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THE PERFORMANCE OF GLYPHOSATE AND MICROBIAL BIOMASS IN SOILS DEGRADED BY SAND EXTRACTION

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Resumo

El objetivo de este estudio fue analizar la acción de glifosato sobre la rehabilitación de áreas degradadas a través de la determinación de las propiedades físicas y químicas del suelo, así como el análisis de la biomasa microbiana en tres áreas diferentes: A1, A2 y A3. El glifosato influyó en parámetros como el pH, CEC, la concentración de hierro (Fe), la humedad del suelo y la materia orgánica de forma mucho más significativa que los otros factores quí analizados. Después de la aplicación de glifosato, la humedad total del suelo y el contenido en BMS-C en las áreas 1 y 2 se incrementó. En el área 3, la disminución en la cantidad de biomasa microbiana puede estar relacionada con una mayor concentración de óxidos de hierro en el suelo, la cual se detectó en pruebas de laboratorio.

Palabras clave: granulometría, nutrientes, biomasa microbiana, porosidad el suelo, percolación

Abstract

The aim of this study was to analyze the performance of glyphosate over the rehabilitation of degraded areas through the definition of the soil physical and chemical properties as well as the analysis of the microbial biomass in three different areas A1, A2 and A3. The glyphosate influenced the parameters such as the pH, CEC, the iron concentration (Fe), the soil moisture and the organic matter more significantly than the other factors here analyzed. After the application of glyphosate, the total soil moisture and the BMS-C content in areas 1 and 2 increased. In area 3, the decline in the amount of microbial biomass may be related to a higher concentration of iron oxides in the soil, which was detected in laboratory tests

Key words: granulometry, nutrients, microbial biomass, soil porosity, percolation

1. Introdução

The urban occupation historical process shows its predatory characteristics which resulted in the destruction of a significant part of the original vegetal formations in most of the regions in São Paulo state and in Brazil [1]. The idea of endless natural resources in such a large country area has encouraged the expansion of the agricultural frontiers with no concern regarding the increase, or at least, the maintenance of the productivity in cultivated areas.

Consequently, the forest fragmentation process is intense in regions which are more economically developed in Brazil (Southeast and South), so the arboreal native vegetation is represented by secondary forests in different degrees of degradation.

In the last 50 years, Vale do Paraíba region (Southeast of Brazil) has shown one of the highest rates of industrial growth of the country, in addition to this, the population has grown and the result of both factors is that the Paraíba do Sul river basin has presented very critical aspects such as water consumption, high levels of urban and industrial pollution and erosion. Another alarming fact is that river banks deforestation and sand extraction have increased in considerable proportions.

Taking into consideration all the negative environmental impacts brought about by sand extraction, the resulting landscape is completely different from the one observed before the mining activity: the soil deeper layers are subject to the chemical and physical damages caused by the bad weather because there is no vegetation and the superficial layer had been destroyed. Thus, any action towards the recovery of these degraded areas takes much longer than when the superficial layer is preserved. Even though sand mining is one of the activities which modifies the most the land surface, sand is a mineral resource that is essential for the survival of human beings; it is used in many different areas, especially in the construction industry [2].

The Federal Decree 97.632 and the State Resolution SMA 19 approved in 1989 establish that mining companies have to develop and carry out a Degraded Areas Recovery Plan; consequently companies in this sector are much more concerned with the environmental problems resulting from the mining activities.

The discovery regarding the power of some organosynthetic substances which are used to control the action of some undesirable or harmful agents such as insects, fungus, and weed enabled the expansion of the cultivated areas and the increase in food production all over the world. In less than forty years these chemical products for the agronomic use were the most used components in large scale agricultural production, so in the middle 1970s its use was intensified due to the Green Revolution [3].

The herbicide glyphosate has been used in Brazil since 1978 in many agricultural conditions, in urban areas, for railway and road maintenance; it can also be found in many commercial formulations produced by companies which have different technological levels however there is no scientific evidence concerning significant impacts on the environment [4]. The glyphosate application and the direct planting technique have been used in agriculture bringing about a meaningful growth in its use around the world. Nowadays, the use of these procedures in Brazil has reached around 20 million hectare.

