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Artigo

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Enzyme activity in soil after different procedures for managing rice straw

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Abstract Severe problems are caused by site burning of rice straw in Valencia, the third largest Spanish city. Removal, incorporation or composting are being tested as alternatives to burning, and the changes they produce in selected soil biological properties have been studied in two field trials. One compares removal, burning and incorporation the straw, and a second evaluates the application of straw-derived compost for rice production. No statistically-significant effects on the measured indicators of biological activity were found in either experiment, indicating that management-induced changes are small. Unexpectedly, burning did not affect negatively enzyme activities or microbial biomass contents since there were no differences between treatments, or usual levels were recovered in a few months. The changes induced by straw removal or incorporation were also not statistically significant. When straw-derived compost applications were assayed, dehydrogenase activity was slightly variable and apparently unaffected by N and compost rates or compost/mineral N combinations, but phosphomonosterase activity seems to increase parallel to compost to mineral N ratio.

Keywords soil biological properties, dehydrogenase activity, phosphomonosterase activity, microbial biomass, burning rice straw

Actividades enzimáticas en suelos después de distintas modalidades de gestión de la paja de arroz

Resumen La quema de la paja de arroz en Valencia, tercera ciudad española, está causando severos problemas. Diversas prácticas de manejo como la retirada, la incorporación al suelo o el compostaje de la misma están siendo ensayadas como alternativas a la quema. Para el estudio de los cambios que estas prácticas generan en algunas propiedades biológicas de los suelos se han realizado dos ensayos en parcelas experimentales. El primer ensayo compara la retirada, quema e incorporación de la paja, como distintas formas de manejo de la misma, y el segundo ensayo evalua el efecto de la aplicación de un compost de paja de arroz en el suelo del arrozal. No se encontraron diferencias estadísticamente significativas en las medidas de actividad biológica en ninguno de los dos ensayos, indicando que la modalidad de manejo de la paja tan solo induce pequeños cambios en el suelo. Sorprendentemente, la quema no afectó a las actividades enzimáticas ni a la biomasa microbiana del suelo, ya que no se observaron diferencias entre tratamientos, o puede que se recuperaran los niveles usuales en pocos meses. Asimismo, en el ensayo de la aplicación del compost de la paja de arroz, se observó una ligera variación en la actividad deshidrogenasa, pero aparentemente no le afectaron ni la dosis de compost aplicada ni la combinación conjunta de fertilización mineral y fertilización orgánica. Sin embargo, la actividad fosfomonoesterasa pareció incrementar de forma paralela con las dosis aplicación de compost/fertilización mineral.

Palabras clave propiedades biológicas del suelo, actividad deshidrogenasa, actividad fosfomonoesterasa, biomasa microbiana, quema de la paja de arroz

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Introduction

Environmental pollution and severe health risks are recurrent problems caused every year by on-site burning of rice straw in the area surrounding the one-million inhabitant city of Valencia (Easter-Spain). A serious environmental damage is also done, since most of the land devoted to rice production lies within the bounds of the Natural Park *La Albufera*, one of the most important humid areas in the Mediterranean Basin. Besides, burning may represent a big loss of nutrients, organic matter and soil biological activity which should be avoided (Dobermann, 2002).

The European Common Agricultural Policy is developed in Valencia by the Rural Development Programme. In its last reform (2014-2020) burning of rice straw has been strictly forbidden. Therefore, different management alternatives have been assayed during these last years: removal of the straw to be used for paper manufacturing, animal bedding and other uses, or incorporation into the soil. It should be noted that both procedures are not without problems. Contrary to most cereals, rice straw is a very difficult material to degrade because of its hydrophobicity and high contents of lignin, especially in fields that have to be inundated shortly after the harvest for being located within a Natural Park of high ornithological interest. Foul odours may therefore be generated, and irrigation channels may be clogged by undegraded residues if not deeply ploughed. On the other hand, straw removal is expensive and may lead to a faster depletion of other nutrients than nitrogen in soil compared to burning.

