**PERIODICO di MINERALOGIA**
*established in 1930*

*An International Journal of*
Mineralogy, Crystallography, Geochemistry,
Ore Deposits, Petrology, Volcanology
and applied topics on Environment, Archaeometry and Cultural Heritage

Dipartimento di Scienze della Terra
Sapienza Università di Roma

# Is it possible to cultivate corn in a sustainable way using a quarry waste?

Dario Di Giuseppe [a,*], Giacomo Ferretti [a], Barbara Faccini [a], Emanuele Blasi [b], Nicolò Passeri [b], Gianluca Bianchini [a], Massimo Coltorti [a]

[a] University of Ferrara, Department of Physics and Earth Sciences, Via Saragat 1, 44122 Ferrara, Italy
[b] University of Tuscia, Department of Economics & Management (DEIM), Viterbo, Italy

**ARTICLE INFO**

Submitted: March 2016
Accepted: July 2016
Available on line: July 2016

* Corresponding author: dgsdra@unife.it

DOI: 10.2451/2016PM633

How to cite this article: Di Giuseppe D. et al. (2016) Period. Mineral. 85, 179-183

**ABSTRACT**

In this preliminary work we investigated the possibility to improve corn cultivation efficiency and sustainability through the use of a quarry waste material rich in zeolite minerals as soil conditioner. Corn grown under traditional fertilization was compared to corn grown on zeolitite amended soil, under fertilization reductions. Corn plants grown on zeolitite treatments showed higher chlorophyll content, a more balanced nitrogen use efficiency and a higher yield compared to zeolite-free control parcel cultivated in conventional mode.

Keywords: zeolite, sustainable agriculture, quarry waste, NUE, corn.

## INTRODUCTION

Since 1965 to nowadays, human population raised by 4 billion, causing a strong increase in food demand and forcing the agricultural production to constantly increase.

Intensive agricultural activities are accompanied by an increase in fertilizers application which causes serious environmental threats such as $NO_3$ leaching, $NO_x$ and $NH_3$ emissions (Ju et al., 2009; Mastrocicco et al., 2013; Skinner et al., 2014). In 2014, 18,355,058 ha were designed to corn cultivation (FAOSTAT, 2015) for animal feeding, sugar production, maize-meal-products, packing materials and biogas systems. However in intensive cropping system, this cultivation requires very high amounts of N inputs from fertilizers (Millar et al., 2010), causing remarkable environmental impacts, as remarked by IPCC (IPCC, 2006). In order to avoid the pollution linked to an excessive use of fertilizers, European Community have indicated a regulation framework that set the maximum amount of N usable per hectare (i.e. Nitrates Directive and Water Framework Directive). However, recent studies (Van Groenigen et al., 2010) showed that, in order to make agriculture a more sustainable activity, fertilization reductions must be combined with nitrogen use efficiency improvements. Into the huge amount of possibilities into cultivation techniques, one of the advanced and natural-based techniques to improve fertilizers efficiency is the use of rocks and minerals to slow the fertilizer release and as soil conditioner (Zareabyaneh and Bayatvarkeshi, 2015). In particular, natural zeolitites (NZ) are rocks containing more than 50% of zeolites (Galli and Passaglia, 2011), that are minerals with peculiar physical and chemical properties, like high and selective cation exchange capacity (CEC), molecular adsorption and reversible dehydration (Malferrari et al., 2013). In Central Italy, many quarries are actually extracting a K-chabazite bearing zeolitite for the production of construction bricks, and large amounts of NZ byproduct remain unused, constituting thus a waste material (see Figure 1).

In this study, it has been tested the potential of scrap material, named natural zeolitites, for a more sustainable corn cultivation, determining the effects on: (i) *Zea mays* yield and quality under a fertilization reduction (with respect to common agricultural practices); (ii) Nitrogen Use Efficiency (NUE) of a maize cultivation in an open field.

## MATERIALS AND METHODS

The zeolitite used as soil amendant is a K-chabazite developed during the weathering process of pyroclastic volcanic rocks in the surrounding of Grosseto (Italy) and is included in the Sorano Formation (the so-called Lithic Yellow Tuff body). Additional information on

Figure 1. Quarry waste material constituted by K-chabazite bearing zeolitite.

