008), can be adapted to semiarid environments; 2) achieve minimum soil losses by water erosion.

Organic wastes will be used as necessary ammendments providing nutrients (N) and soil structure (Moreno-Peñaranda et al., 2004; Jorba and Andrés, 2008).

METHODS

Study Area

The area is located at 370 m a.s.l. in the western versant of Sierra de Gádor, a calcareous-dolomitic mountain. The Mediterranean semiarid climate in the region is characterized by dry and warm summers, and mild autumns and winters which concentrate most annual rainfall. Mean annual precipitation in the last 8 years (2001-2008) at the nearby station of Alhama de Almería (510 m s.n.m.) was 230 mm.

Experimental Design

Eight plots (15 m x 5 m) were set in each of two experimental areas with different substrates: A is a bare marly substrate and B has a topsoil which was layed down 10 years ago, with an important seed bank of opportunistic plant species. Once selected, plots were subsoiled with a ripper following contour lines (2 m apart, 40 cm deep) and the organic amendments added in different plots. Composts (C) were directly applied and mixed with the substrate with a mechanical spade. Sewage sludges (SS) were previously mixed with the substrate in a pile outside the experimental areas and then layed down at the plots. Before the revegetation, two types of mulches consisting in chopped forest residues (F) and fine gravels (G) were layed down either over the amended substrate or over the blank one. Every plot is identified by an acronym indicating both the type of mulch and the organic ammendment. B indicates the blank (control) for either mulch of amendment (e.g. plot G-SS has a gravel mulch and sewage sludge as organic amendment. Finally, a total of 1200 plants supplied by a local nursery were manually planted on the experimental plots. The species selected for the revegetation are widely distributed in the study area and consisted of a perennial grass (*Stipa tenacissima,* alpha grass) and two leguminous shrubs (*Antyllis terniflora* and *Anthyllis cytisoides*). After the plantation at the beginning of May 2008, and to avoid soil desiccation, water was supplied from weekly by a drip irrigation system.

Vegetation variables and statistical analysis

Different qualitative and quantitative variables related with vegetation survival and "plant health" traits were measured 6 months after the plantation. These variables were: 1) State of the plant (dead-alive), 2) Height (quantitative), 3) Maximum and minimum width (quantitative), 4) B*iovolume* index, i.e. height x average width, 5) Amount of leaves or stems (qualitative, from 1 to 4 depending on the number of leaves-stems), 6) Colour of the leaves (qualitative: 1-green, 2-yellow, 3-brown). The survival rate, defined here as the ratio between the number of alive plants and the total of plants planted, were also computed at the area, plot and sub-plot experimental scales.

Four factors (soil substrate, organic amendment, mulch and plant type) were considered to evaluate their impacts on the vegetation variables measured, as well as the impact of possible significant interactions between factors. This was carried out by a General Linear Model (GLM) analysis with quantitative variables. Kruskall-Wallis and chi-square tests were used, for quantitative and qualitative variables, respectively".

RESULTS AND DISCUSSION

The contents of organic carbon (OC) and nitrogen (N) were heterogeneous among the different plots because of the irregular way in which the organic amendments we layed down. Despite this variability, and because of the existence of a previous topsoil, control plots in area B showed higher OC and N contents than those in area A.

The general survival rate reached after six months from the plantation was 73%. Higher survival rates, although not significant, were measured in those revegetated plots on the substrate A than on the substrate B despite the higher OC and N contents measured in the last ones (Fig 2). *Biovolume* index was significantly higher in the A plots than in the B ones.

Stipa tenacissima showed the highest survival rate followed by *Anthyllis cytisoides* and *Anthyllis terniflora* (Fig 3). However, the biovolume index was the highest in *Anthyllis cytisoides*.

The positive impact of organic amendments on *biovolume* was highlighted in the experimental plots with a marly soil substrate (area A). However, in area B, the theoretical better quality of the topsoil might have had some negative influence on both survival and biovolume. In general terms, the use of sewage sludges as an organic amendment performed much better than the compost derived from municipal wastes.

The addition of organic amendments had a little effect on the plant survival rates observed in both A and B sites (Fig 2) but better positive effects on the *biovolume* indexes.