Several authors have studied the effects of the incorporation of rice straw or rice-straw compost on several biological and biochemical properties of rice soils, mostly in laboratory conditions. Liang et al. (2003) reported increases of dehydrogenase, alkaline phosphatase and urease activities after the application of rice straw, alone or combined with pig manure, in a laboratory assay. In similar conditions, Guo et al. (2009) found increments in microbial biomass and phosphatase activity after the application to soil of rice straw, and Rajashehara Rao and Siddaramapa (2008) reported increases of phosphatase and urease after applying rice straw or tree leaves to soil. In a long-term field experiment, Hao et al. (2008) reported a significant increment of the microbial biomass-C after the application of mineral fertilizer combined with manure or rice straw. Similar results were reported by Nayak et al. (2007) after the application of rice-straw compost alone or combined with mineral fertilizer. Similarly, Goyal et al. (2009) found in a field experiment increases of microbial biomass and dehydrogenase and phosphatase activities after the application of rice-straw compost alone or combined with mineral fertilizer. Finally, Cheema et al. (2008) reported that application of rice-straw compost was the organic treatment giving rise to the highest increases of phosphatase and dehydrogenase activities in comparison to other organic and inorganic sources, although the latter was decreased by the use of mineral fertilizers.

Most of those studies have been performed in India and China, so the objective of this work was to evaluate the changes on some biochemical properties of a soil after removal, incorporation and burning of rice straw on the conditions prevalent in a Mediterranean area such as the Valencian region.

Material and methods

In an experiment located at Llaurí (Spain) the effects of burning, incorporation and removal of the straw were evaluated by means of a random-block statistical design with triplicate 400 m^2 experimental plots for each treatment situated within a rice field managed as usual in the area. The soil used was a sandy loam soil. Soil contents of organic matter and organic nitrogen were 2% and 0.11%, respectively.

Every year, the straw was managed accordingly to the corresponding treatment in autumn. Two years after the trial was started, β-D-glucosidase (Eivazi and Tabatabai 1988), alkaline phosphomonosterase (Tabatabai and Bremner 1969), urease (Tabatabai and Bremner 1972) and dehydrogenase (Casida et al. 1964) activities in soil taken in early spring were measured. Two years later, C-microbial biomass content (Vance et al. 1987), alkaline phosphomonosterase and dehydrogenase activities in soil were determined in a similar way.

In a second experiment located at Sueca (Spain), two rates of N (80 and 120 Kg N/ha) were applied as combinations of mineral fertilizer and compost from sewage sludge and rice straw (0, 25 and 50% of compost as a substitute of nitrogen mineral fertilizer to reach N doses) in an split-plot experiment with four replicates per treatment in 7x15 m experimental plots (Figure 1). The composts used every year were elaborated from rice straw and sewage sludge according to the procedure described in Ferrer et al. (2002), and their analytical properties are summarized in Table 1. The soil used was a sandy loam soil. Soil contents of organic matter and organic nitrogen were 3.32% and 0.19%, respectively.

Five years afterwards, soils were sampled in October, processed for analysis and alkaline phosphomonoesterase and dehydrogenase activities in were measured.

In both experiments, composite soil samples were made up of ten subsamples taken from the 0-15 cm arable layer of each 400 m^2 experimental unit, air-dried, and passed through a 2-mm sieve prior to analysis, except for the determination of the content of C-biomass, which was carried out on fresh samples. All determinations were made at least three times according to the Official Methods of the Spanish Ministry of Agriculture, Fisheries and Food (MAPA 1986) for the chemical and physicochemical properties of soils and composts. Statistical analysis was performed using the software package Statgraphics Plus (Manugistics Inc.).

Results and discussion

Figure 2 shows the effect of the three management alternatives for rice straw in the four enzyme activities assayed after two years of the start of the Llaurí experiment. Surprisingly, given that urea was used as N-fertilizer in the experiment as usual in rice cropping in Valencia, values of urease activity were particularly low when compared with those reported for other Valencian agricultural areas (Albiach et al. 1999, 2000, 2001). The changes in all enzyme activities were rather small and consequently no statistically-significant differences were found. This suggests that straw management (incorporation, removal or burning) did not clearly affect the biochemical activity of the soil. Similarly, burning does not seem to imply a severe harm to soil activity or, at least, this is fastly recovered in the period between burning and sampling.

