

USE OF ZEOLITIC MATERIAL FROM MUNELLA REGION (ALBANIA) AS FERTILIZER IN THE SANDY SOILS OF DIVJAKA REGION (ALBANIA)

Enkeleida BEQIRAJ (GOGA)*, Fran GJOKA**, Fabrice MULLER*** & Patrick BAILLIF***

*Polytechnic University of Tirana, Sheshi "Nene Tereza", Albania

ea_begiraj@yahoo.com

**Agricultural University of Tirana, Albania fgjoka@yahoo.com

***Institut des Sciences de la Terre d'Orleans, Rue de la Férollerie Orleans, Cedex 2, France Fabrice.Muller@univ-orleans.fr, patrick.baillif@univ-orleans.fr

Abstract. Use of zeolitic material from Munella region (Albania), as fertilizer in the sandy soils of Divjaka region (Albania). In Munella region, Albania there are important zeolitic resources, which have various applications in agriculture. The zeolites in this area have been used in experiments as fertilizers in the sandy soils of Divjaka region (Central-western Albania). *Lolium multiflorum* was used as experimental plant. The experiment was realized in the green – house of the Tirana Agricultural University. Natural zeolites of Munella occur as separate layers hosted by andesite-dacite volcanic sequence of the eastern-type Albanian ophiolites. The zeolite assemblage consists of Stilbite-Stellerite solid-solution. Their cation-exchange capacity ranges from 192-242 meq/100g. They have strong affinity for the cations of Pb^{2+} , Cu^{2+} and Zn^{2+} up to their concentration in solution. On the other hand, the respective concentrations of the introducing cations in zeolite are 137, 81 and 65 meq/100g, which are below the above measured cation-exchange capacity value.

Sandy soils of Divjaka are undeveloped soils. They are characterized by small thickness of active layer, low content of humus and other essential nutriment of plants. These soils have homogeneous mechanical and mineralogical composition because of their uniform parental material, mainly composed by quartz of sea-sediment formations. Different combinations (seven) of Munella zeolites with chemical fertilizers (NPK) are experimented in order to study the impact of zeolites in the increase of fertility of the poor sandy Divjaka soils. The faster growing rates of plants, more healthy plants and greater number of individuals observed in the case of zeolite-treated plants are some of indications that evidence the role of zeolite as fertilizer. In addition, the "buffer" role of the zeolites in improving the water capacity of soils is observed especially during the most dry period of the year (July-August). The variant with zeolite is distinguished for a longer conservation of soil humidity and, consequently, giving more healthy plant.

Key Words: zeolite, fertilizer, sandy-soil, Stilbite-Stellerite solid-solution

1. INTRODUCTION

The attractive physical and chemical properties of natural zeolites will be used worldwide even more in the years to come in the solutions of different problems (Mumpton, 1976). The structure of each of these minerals is different, but all have large open “channels” in crystal structure that provide a large void space for the adsorption and exchange of cations. The internal surface area of these channels can reach as much as several hundred square meters per gram of zeolite, making zeolites extremely effective ion exchangers (Mumpton 1984).

Zeolites have been increasingly used in various application areas such as industry, agriculture, environmental protection, and even medicine. 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 (Polat et al., 2004). Natural zeolites have been shown to increase the soil cation exchange capacity and soil moisture, improve hydraulic conductivity, increase yields in acidified soils, and reduce plant uptake of metal contaminants in soil (Allen & Ming, 1995, Stead et al, 2002).

This work involves a study of the effects of zeolitic material in a sandy soil. Natural zeolitic material as Stilbite-Stellerite solid solution, with Ca-trend, has optimal physical and chemical properties that could improve the ones of the soil. The purpose was to test the effects of zeolitic material, which was used as directly fertilizer or combined with chemical fertilizers, for lolium plant (*Lolium multiflorum*, L.) grown in a sandy soil of Divjaka (Lushnje).