Glyphosate is a post-emergent herbicide which belongs to the substituted glycine chemical group; it is classified as a systemic action non-selective herbicide. It has a wide spectrum of action that enables the effective control of annual or perennial weeds with broad or narrow leaves [4]. Most of the research for academic papers on the glyphosate behavior in the soil is carried out in places where the soil and weather conditions are strikingly different from the ones in Brazil, proving that the evaluation of the glyphosate in tropical climate soils is important [5].

FVE is the owner of Fazenda Santana do Poço (Jacareí-SP/Brazil) and it has undertaken the environmental liabilities for many years of sand extraction in this area (from 1970 to 1990). Therefore, according to the Plan for the Rehabilitation of Degraded Areas (PRAD), it is recommended to apply the Original Round-Up (glyphosate) herbicide to prevent that weeds take most of the nutrients and water from the newly planted seedlings.

The purpose of this study was to analyze the performance of glyphosate over the rehabilitation of degraded areas located in the Basin of the Paraíba do Sul River through the analysis of the microbial biomass and the definition of the soil physical and chemical properties as well.

2. Methods

To perform the analysis the three areas which were selected (Figure 1) have different histories of herbicide application (Table I) and different management: area 1, liming; area 2, no-tillage system; and area 3, addition of top soil.

After the demarcation, composite samples of the three areas of study were collected in July, in order to carry out a textural analysis, determine porosity [6] and do the chemical analysis [7]. In October, soil samples from each area were collected to determine the moisture and the soil microbial biomass carbon (BMS-C) [8] without the herbicide application.

Later new samples were collected and stored in airtight containers for the application of Round-Up, according to the concentration indicated by the manufacturer. Sixteen days after the application, samples were collected from the containers to determine the soil moisture and BMS-C.

From May 2004 to April 2010, data on precipitation and temperature for the region water balance were obtained from the UNIVAP Meteorological Station (Urbanova). So, the climatic classification and percolation have been set by the water balance method [9].

3.Results and Discussion

Generally, soil acidity is quantified on the basis of pH and Al3+ concentrations of soils. However, soil acidity is a complex of numerous factors involving nutrient/element deficiencies and toxicities, low activity of microorganisms and reduced plant root growth that limit nutrient and water uptake.

Table II shows the pH variation observed in the different areas. The area 1 received in the beginning of 2010 32.3 kg of limestone [10] and it explains the pH value of 6.0 which is considered ideal compared to the other areas whose pH was 4.1 and classified as very acid.

Table II. pH values and organic matter

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Areas	pH (CaCl$_2$)	OM g/dm^3
1	6	19
2	4,1	18
3	4,1	18

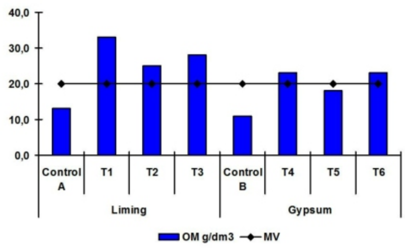
The yield increase of field crops with liming is due to improvement of the Ca and Mg soil contents and reduction of soil acidity [11]. In addition, liming also improves biological N2 fixation in acid soils and enhances net mineralization of organic N [12]. Thus, it can be observed that these nutrients are in greater amounts in area 1 than in the other areas (Figure 2).

The nutrient concentration (nutrient content per unit dry matter) decreased with increasing shoot dry matter in crop plants and this phenomenon is known as dilution effect in plant mineral nutrition [13]. In general, the N, Ca, and Mg concentrations increase as the lime rates go up. This may be associated with higher N2-fixation rate by N2-fixing bacteria and higher Ca and Mg uptake with increasing lime rates. The application of limestone significantly increased the Ca and Mg concentrations in area 1 and, in the other areas the amount of these nutrients was lower.

In the liming practice, although copper (Cu2+), manganese (Mn2+), zinc (Zn2+) and boron (a neutral, H3BO30) are not directly added to the soil, it makes them available in ideal quantities for plants and microorganisms in soils whose pH is between 6.0 and 7.0 [7] (Figure 3).

Figure 2. Macronutrient Amounts, potential acidity, sum of base and cation exchange capacity in the areas.

Figure 3. Micronutrient values in the areas.