	1º year	2º year	3º year	4º year	5º year
Moisture (%)	28.4	34.2	37.5	46.6	39.0
pH (1:25)	6.7	6.6	6.5	6.99	7.1
Electrical conductivity (1:5) (dS/m)	11.5	11.2	10.4	5.15	6.3
Organic matter (%)	51.4	50.5	52.7	60.5	75.3
Nitrogen (%)	2.69	2.73	2.48	2.48	2.38
Relation C/N	11.1	10.7	12.3	14.2	18.4
Phosphorus (% P_2O_5)	5.14	5.28	4.86	2.67	2.02
Potassium (% K_2O)	0.99	1.05	1.20	0.21	1.01
Calcium (% CaO)	14.3	15.6	12.8	5.53	4.47
Magnesium (% MgO)	1.26	1.34	1.45	0.43	0.39
Iron (mg/Kg)	3655	3874	3576	10005	10140
Manganese (mg/Kg)	153	167	174	132	126
Copper (mg/Kg)	284	292	285	165	115
Zinc (mg/Kg)	680	698	647	840	827
Cadmium (mg/Kg)	0.9	0.9	0.8	<1	<1
Nickel (mg/Kg)	8.4	8.8	7.6	44.6	26.1
Lead (mg/Kg)	71	76	68	48	37.8
Chrome (mg/Kg)	218	225	194	33	20.6
Mercury (mg/Kg)	< 0.5	< 0.5	< 0.5	<0.5	<0.5

Table 1.- Analytical parameters of the composts applied during the trial at Sueca

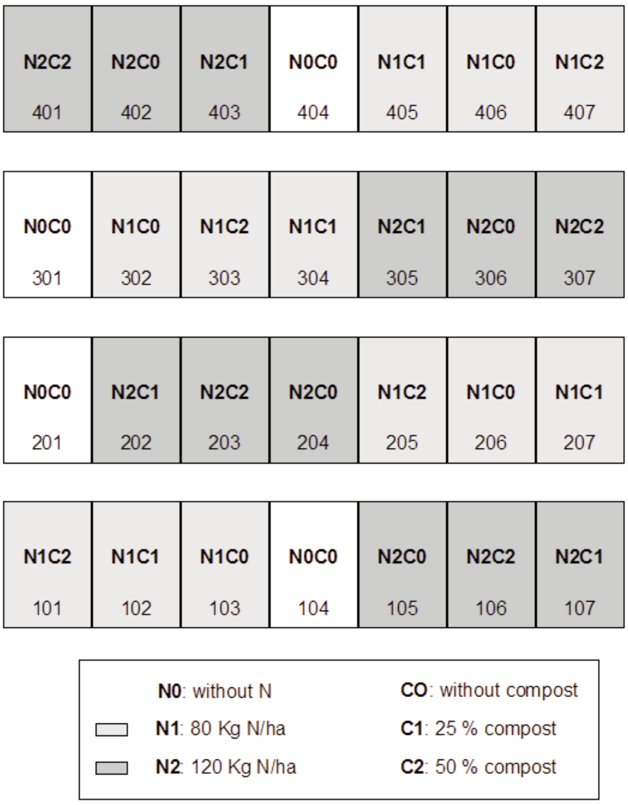

Figure 1.- Experimental design at Sueca assay

Figure 3 shows the effect of straw management on soil dehydrogenase, alkaline phosphomonoesterase and microbial biomass four years after the start of the Llaurí experiment. Again, no changes were found for the biochemical parameters, which showed slightly higher values than in the former sampling season. Although the experimental conditions are hardly comparable, this lack of significant changes does not agree with those results reported by others authors in laboratory conditions (Liang et al. 2003; Rajashehara Rao & Siddaramapa, 2008) or field (Goyal et al. 2009; Cheema et al. 2009). Microbial biomass seemed to be independent from straw management, although straw incorporation brought about a small increment due to organic matter application. Similar results have also reported by Guo et al. (2009) and Hao et al. (2008). The unexpected result that burning did not affect microbial activity could be attributed to fast recovery during the period from burning to sampling.