Table 1. Mineralogical composition and cation exchange capacity (CEC) of K-chabazite bearing zeolitite.

| | Chabazite | Philipsite | Analcime | K-feldspar | Mica | Pyroxene | Amorph | CEC |
|---|---|---|---|---|---|---|---|---|
| Zeolitite | 68.5 (0.9) | 1.8 (0.4) | 0.6 (0.3) | 9.7 (0.7) | 5.3 (0.6) | 2.9 (0.4) | 11.2 (1.0) | 0.0563 |

Table 2. Parcel surface, applied fertilizer and N reduction with respect to CON. Agronomic measurements (standard deviation within brackets), yield, total N content of maize grain, amount of leaves chlorophyll and NUE values (see text for more informations).

| Treatment | Added zeolitite (kg $m^2$) | Area (ha) | Applied N (kg $ha^{-1}$)* | N reduction (%) | n°of plants x $m^2$ | Height (cm) | n° of plants with cobs ** | Yield (kg $ha^{-1}$) | Total N (%) | Chlorophyll content (μmol $m^{-2}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| CON | 0 | 1.48 | 241 | / | 8.7 (±3) | 167 (±42) | 43 | 9486 | 1.55 | 712 (±155) |
| NZ5 | 5 | 0.97 | 179 | 26 | 10.6 (±2) | 152 (±47) | 48 | 10309 | 1.49 | 780 (±175) |
| NZ15 | 15 | 0.92 | 175 | 27 | 11.2 (±3) | 160 (±43) | 69 | 11804 | 1.27 | 827 (±132) |

* Nitrogen fertilization was done using di-ammonium phosphate (18% N) and urea (46% N).
** Refers to the total number of plants with cobs observed during the measurement.

this lithology is reported in Galli and Passaglia (2011). Mineralogical composition and cation exchange capacity of the employed material are reported in Table 1. The material used in this study was taken in a quarry located in the Sorano village (42°41'26.53'' N; 11°44'35.07'' E).

The test was conducted under *Zea mays* cultivation during the 2014 growing seasons in the ZeoLIFE (LIFE+10/ENV/IT000321) experimental field (Di

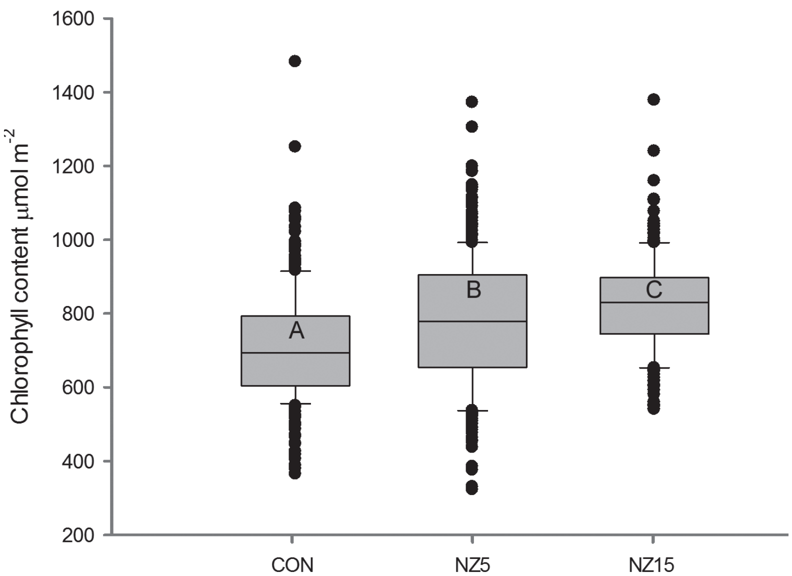


Figure 2. Box plot of maize leaves chlorophyll content. Capital letters represent ANOVA and Tukey (HSD) test results. Treatments labels as in Table 2. The bottom and top of the box are the 25th and 75th percentiles; the band inside the box is the median; whiskers represents the 10th and 95th percentiles; data not included between the whiskers (dots) are the outlayers.

Giuseppe et al., 2014; Faccini et al., 2015). In order to compare conventional agricultural practices with those related to innovative NZ method, a subset of the field was divided in 3 parcels. Non-zeolitite amended soil (CON) was compared with NZ amended treatments; a reduction of fertilization was applied in both NZ parcels with respect to CON (Table 2). Yield and quality of corn grown in each plot were determined by plant morphology measurements, NUE determination and leaves greenness (chlorophyll content) of corn through the use of a SPAD chlorophyll meter. NZ characteristics are described by Faccini et al. (2015). Morphology measurements (Table 2) were performed at the development of corncob phenological growth stage. For each parcels, ten measuring points of $1m^2$ were identified. The determination of the relative amount of leaves chlorophyll was measured by a chlorophyll meter SPAD-502Plus (Konica Minolta). Measurements and calibrations have been made applying the methodology defined by Markwell et al. (1995). ANOVA and Tukey (HSD) tests were used for statistical analysis. NUE was calculated using the equation:

$$\text{(1)} \qquad \text{NUE}=\frac{\text{Nr}}{\text{Nin}}*100$$

were Nr is nitrogen (kg-N $ha^{-1}$) uptaken by crops and Nin is the mineral N input (kg-N $ha^{-1}$). To calculate Nr, elemental nitrogen content of maize grains was used (six plants for each parcels), determined by an Elementar Vario Micro Cube Elemental Analyzer.