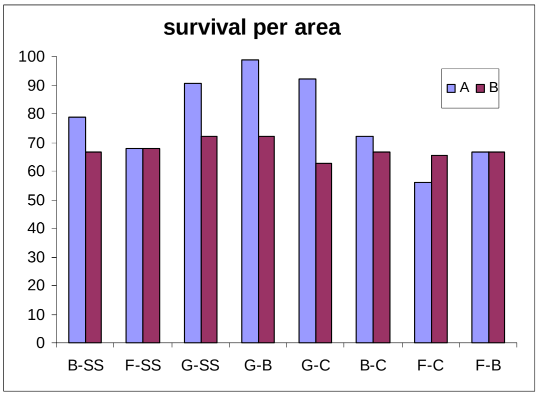

Figure 2. Survival rate of all species per area

Such positive effects on the *biovolume* were better highlighted in experimental plots on a marly soil substrate (area A) than in plots with a previous topsoil and an important seed bank of opportunistic plants (area B). The emergence of these opportunistic plant species after the addition of the organic amendments (Fig 4), and their effects in reducing the soil moisture availability, may explain why survival rates and biovolume indexes had lower values in area B. In general terms, the use of sewage sludges performed much better than the compost derived from urban wastes.

Because their role in maintaining soil moisture, mulches had a positive impact on the survival and *biovolume* of planted vegetation (Fig 5). Average soil moisture content was 20% higher under mulched substrates (Fig 4).

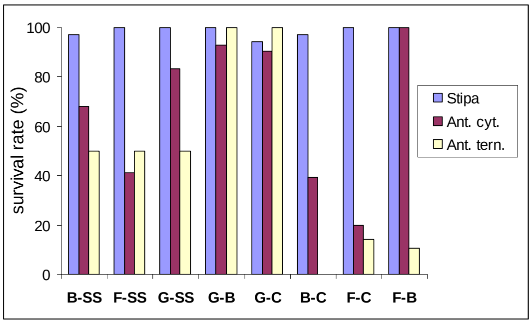

Figure 3. Survival rate per species in plots A

The highest *biovolume* indexes were reached when gravel mulches were used. However, the use of a forest residue had a negligible effect on this variable, as no statistical differences were found when those plots were compared with the control plots without mulch.

One year after the plantation the amount of opportunistic species is significantly higher in plots where organic amendments were added (Fig 4).

Figure 4. Plots on marly substrate after one year after the plantation. No cover of opportunistic species is observed on plots with no organic amendments (4th and 8th plots starting from the right).

The General Linear Model (GLM) analysis indicated that the addition of organic amendments and the use of mulches were the main factors in explaining the success in the vegetation establishment and growth in this semiarid environment.

CONCLUSIONS

- Organic wastes used as amendments had a significant positive role in the biovolume index of planted species. This role was more effective on marly substrate than on a topsoil. In general, the use of sewage sludge had a higher positive effect on both the plant survival and the *biovolume* index than the compost.
- Six months after the plantation, *Stipa tenacissima* had the highest survival rate but *Anthyllis cytosoides* had the highest *biovolume*.
- Both organic and mineral mulches maintained higher soil moisture levels though only gravel mulch had a siginficant positive effect on the *biovolume* index.

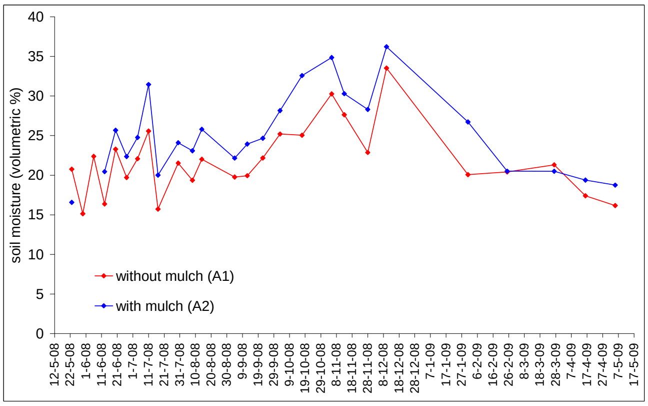

Figure 5. Influence of mulch in the evolution of soil moisture at 10 cm depth (plots B-SS and F-SS).

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