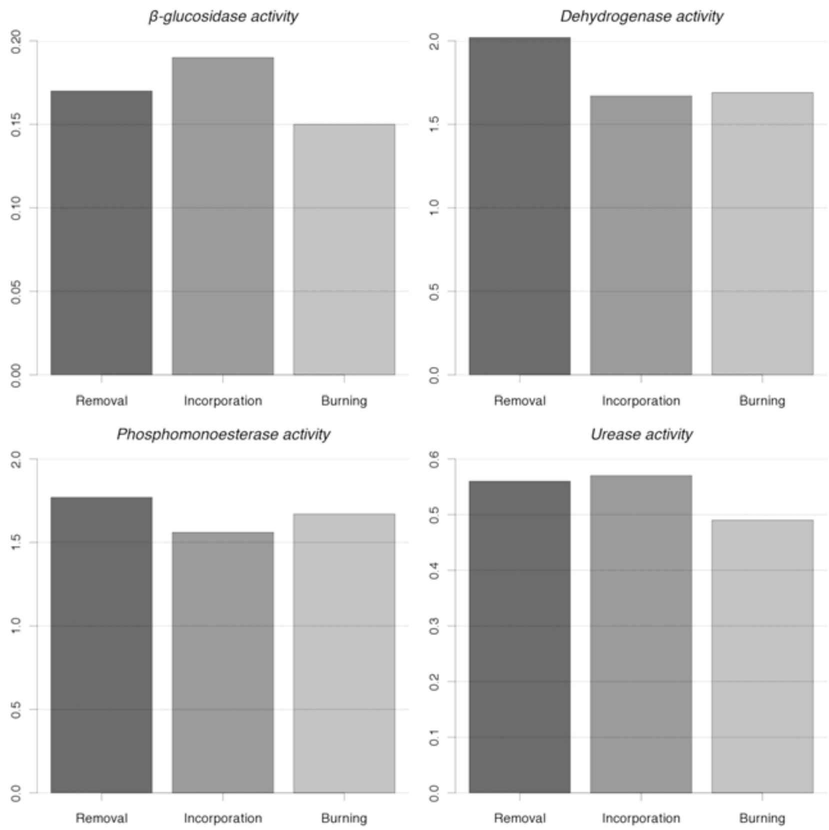

Figure 2.- Effect of rice straw removal, incorporation and burning, in soil enzyme activities and microbial biomass two years after the start of the experiment. Soil dehydrogenase activity, (µg TPF·g-1·h^{-1}), TPF: triphenylformazan; Soil alkaline phosphomonoesterase activity (µmol PNP·g-1·h^{-1}), PNP: p-nitrophenol; Microbial biomass (µg C·g^{-1})

