



Sustainable agriculture and nitrogen reduction: an open field experiment using natural zeolites in silty-clay reclaimed soil at Codigoro (Po River Delta, Ferrara, Italy)

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Following the guidelines of Nitrate and Water Framework Directives (91/676/CEE, 200/60/CE) an innovative integrated zeolite cycle is being tested on a reclaimed clayey-silt soil in the Po Delta area (Ferrara Province, Italy), in the framework of the EU-funded ZeoLIFE project (LIFE+10 ENV/IT/000321).

Natural zeolites are pyroclastic rocks containing more than 50% of zeolites, a kind of hydrous minerals with peculiar physical and chemical properties, like high and selective cation exchange capacity (CEC), molecular adsorption and reversible dehydration. Zeolites can trap NH_4^+ from solutions and release it gradually to the plant roots once they have been mixed in agricultural soils, allowing both fertilization and irrigation reduction and improvement of the yield. The fertilization reduction can result in a decrease of the nitrate content in groundwater and surface waters, ultimately leading to a mitigation of nutrient excess in the environment. Similarly, reduction of irrigation water means a minor exploitation of the water resource.

The selected material used in the project is a chabazite zeolite coming from a quarry near Sorano in Central Italy (Bolsena volcanic district). The open-field experimentation foresees two year of cultivation. A surface of about 6 ha has been divided into six parcels: three control parcels are cultivated and irrigated in traditional way; two parcels have been added with coarse-grained ($\phi = 3-6$ mm) natural zeolite at different zeolite/soil ratios (5 kg/m^2 and 15 kg/m^2) and one has been mixed with fine-grained ($\phi < 3$ mm) NH_4^+ -charged zeolite at 10 kg/m^2 . Zeolite/soil ratios have been determined upon a series of greenhouse tests, and the ammonium enriched material is obtained by cation exchange with swine manure in a specifically conceived prototype.

The environmental quality of soil and water in each parcel is monitored by periodic soil, groundwater and porewater analyses. Soil EC, temperature and volumetric water content are continuously measured with probes at different depth (5-30-50-100-150 cm). The quality of surface water is checked by analyzing the outflow from the drains of the sub-irrigation system installed in the field. An automated meteorological station has been also installed in order to quantify rainfalls and sun irradiation for water balance calculation.

During the first year, a no-food variety of sorghum has been cultivated. In the parcels treated with natural zeolite and in that bearing NH_4^+ -charged zeolite, the fertilization has been reduced by 30% and 50% with respect to the controls. Notwithstanding these reductions, the yield increased by 5% and 15% in the parcel added with natural zeolite and in that treated with NH_4^+ -charged zeolite, respectively.

As confirmed by previously performed laboratory leaching tests, NH_4^+ in porewater and surface water was comparable in all parcels ($< 7 \text{ mg/l}$). Similarly, NO_3^- in the first 100 cm of the soil column, in porewater and surface water were comparable in all parcels or lower in those treated with both NH_4^+ -charged and natural zeolite.

The results obtained in the first year of experimental cultivation testify for the efficacy of the proposed method and suggest that environmental preservation and sustainable agriculture are compatible.