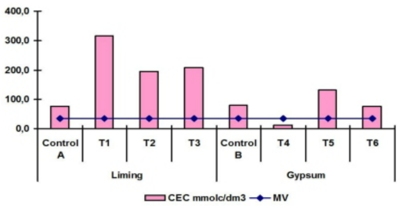


Also, the area 1 (Figure 2) presents high values of Cation Exchange Capacity (CEC) regarding the clay in the soil, so it reduces the cations leaching, consequently there is a greater Sum of Bases (SB) compared to the sum of calcium, magnesium and exchangeable potassium. In addition to this, the base saturation (V) is 81% which refers to the relative amount of nutrients in the soil, increasing their adsorption [7].

Concerning the potential acidity (H+Al), liming increased the soil pH and thus reduced the toxicity of aluminum (Figure 2). In areas 2 and 3, the values of macro and micronutrients, potential acidity, sum of bases, base saturation and CEC were similar, proving that the major difference occurs when there is any kind of practice to improve the soil characteristics. Both areas were influenced by the low pH, the high levels of iron oxides and toxic aluminum, so the availability of nutrients for the microbial activity and to the development of vegetation was reduced.

Another important point to be considered is that the fixation of phosphorus (as phosphate H2PO4-) in tropical soils is related to the Fe2+ and Al3+ oxides, that is, soils which are rich in these elements keep a lot of P (Figure 4). As the iron content increases the phosphorus content decreases. It is also essential to consider the texture along with the quantity of oxides ($Fe2+$ and $Al3+$) in the process of P fixation because in soils with more clay the P fixation is higher [14].

Figure 4. Values of iron and phosphorus in each area.



Fe2+) found in area 3 was significantly higher than in the other areas (Figure 4), which allows the complexation of glyphosate, the iron molecules and the humic acids. It can be a connection mechanism with the soil particles and the most active is clay [15].

The ions or herbicide molecules adsorption occurs by the inorganic colloidal fractions (clay) or the organic (humus) ones. Herbicides are more strongly adsorbed in dry soils than in wet ones due to the fact that water molecules compete with the herbicide to achieve the points of adsorption in clays. Also, the herbicides are more strongly adsorbed in humus particles than in clay particles [16].

Soil Porosity

The microbial diversity in soils is influenced by the particle size, where biomass is higher in clay and silt fractions [17] (Table III).

Table III: Soil physical analysis (august/2010)

Areas	Total Sand (%)	Silt (%)	Clay (%)	Textural Classification
1	50,2	25,3	24,5	Sand clay loam
2	73,2	9,7	17,1	Loamy sand
3	60,8	15	24,2	Sand clay loam

The soil microbial biomass is also modified by the soil structure and, with the increase in size and in the aggregate stability, an increase in the concentration of biomass [18] usually occurs.

The presence of iron oxides increases the particle density (Pd) value (Figure 4 and Table IV). On the other hand, low values in soil density (Sd) are associated with soils that have a granular structure and high values are associated with the block-type structure or something similar [6].

Table IV: Total Pore Volume analysis (September/2010).

Areas	Pd (g/m^3)	Sd (g/m^3)	TPV (%)
1	2,5	1,37	45,2
2	2,56	1,34	47,7
3	2,74	1,24	54,7

Water Indicators

Based on the water balance, the moisture index of around 47 for all the areas indicates that the the region has humid weather, aridity index 0.6 represents little or no water deficiency and the water index of 46.6 represents an excess of water in the summer except for July that has shown water surplus in the last five years.

The Tables V and VI show the data about precipitation, infiltration, percolation and the water flow for the different areas. The soil percolation in January, July, November and December may have contributed to the herbicide glyphosate leaching to the subsoil layers.

Table V. Estimation of leachate flow by the Water Balance Assessment Method in areas 1 and 3.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
P (mm)	254	188	160	75	58	51	78	34	66	113	137	186	1400
I (mm)	153	92	81	35	38	41	64	27	63	112	114	133	953
Per (mm)	47	0	0	0	0	0	3	0	0	0	22	30	102
Q (m³/day)	59	0	0	0	0	0	4	0	0	0	27	37	127

Table VI. Estimation of leachate flow by the Water Balance Assessment Method in area 2

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
P (mm)	254	188	160	75	58	51	78	34	66	113	137	186	1400
I (mm)	154	92	81	35	38	41	65	27	63	112	115	133	956
Per (mm)	48	0	0	0	0	0	3	0	0	0	21	30	102
Q (m³/day)	60	0	0	0	0	0	4	0	0	0	26	37	127

Legend: P - monthly precipitation; I - infiltration into the soil; Per - amount of water that percolates into the soil; Q - flow of leachate

Soil Microbial Biomass Carbon (SMBC)

Drastic anthropic interferences like mining bring about considerable organic matter losses, as a result the microbial activity decreases because the organic matter is a source of nutrients and energy to the soil microbial population and it also provides nutrients to the plants, therefore it is considered a key attribute to the success of the recovery of soils which had been damaged by the mining activity [19, 20, 21]. The BMS evaluation makes it possible to get quick information about the changes in the soil organic properties, detect changes that were caused by cultivation or forest devastation, measure the soil regeneration after the superficial layer had been removed and evaluate the effects of pollutants such as heavy metals and pesticides among others [22].