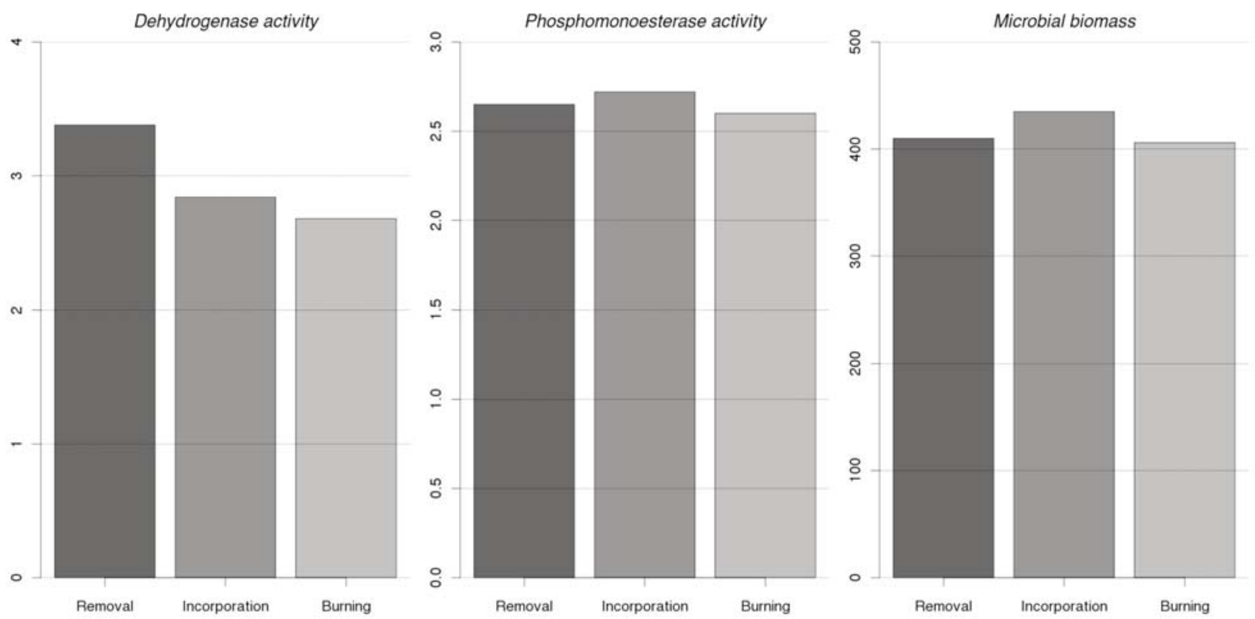

Figure 3.- Effect of rice straw removal, incorporation and burning, in soil enzymatic activities four years after the start of the experiment. Soil dehydrogenase activity, (µg TPF·g^{-1}·h^{-1}), TPF: triphenylformazan; B-glucosidase activity (µmol PNP·g^{-1}·h^{-1}), PNP: p-nitrophenol; soil alkaline phosphomonoesterase activity (µmol PNP·g^{-1}·h^{-1}), PNP: p-nitrophenol; urease activity (µmol NH3·g^{-1}·h^{-1})

In the Sueca experiment evaluating the effect of using straw-derived compost, values of dehydrogenase activity were higher than those in the trial at Llaurí as displayed in Figure 4, but no significant effects of the treatments were observed.

Figure 5 shows the results found for alkaline phosphomonoesterase activity. Again, no statistically-significant effects were found, although in this case the application of compost seemed to increase slightly the activity according to the rate used, in agreement with results reported by Cheema et al. (2008) in a field experiment.