2. MATERIALS AND METHODS

2.1 Zeolitic Material of Munella Region (Albania)

The zeolitic material used in the experiment has been sampled from the Munella region. Zeolitic material was ground to 100 mesh. A sample from this material was analyzed for the chemical characteristics by the X-/fluorescence, in Activation Laboratories LTD, Canada..

Natural Stilbite-Stellerite from the deposit of Munella region (Albania) was used (Fig. 1). Volcanic rocks, that form the upper part of an hartzburgite-sub type ophiolite suite (Shallo, 1994), crop out in the Central Mirdita zone (Munella region included), where they constitute a complete, differentiated sequence. On the basis of petrographic characteristics and chemistry (Beccaluva et al., 1994) the following rock types can be recognized: basalts and basaltic andesites, dacites and rhyolites. The lower (1.0-1.5 km thick) part of the volcanic sequence consists of intersertal, porphyric and aphyric basaltic pillow lavas, whereas the upper part (0.5-0.7 km thick) consists of aphyric, porphyric, microlitic and vitrophyric pillowed and massive.

The mineralogic study of zeolite-bearing rocks reveals authigenic cement consisting of zeolitic material and vesicles filled with zeolites, chlorite, quartz and carbonate. Based on microprobe analyses, a continuous variation was observed for the

Si/Al and Na+K/Na+K+Ca+Mg ratios that scatter in the range 3 – 3.5 and 0.01-0.18, respectively (Beqiraj, 2005).

Physical and chemical characterization of zeolitic material, based on methods by Collela et al. (1982), Pansini (1996), Capelletti et al. (1999), consists in: a cation exchange capacity CEC = 1.9 -2.42 meq/g and this selectivity for cations: $Zn^{2+} < Cu^{2+} < Pb^{2+}$ (Beqiraj, 2005).

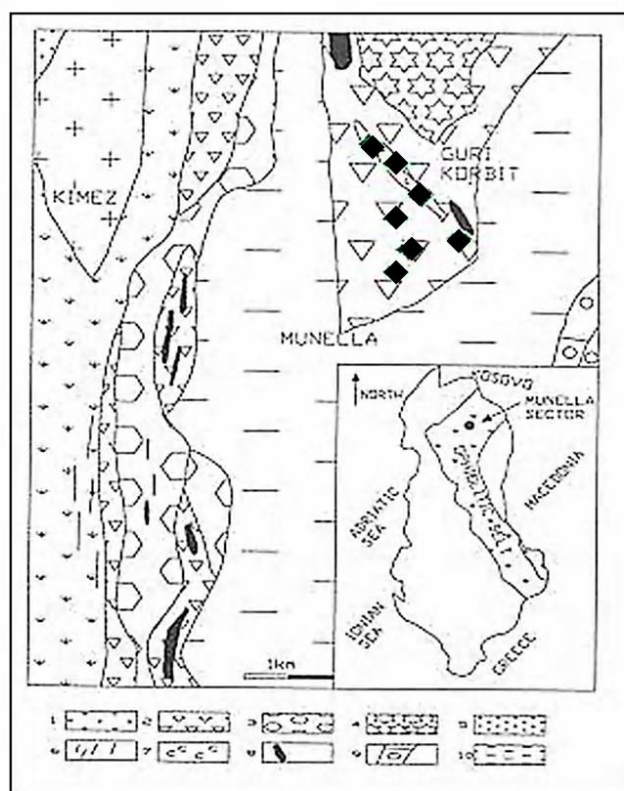


Figure 1. Geological map of Munella region (1:50000). 1-Basalt; 2- Andesite; 3- Dacite; 4- Rhyolite; 5- Plagiogranite; 6- Shetted Dyke; 7- Zeolitic rocks; 8- Sulphide mineralization; 9- Limestones (Cr_1); 10. Melange ($J_3^1 - Cr_1$) (The solid diamonds show sampling points).

2.2 Soil and soil sampling

The studied soils that have been sampled are represented by a sandy soil (Haplic Arenosol, FAO-1988) from Lushnja District (Fig. 2). This soil type is considered as a problematic one because of its unfavorable properties for plant growth. Total surface of arenosols in Albania is estimated at about 10. 000 ha. This surface is in agricultural production (Gjoka & Cara. 2003).

