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A Review

Using Assessment of Zeolite Amendments in Agriculture

SFECHIŞ Susana[1], VIDICAN Roxana[1*], ŞANDOR Mignon[1], STOIAN Vlad [1], ŞANDOR Valentina[1], MUSTE Bogdan [2]

University of Agricultural Sciences and Veterinary Medicine Cluj - Napoca, Mănăştur St., No. 3 – 5, 400327 Cluj-Napoca, Romania
[2]BT Bison Ranch, Recea Cristur, No. 277, Cluj, Romania

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Abstract

One of the current trends in agriculture is finding new sustainable alternatives to increase soil fertility and productivity. Besides the advantage of sustainability, the zeolite is considered a natural element, which has no negative consequences on environmental quality. The present paper discusses some aspects regarding the use of zeolites in agriculture. This study will help on reaching the full potential in developing of unconventional amendments based on zeolite in developing country agriculture.

Keywords: aluminosilicate, clinoptilolite, properties, minerals, soil.

1. Introduction

Lately, the use of minerals for agricultural purposes is becoming widespread [25] zeolitic amendaments represent a special niche in this category. There are for about forty identified natural zeolites [5]. Also, more than 150 zeolites have been synthesized.

Zeolites are crystalline hydrated aluminosilicate minerals made from interlinked tetrahedral of alumina (AlO_4) and silica (SiO_4). In simple words, they are solids with a relatively open, three-dimensional crystal structure built from the elements aluminum, oxygen, and silicon, with alkali or alkaline-Earth metals (such as sodium, potassium, and magnesium) plus water molecules trapped in the gaps between them. Zeolites form with many different crystalline structures, which have large open pores (sometimes referred to as cavities) in a very regular arrangement and roughly the same size as small molecules [15].

According to reports of 2001, the total consumption of zeolites was 3.5 million tons of which 18% came from their natural resources and the rest from synthetics [18].

By using clinoptilolite tuff zeolite as a soil conditioner were reported a significant increases in the yields of wheat 13-15%, eggplant 19-55%, apples 13-38% and carrots 63% only by adding 4-8 t of zeolite per acre [20].

2. Zeolite properties

Zeolites have been increasingly used in various application areas such as industry, agriculture, environmental protection, and even medicine. Although, there are no certain figures on the total amount of these minerals the world, some countries e.g. Cuba, USA, Russia, Japan, Italy, South Africa, Hungary and Bulgaria, have important reserves and production potentials.

These minerals have three main properties, which are of great interest for agricultural purposes: high cation exchange capacity, high water holding

* Corresponding author.
Tel: +40-264596384
Fax: +40-264593792
e-mail: roxana.vidican@usanmvcluj.ro

capacity in the free channels, and high adsorption capacity [16].

The most common for agricultural applications is clinoptilolite since it has high absorption, cation exchange, catalysis and dehydration capacities.

Zeolites are, therefore, used as a promoter for better plant growth by improving the value of fertilizers; retaining valuable nitrogen and improving the quality of resulting manures and sludge. They can also be used as a molecular sieve or filter medium.

Zeolites improves the efficiency of nutrient use by increasing the availability of P from phosphate rock, the utilization of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ and reduced losses by leaching of exchangeable cations, especially K^+ [10, 17]. Zeolites mixed with phosphate rock, can act as controlled delivery system and renewable source of nutrients for plants [1, 2]. It was demonstrated increased efficiency of N utilization when urea is used together with zeolite [3].

Together with fertilizers, zeolites achieved increasing of N use efficiency, N uptake, dry matter yield and reductions of losses by ammonia volatilization [6]. Zeolites also improve the efficiency of water use by increasing the soil water holding capacity and its availability to plants [26].

Zeolite is also used to remove nitrates from water [12].

The pronounced selectivity of clinoptilolite for large cations, such as ammonium and potassium, has also been exploited in the preparation of chemical fertilizers that improve the nutrient-retention ability of the soils by promoting a slower release of these elements for uptake by plants.

Zeolites have many important tasks such as ion exchange, filtering, odour removal, chemical sieve, water softener and gas absorption.

