Floresta e Ambiente

Establishment of legume trees on heaps of blast furnace slag

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Abstract

Blast furnace slag is usually stored in open air deposits and it can be carried by the wind. This problem can be reduced using plant cover. This work aim to evaluate: a) the potential of *A.angustissima* and *M.caesalpiniifolia* to cover the heaps of blast furnace slag and b) the effect of hydrogel Stockosorb®Agro on the establishment and growth of these species on blast furnace slag. The results showed a good capacity of species to establish, to grow and are to cover the heaps of blast furnace slag. The hydrogel had no influence on the parameters evaluated. Phosphate fertiliser, micronutrients and manure amendments are sufficient for the establishment of species.

Key words: hydrophilic polymer, degraded land reclamation, revegetation

Introduction

Species of the family Leguminosae have been widely used in landscape recuperation projects (Franco et al., 1992; Herrera et al., 1993; Franco & Faria 1994; Franco et al., 1996). These species are capable of establishment under adverse conditions due to associations with nitrogen-fixing bacteria and arbuscular mycorrhizal fungi. Because of associations with these micro-organisms, these species can obtain more nutrients (mainly phosphorus and nitrogen) and water (Monteiro, 1990; Franco et al., 1992; Herrera et al., 1993). Further more, they are a source of organic matter rich in nutrients and with a low C:N ratio (Franco et al., 1992).

Blast furnace slag is a by-product of iron melting by the metallurgical industry and has been used in cement fabrication to reduce its final cost. Since slag is usually stored in open air deposits, it can be carried by the wind and have detrimental effects on air quality. Covering the slag with legume trees associated with nitrogen fixing bacteria and arbuscular mycorrhizal fungi (Franco et al., 1992; Herrera et al., 1993), can eventually eliminate the dust problem and its associated potential health hazards (e.g. silicosis).

On the other hand, as the larger part of this substrate is coarse sand it is possible that the utilisation of a hydrophilic polymer, known as hydrogel whose principal characteristic is to absorb and store water (Bouranis, 1995), may help in plant establishment. These products can absorb and store water a hundred times their own weight (Johnson, 1984).

Thus, this work aimed to evaluate: a) the potential of these species to cover the heaps of blast furnace slag and b) the effect of hydrogel Stockosorb®Agro on the establishment and growth of *A.angustissima* and *M.caesalpiniifolia* on blast furnace slag.

Materials e Methods

Two experiments were conducted on the Belmonte property in Barra Mansa (Rio de Janeiro State - 22º 31' S 44º 08' W), owned by the Tupi Cement factory. On this property, almost 2.2 million Mg of blast furnace slag are deposited, which are accumulated in piles, 50 to 80 m height. The climate of area, according to Köppen classification, is of Cwa type, mesothermic with a dry winter. The total precipitation during the evaluating of the experiments (December 2001 to April 2003) was 2,293 mm, mean temperature 24.9 ^oC and relative humidity 72.5 %.

These experiments were conducted on two piles of blast furnace slag, one on the side of a slag heap with a slope of 37.5^o, and the other on a flat area, on the top of another slag pile (plateau), 62 meters above the soil. The species utilised were *Acacia angustissima* (Miller) Kuntze and *Mimosa caesalpiniifolia* Benth., inoculated with arbuscular mycorrhizal fungi *Glomus clarum* Nicolson & Schenck and *Gigaspora margarita* Becker & Hall and rhizobia. The rhizobia strains utilised were BR 10049 and BR 3616 for *A.angustissima* and for *M. caesalpiniifolia* were BR 3407 and BR 3446, from the rhizobia collection of Embrapa Agrobiologia (see details Faria & Franco, 2002; Franco et al., 1992; Monteiro, 1990). The seedlings were approximately 30 cm in height when planted in the field.

For the two experiments, the experimental design was randomised complete blocks with split-plots and three replicates, with subplots of 4 x 5 m. Main plots with tree species (2) and the subplots with 5 treatments, with increasing quantities of hydrogel. The spacing between trees was of 1 x 1 m. The holes for seedlings were 15 x 15 x 15 cm fertilised with: 1 dm^3 of cow manure, 10 g of micro-nutrient fertiliser FTE Br 12 and 150g of Araxá rock phosphate. The doses of hydrogel tested were: 0, 3, 6, 9 and 12 g $hole^{-1}$. The hydrogel utilised in this study is known as Stockosorb®Agro (produced by Stockhausen GmH & Co. KG, Germany).