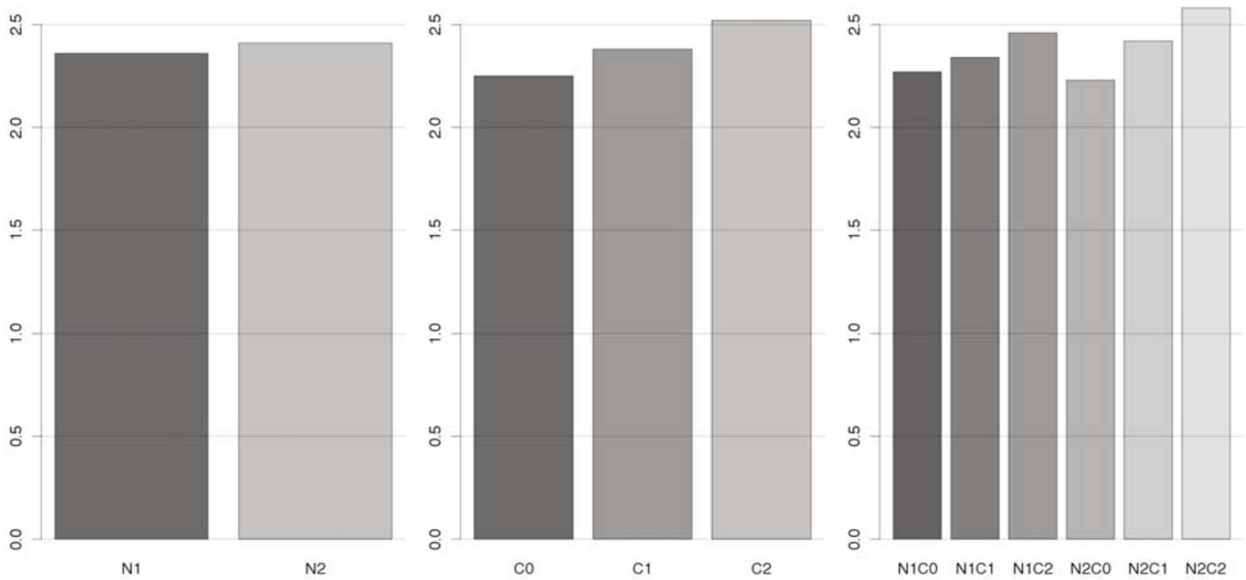

Figure 4.-Effect of two rates of N (N1:80 Kg N ha-1, N2:120 Kg N ha^{-1}) applied as combination of mineral fertilizer and compost (C0: 0% compost, C1: 25% compost, C2: 50% compost) on soil dehydrogenase activity (µg TPF·g^{-1}·h^{-1}), TPF: triphenylformazan

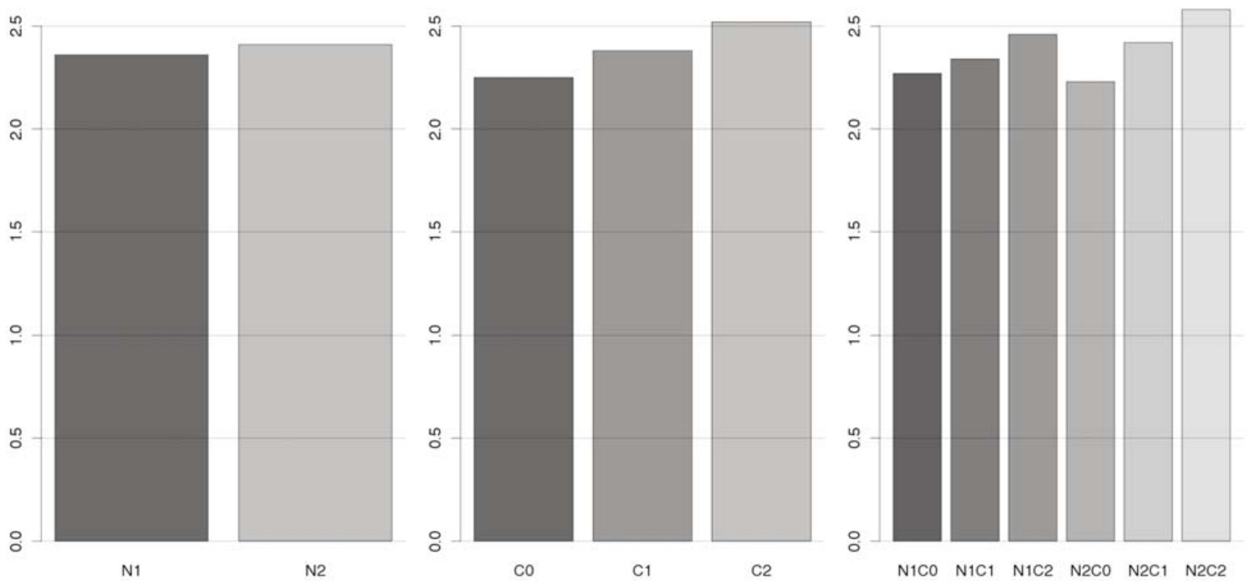

Figure 5.-Effect of two rates of N (N1:80 Kg N ha-1, N2:120 Kg N ha^{-1}) applied as combination of mineral fertilizer and compost (C0: 0% compost, C1: 25% compost, C2: 50% compost) on soil alkaline phosphomonoesterase activity (µmol PNP·g^{-1}·h^{-1}), PNP: p-nitrophenol

Conclusions

No statistically-significant effects were found in both experiments, indicating that straw management practices brought about only very small modifications to soil biological condition. Surprisingly, burning did not affect negatively enzyme activities or microbial biomass or, at least, did not hamper a recovery of the usual levels in a few months. The changes induced by straw removal or incorporation were also very small. When straw-derived compost applications were assayed, levels of enzyme activities were slightly variable and apparently not affected by N and compost rates or compost/mineral N combinations.

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