**RESULTS AND DISCUSSION**

No significant differences ($p>0.05$) were found among plants height during the initial growth stage (Table 1) notwithstanding the fertilization reductions. Even if not supported by a statistical index, it is possible to observe that the NZ15 (three months after sowing) had more cobs per plant compared to other treatments.

Chlorophyll content of maize leaves (Figure 2) showed significant differences ($p<0.05$) between the treatments. CON had a significantly lower mean values with respect to both NZ5 and NZ15 treatments. Chlorophyll content seems to be positively correlated to the amount of applied NZ into the soil. Very good results in terms of maize grains production were obtained at the harvest, considering the applied fertilization reductions (Table 2): NZ15 and NZ5 yield were 24.4% and 8.7% higher than CON, respectively. However total amount of N, content into grains, was significantly lower ($p<0.05$) in NZ15 with respect to 5NZ and CON, while no difference were found between NZ5 and CON (p>0.0.5). Thanks to yield results, it is possible to calculate NUE (Table 2) using total grains-N harvested and N input from fertilization. Being the ratio between the amount of fertilizer-N up taken by the crops and the total N input from fertilization, NUE values of 90-100% mean a risk of soil mining, as the additional N requirements for roots and straw are not met by N input; values of 80-90% suggest that the inputs and outputs are balanced while N application rates with NUE values below 70% connote a risk of nitrogen losses (Bremtrup and Palliere, 2010).

The NUE values determined in this trial are reported in

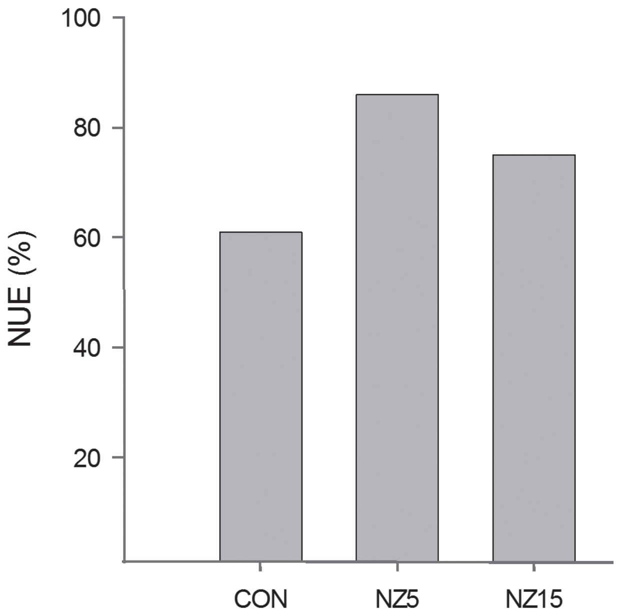


Figure 3. Nitrogen Use Efficiency (NUE) of a maize cultivation. Treatments label are explained in Table 2.

Figure 3. CON show a risk of high N losses, as N fertilizer inputs exceed total crop demand, whereas for NZ5 and NZ15 N fertilizer inputs meets total crops demand, reflecting a more balanced system. It has to be noticed that, notwithstanding NZ15 had lower grain N content with respect to CON, this had no influence on the total production as evidenced by yield results. Probably, the improvement in nutrients use efficiency induced a better photosynthetic activity and an improved fruit settings, resulting thus in a higher yield (Table 2).

## CONCLUSION

This preliminary work highlights the possibility to improve the efficiency and sustainability of corn cultivation through the use of a quarry waste NZ material. NZ15 although heaving less N in grains have higher plants/$m^2$ and therefore higher yield, and according to the studies of Colombani et al. (2015) N is sequestrated in the soil matrix.

The results of the corn cultivation have shown that NZ behaves as slow releasing fertilizer, increases the NUE and is able to positively influence leaves chlorophyll content. The NZ application into modern agriculture could lead to a sustainable cropping management, decreasing the amount of fertilizers (influencing the yield), in line to an eco-innovation perspective.