The planting was performed in the rainy season, in December 2001 (on the side of the slag heap) and in January 2002 (plateau). The parameters assessed were seedling survival, by counting the number of plants, and height obtained by measuring the tallest branch, two months after planting. On this same occasion, after evaluation, the dead seedlings were replaced. After this**,** three evaluations were made of the survival and height at four-month intervals, over a period of one year (14 months after planting). At this time the percentage cover of each area was evaluated. A radiometer was used to measure plant cover in a total of six replicates per plot.

For the characterisation of the texture and fertility of the blast furnace slag, samples were collected in the areas before the implantation of the experiments to a depth of 0-20cm. These samples were analysed for: pH (in water), exchangeable Ca and Mg (extracted with 1M KCL solution), P and K (method Mehlich-1) and texture, according to Embrapa (1997). The chemical characteristics at the side of the heap and at the plateau, respectively, were as follows: pH 8.8 and 8.2; Ca+Mg 8.6 and 8.2 $cmol_c\ dm^{-3}$; Ca 7.6 and 6.8 $cmol_c\ dm^{-3}$; Mg 0.9 and 1.3 $cmol_c\ dm^{-3}$; P 0.1 and 0.8 mg dm^{-3}; and K 117 and 61.5 mg dm^{-3}. The texture analysis of the substrate showed: 85.2 % coarse sand, 5.5 % fine sand and 9.3 % silt in blast furnace slag from the slag-heap side, and 86.3 % coarse sand, 6.3% fine sand and 7.4 % silt from the plateau.

Simultaneous with the field experiments, water retention curves were, separately, elaborated utilising the "Richards's Extractor" apparatus developed by Richards (1954, as described by Kramer and Boyer, 1995), aiming to determine the capacity of water retention of blast furnace slag when different quantities of hydrogel were added to the substrate and if the utilisation of cow manure can change the hydrogel performance. For this, the slag mixed with cow dung and different quantities hydrogel was tested in the laboratory in 2.5 dm^3 plastic containers. Two experiments were performed: in one, the substrate utilised for hydrogel testing was 1.5 dm^3 of the blast furnace slag + 1 dm^3 of dry cow manure + 10 g of FTE Br 12 + 150 g of phosphate of rock and in the

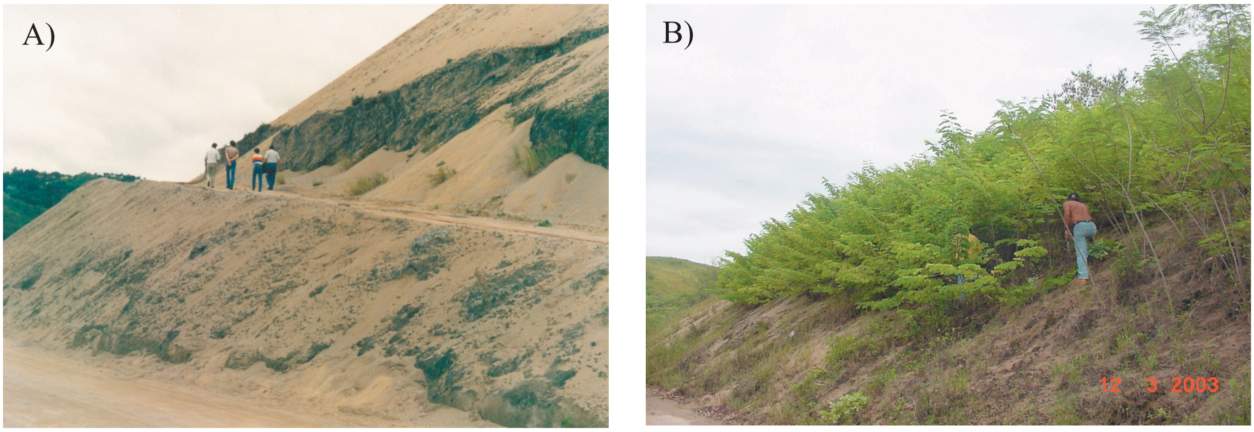

Figure 1. A) View of the slag heap side before the implantation of the legume trees of experiment 1; B) View of the slag heap side (Experiment 1) 14 months after planting showing *Mimosa caesalpiniifolia*.

other was 2.5 dm^3 of the blast furnace slag + 10 g of FTE Br 12 + 150 g of phosphate of rock (where 1 dm^3 of cow manure was replaced by the same volume of blast furnace slag). The experimental design was complete blocks. Two factors were evaluated: five doses of hydrogel (0, 3, 6, 9 e 12 g) and 7 levels of water tension, 0.006, 0.01, 0.033, 0.07, 0.1, 0.5 e 1.5 MPa, with four replicates. For this, the mixture was placed in plastic recipients of 1 dm^3 and saturated with water. After 30 minutes samples were collected using a volumetric ring, and this was followed by the usual procedure for obtaining values for the construction of a water retention curve (Embrapa, 1997).