Studies performed in paleudalf indicated that the glyphosate herbicide addition (commercial formulation or pure form) did not inhibit the growth in the population of bacteria and fungi, suggesting that the bacteria and fungi were able to use the glyphosate as a substrate when compared to the result presented by the control treatment. It was highlighted that in the absence of nitrogen and phosphorus, glyphosate was used to enable the growth of filamentous fungi, however, no strain showed significant growth without the addition of glucose when compared to the other substrates studied [23].

The factors that alter the levels of organic matter in the soil usually cause changes in the microbial biomass, which is partly controlled by the soil moisture and temperature [18].

It was observed that the microbial biomass responded positively to different levels of soil moisture. After the test which applied glyphosate, the total soil moisture increased and consequently the soil microbial biomass level of carbon content (Figure 5). This fact was observed in areas 1 and 2, but in area 3 the effect was opposite, showing that the biomass reduction in the soil with glyphosate may have been influenced by other factors, because the relative humidity percentage in all the areas has increased to a percentage which is favorable to the development of the microbial biomass. The decline in the amount of microbial biomass in area 3, may be related to a higher concentration of iron oxides in the soil, which was detected in laboratory tests. The complexation promoted by these ions, together with the particles of clay in the soil and the glyphosate may affect the microbial biomass in a negative way [15].

Another factor to be considered is that the acid soil with high concentrations of iron and aluminum oxides enabled the precipitation of phosphorus, becoming unavailable [7], and it may have led to a reduction in the activity and in the microbial biomass as well. This activity would only be more intense in areas where the vegetation is more developed, which is not the case in area 3. The revegetation has just started and there is little mulch - materials placed over the soil surface to maintain moisture and improve soil conditions. Mulch suffers decomposition by the microorganisms that turn it into organic matter and thus increase the microbial activity, accelerating the glyphosate degradation [24].

Figure 5a: Relationship of Moisture and Microbial Biomass in the Soil without glyphosate.

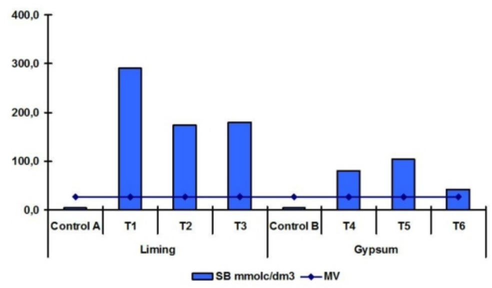
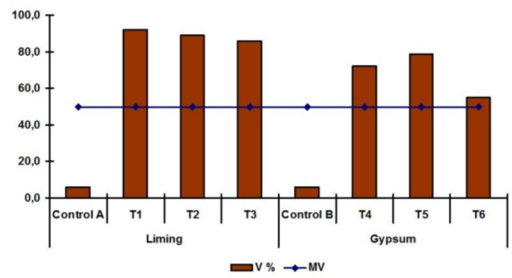


Figure 5b: Relationship of Moisture and Microbial Biomass in the Soil with glyphosate.



4. Conclusions

The application of Glyphosate influenced the factors such as the pH, CEC, the iron concentration (Fe), the soil moisture and the organic matter more significantly than the other factors here analyzed. The microbial biomass responded positively to different levels of soil moisture. After the test which applied glyphosate, the total soil moisture increased and the BMS-C content in areas 1 and 2 increased too. In area 3, the decline in the amount of microbial biomass may be related to a higher concentration of iron oxides in the soil, which was detected in laboratory tests. Then, to recover degraded areas it's essential to consider the soil physical, chemical and biological features. However, further studies regarding the performance of glyphosate in Brazilian soils must be conducted so that the combination of these factors with certain nutrients will not cause a negative impact on the attempt to recover the degraded areas.

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