In conclusion we can state that the employment of zeolite ammendants in agricultural soils increase the crop production and prevent N losses, preventing pollution of the surrounding water resources.

ACKNOWLEDGMENTS

The authors thank Dr. Giuseppe Forlani for his important technical support. This work has been sustained by the EU-funded ZeoLIFE project (LIFE+10/ENV/IT000321).

## REFERENCES

Bremtrup F. and Palliere C. (2010) Nitrogen Use Efficiency as an agro-environmental indicator. OECD workshop “Agri-environmental indicators: lessons learned and future directions”, 23-26 March 2010, Leysin, Switzerland.

Colombani N., Mastrocicco M., Di Giuseppe D., Faccini B., Coltorti M. (2015) Batch and column experiments on nutrient leaching in soils amended with Italian natural zeolitites. Catena 127, 64-71.

Di Giuseppe D., Faccini B., Mastrocicco M., Colombani N., Coltorti M. (2014) Reclamation influence and background geochemistry of neutral saline soils in the Po River Delta Plain (Northern Italy). Environmental Earth Sciences 72, 2457-2473.

Faccini B., Di Giuseppe D., Malferrari D., Coltorti M., Abbondanzi F., Campisi T., Laurora A., Passaglia E., (2015) Ammonium-exchanged zeolitite preparation for agricultural uses: From laboratory tests to large-scale application in ZeoLIFE project prototype. Periodico di Mineralogia 84, 303-321.

Galli E. and Passaglia E. (2011) Natural zeolites in environmental engineering. In: Zeolites in chemical engineering. (eds): H. Holzapfel. Verlag ProcessEng Engineering GmbH, Vienna, 392-416.

FAOSTAT (2015). Food and Agricultural Organization Statistics Database. Food and Agricultural Organization of the United Nations, Rome, Italy. http://www. fao.org. (accessed 25.02. 2016).

IPCC (2006) 2006 IPCC guidelines for national greenhouse gas inventories, prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., Tanabe K. (eds). Published: IGES, Japan.

Ju X.T., Xing G.X., Chen X.P., Zhang S.L., Zhang L.J., Liu X.J., Cui Z.L., Yin B., Christie P., Zhu Z.L., Zhang F.S. (2009). Reducing environmental risk by improving N management in intensive Chinese agricultural systems. Proceedings of the National Academy of Sciences U.S.A. 106, 3041-3046.

Malferrari D., Laurora A., Brigatti M.F., Coltorti M., Di Giuseppe D., Faccini B., Passaglia E., Vezzalini M.G., (2013) Open-field experimentation of an innovative and integrated zeolitite cycle: project definition and material characterization. Rendiconti della Classe di Scienze Fisiche, Matematiche e Naturali dell’Accademia Nazionale dei Lincei 24, 141-150.

Markwell J., Osterman J.C., Mitchell J.L. (1995) Calibration of the Minolta SPAD-502 leaf chlorophyll meter. Photosynthesis Research 46, 467-472.

Mastrocicco M., Colombani N., Di Giuseppe D., Faccini B., Coltorti M. (2013) Contribution of the subsurface drainage system in changing the nitrogen speciation of an agricultural soil located in a complex marsh environment (Ferrara, Italy). Agricultural Water Management 119, 144-153.

Millar N., Robertson G.P., Grace P.R., Gehl R.J., Hoben J.P., (2010) Nitrogen fertilizer management for nitrous oxide

(N2O) mitigation in intensive corn (Maize) production: an emissions reduction protocol for US Midwest agriculture. Mitigation and Adaptation Strategies for Global Change 15, 185-204.

Skinner C., Gattinger A., Muller A., Mäder P., Flieβbach A., Stolze M., Ruser R., Niggli U., (2014) Greenhouse gas fluxes from agricultural soils under organic and non-organic management - A global meta-analysis. Science of The Total Environment 468-469, 553-563.

Van Groenigen J.W., Velthof G.L., Oenema O., Van Groenigen K.J., Van Kessel C. (2010) Towards an agronomic assessment of $N_2O$ emissions: a case study for arable crops. European Journal of Soil Science 61, 903-913.

Zareabyaneh H., Bayatvarkeshi M. (2015) Effects of slow-release fertilizers on nitrate leaching, its distribution in soil profile, N-use efficiency, and yield in potato crop. Environmental Earth Sciences doi 10.1007/s12665-015-4374-y.