For the analysis of electrical conductivity of the substrate and the availability of salts in the substrate solution, two samples of this blast furnace slag utilised for the elaboration of the water retention curve were separated, and the methodology utilised was the saturated paste (Embrapa, 1997). The soluble salts in the blast furnace slag solution was quantified utilising a atomic absorption spectrophotometer (Ca^{2+} and $Mg^{2+)}$, and a flame photometer (Na^+ and K^+)(Embrapa, 1997).

To prepare the data for analysis of variance (F test), all results obtained were submitted to the tests for normality (Lilliefors test) and homogeneity of variance errors (Cochran test). When the results did not show normal distribution, they were transformed. Where relevant, Tukey's test (at P=0.05) was performed to compare means in the case of independent variables, and when the variables were quantitative, regression analysis was applied.

Results and Discusion

A view of the slag heap side before planting, and 14 months after planting the legume trees, are shown in Figs 1A and 1B. In the experiment on the slag-heap side, 14 months after planting, tree survival was almost 100% (Table 1), even at high pH level (pH=8.8) and salts. On the other hand, in the experiment on the plateau on top of the slag heap, a larger mortality was observed, to the species *Acacia angustissima*, which was shown to be more sensitive to local environmental conditions.

Table 1. Survival of two legumes species (%) grown on blast furnace slag after four different periods.

Species	Experiment	Months			
		2	6	10	14
A. angustissima	Slag-heap side (CV=10.9%)	94.3 Aa	95.2 Aa	93.9 Aa	95.4 Aa
M. caesalpiniifolia		82.5 Bb	91.2 Aa	92.4 Aa	94.5 Aa
A. angustissima	Plateau (CV=23.9%)	8.9 Bb	43.4 Ab	43.4 Ab	41.6 Ab
M. caesalpiniifolia		40.7 Ba	94.9 Aa	93.4 Aa	91.4Aa

Means in the same line followed by the same capital letter, or means in the same column followed by the same lower case letter, are not significantly different at P<0.05 (Tukey).

The species *A. angustissima* reached more than 2 m height, and grew better than *M.caesalpiniifolia* on the slag-heap side (Table 2). However, both species grew better on the slag-heap side than on the plateau on top of slag heap (Table 2).

Table 2. Height (cm) of two legumes species grown on blast furnace slag after four different periods.

Species	Experiment	Months					
		2	6	10	14	Prob.*	r2#
A. angustissima	Slag-heap side (CV=15.7 %)	68.6	161.4	168.0	234.7	<0.001	91.1
M. caesalpiniifolia		55.6	112.4	122.1	122.1	<0.001	91.4
A. angustissima	Plateau (CV=15.2 %)	5.0	43.9	89.6	104.1	<0.001	99.6
M. caesalpiniifolia		29.0	35.5	64.1	102.7	<0.001	96.3

* and # Probability and significance of regression analysis (linear model Y=a+bx)

Fourteen months after implantation, the percentage cover obtained for the species *A. angustissima* in the slag-heap side and plateau experiments was 38.9% and 24.5%, respectively, and for *M. caesalpiniifolia*, 83.6% and 44.7%. Thus, the specie *M.caesalpiniifolia* was more efficient to cover the heaps of blast furnace slag than *A.angustissima*, in spite of that, it has shown the smallest height. It is because *M. caesalpiniifolia* is a shrubby with many ramifications at the trunk base while the *A.angustissima* grows around of a central trunk.

According to the regression analysis (at P=0.05), no significant effect of the hydrogel on the survival parameters and the height of species was observed in both experiments at any evaluation date. Work reported by Swietlik (1989) with *Citrus paradisi* and that of Wang (1989) with ornamental tropical plants, also did not show any positive response to the addition of hydrogel. Hutterman et al. (1999), found in a study performed in the greenhouse that, although hydrogel retained a large quantity of water, this was not available for the seedlings of *Pinus halepensis*. Deghan et al., (1994) testing the effect of the hydrophilic polymer on species *Photinia xfraseri* and *Podocarpus macrophyllus*, obtained positive results only for the former species. The species tested in this study have a good natural resistance to drought as they are native from ecosystems where water is a restrictive factor, so probably they were not favoured by the higher availability of water. Hence, it is important to take into consideration the physiological capacity of drought tolerance of the plants when testing the effectiveness of hydrogel. However, according to the analysis of water retention, there was no significant difference between the treatments subjected to different pressures, with the exception of the condition where the substrate remained saturated (Figura 2). This results shown that hydrogel was not efficient to increase water availability corroboring field results