Therefore, apart of agriculture, numerous examples of their application are cement and brick production, stabilization of soil, building materials, paint components with anticorrosive property, defluorination of industrial wastes, desulphurization of flue gas, methylene blue and mercury removal, copper recovery from wastes, fixation of phosphates, chlorinated phenol removal and neutralization of acid wastes, cleanup of sewerage, and both heavy metal, and ammonium ion removal [18].

3. Aplications in agronomy

Regardless of their impressive physicochemical properties, zeolites did not find practical application for a long time because investigations concentrated exclusively on zeolites of volcanic origin. The number of zeolites in the total volume of rocks rarely exceeded a few per cent. The discovery of zeolites of sedimentary origin allowed their use to be investigated seriously. Because of their extremely high sorptive capacity, which depends on the dominant mineral, zeolites can be utilised in different fields of national economy, including agriculture [21].

4. The effect of zeolite in clay soils

During the 5 months of one experiment with clay soil, found higher contents of ammonia nitrogen in the variants with zeolite, which means ammonia nitrogen is gradually released from zeolite and more is available for cultivated plants. Similar effects were found after zeolite application, although their experiments contained significantly higher zeolite amounts [4, 22].

Application of 2 t of zeolite in heavy soils increased the hydrolysable nitrogen content twice, and when they used 4 and 6 t of zeolite, it increased by 4 and 5 times, respectively. Some authors suggested that fertilizer with the addition of zeolite becomes a “slow-releasing fertilizer” [19, 24], but the term was debated in relation to zeolite [9].

As zeolite has an effect on soil for several years after its application, this can be considered to be a significant fact in the prevention of nitrogen loss from soil.

On the other hand, it was noted little change in the vitrification of added ammonia when clinoptilolite was mixed with a Texas clay soil, although the overall ion-exchange capacity of the soil was increased. He attributed these conflicting results to the fact that the Japanese soils contained much less clay, thereby accounting for their inherent low ion-exchange capacity and fast-draining properties.

The addition of zeolite, therefore, resulted in a marked improvement in the soil’s ammonium retentivity [23].

The addition of ammonium-exchanged clinoptilolite in greenhouse experiments with radished results in a 59% and 53% increase in root weight in medium and light clay soils respectively [11]. The nitrogen uptake by plant tops also increased with the zeolite treatment compared with an ammonium sulfate control.

These authors also found that natural clinoptilolite added to soil in conjunction with urea reduced the growth suppression that normally occurs when urea is added alone. The presence of zeolites also resulted in less NO_3-N being leached from the soil.

5. The effect of zeolite in sandy loam soil

Based on their high ion-exchange capacity and water retentivity, natural zeolites have been used extensively in Japan as amendments for sandy soils, and small tonnages have been exported to Taiwan for this purpose [8, 14].

The pronounced selectivity of clinoptilolite for large cations, such as ammonium and potassium, has also been exploited in the preparation of chemical fertilizers that improve the nutrient-retention ability of the soils by promoting a slower release of these elements for uptake by plants.

Small, but significant improvements in the dry-weight yields of sorghum in greenhouse experiments using a sandy loam were noted when 0.5 to 3.0 tons of clinoptilolite per acre was added along with normal fertilizer [13]. However, little improvement was found when raising corn under similar conditions. Hershey, et al. (1980), showed that clinoptilolite added to a potting medium for chrysanthemums did not behave like a soluble K source, but was very similar to a slow-release fertilizer, The same fresh-weight yield was achieved with a one-time addition of clinoptilolite as with a daily irrigation of Hoagland’s solution, containing 238 ppm K, for three, months (total of 7 g potassium added), with no apparent detrimental effect on the plants [7].

Zeolites added to fertilizers help to retain nutrients and, therefore, improving the long term soil quality by enhancing its absorption ability. It concerns the most important plant nutrients such as nitrogen (N) and potassium (K), and also calcium, magnesium and microelements.

5. Conclusion

Because of these unique advantages, properties and behavior, zeolites are considered to be molecular sieves and a successful unconventional amendment.

Application of zeolite improves significantly soil fertility, physical and chemical properties and is very useful in draught conditions, because it absorbs a high quantity of water in its pores.

Zeolite can retain soil nutrients in the root zone to be used by plants when required.

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