Hydrogel retains molecules of water at low suction pressure. Even at very low pressures such as 0.006 MPa and 0.01 MPa (field capacity for sandy soils) (Souza et al., 2002), most of the absorbed water was lost (Figure 2). The lack of effects of different hydrogel doses in the water retention curves, helps to explain the field results which showed that hydrogel

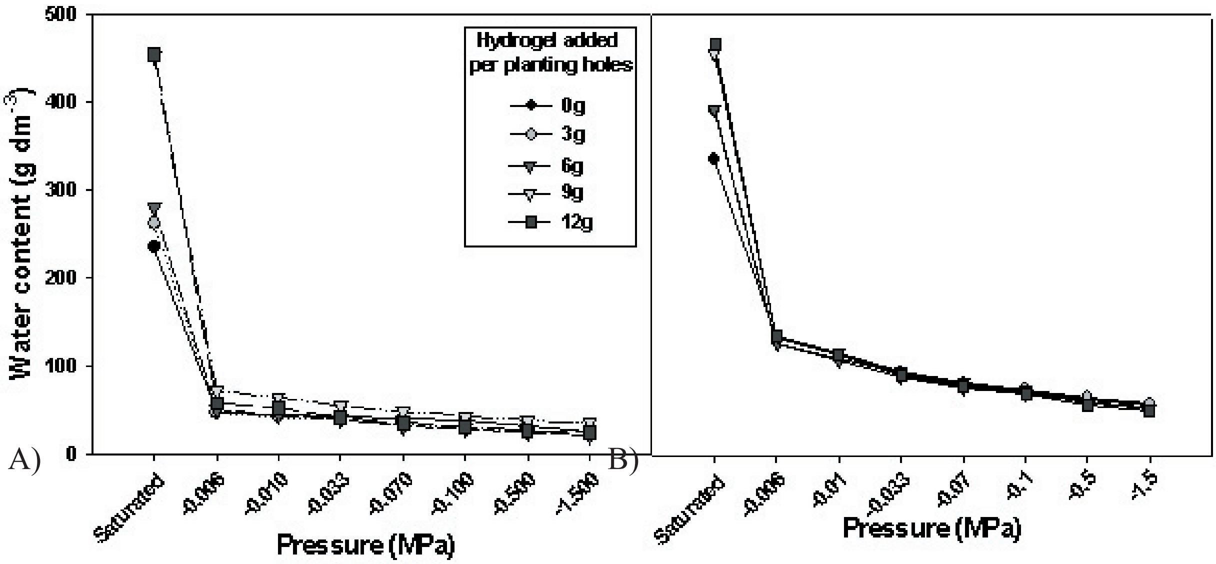

Figure 2. Water retention when different doses of hydrogel are added to blast furnace slag without (A) and with (B) manure under different pressures in the “Richard’s extractor”.

did not have any effect on the development of the species. Moreover, it is possible that in substrates with coarse texture, such as the blast furnace slag (80-85% of sand coarse), the evaporation of water retained by hydrogel is favoured. But Hutterman et al. (1999) argued that as the hydrogel can retain great quantities of water, part of water can be lost by evaporation.

The electrical conductivity of the blast furnace slag solution was found to be 1.16 mS/cm. According to Johnson (1984), an electrical conductivity between 1-5 mS/cm, as encountered in the irrigation water of in India and Australia, make the use of these hydrogels impracticable. The quantities of salts in the solution of the substrate were Na^+ 40,08 $cmol_c/dm^3$, K^+ 6,88 $cmol_c/dm^3$, Ca^{2+} 199.5 mg dm^{-3}, Mg^{2+} 53.7 mg dm^{-3}. According to the literature, mainly divalent ions, such as Ca^{2+} and Mg^{2+}, and to a lesser extent the monovalent Na^+ and K^+, reduce the water retention by polymers due to the competition for the linkage sites with water molecules (Bowman et al., 1990). On the other hand, the species *M.caesalpiniifolia* and *A.angustissima* are capable to establish and grow normally on high level of salts, especially of Na^+.

Conclusion

The study showed that the species *A.angustissima* e *M.caesalpiniifolia* were able to adapt to local conditions and substrate and quickly cover the piles of blast furnace slag, without use of hydrogel. Thus, the phosphate fertiliser, micronutrients and manure amendments are sufficient for the establishment of species on heaps of blast furnace slag. The fact that the hydrogel did not promote a better development of the seedlings can be explained by the low strenght that it retained the water molecules and to the high availability of salts in the solution of blast furnace slag, changing the performance of the polymer. On the other hand, the species *M.caesalpinifolia* and *A.angustissima* were capable to establish and grow very well on high pH and salts concentrations.

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