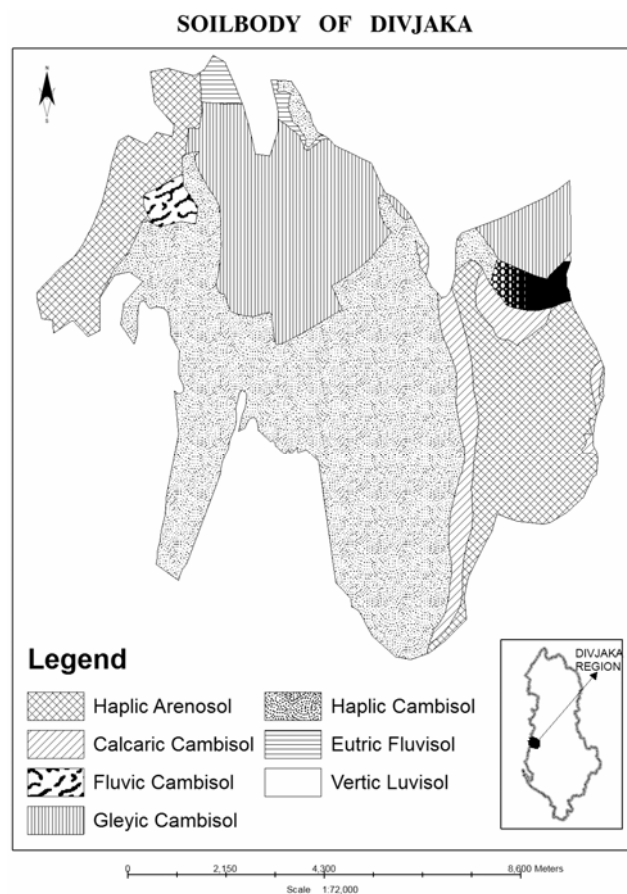


Figure. 2. Pedological map of Divjaka region (Albania)

Main chemical and physical characteristics of the soil under the study, before experiment, are given in table 1 and table 2.

Table 1. Chemical properties of the soil

pH		Humus %	N-total (%)	CaCO3 %	P	K	CEC	Microelement-total				
H ₂ O	KCl				Available mg/kg			Cu	Zn	Mn	Fe	Ca
								mg/kg		%		
8.5	7.8	0.8	0.066	7.14	13.2	75	11.5	44	78.4	0.07	4.57	8.8

Table 2. Physical properties of the soil

Hygroscopic Moisture (%)	Water Capacity (%)	Clay (%)	Silt (%)	Sand (%)
3.08	30.21	2.6	8.0	89.4

Soil samples were taken from 0 to 30 cm soil depth from five locations, because this is the most significant soil depth to study elements in soils devoted to vegetable crops. All the samples were stored in polyethylene containers and transported to the laboratory, where they were air dried for several days and sieved to 2 mm for homogenization and for analysis of soil properties. The pots were filled with prepared soil.

2.3 Chemical fertilizers

Chemical fertilizers used in the experiment were: ammonium nitrate (34% a.s.), urea (46% a.s.), potassium sulphate (50% a.s.), superphosphate (20 % a.s.). The application rates were as follows: urea 0.03 gr/pot (1.0 kv/ha); superphosphate 0.133 g/pot (5.0 kv/ha); potassium sulphate 0.032 g/pot (1.2 kv/ha), and ammonium nitrate 0.09 gr/pot (3 kv/ha).

2.4 Pots

Within the experiments made in the green – house of the “Tirana Agricultural University” we used pots with a weight of 1 kg and dimensions: h=10.7 cm, D=13.7 cm, d=9.15 cm, Vol=1139 cm³.

2.5 Indicator plant

Lolium multiflorum, L. has been used as an indicator plant. Application rate was 1g/5m². The plant deep was 0.5cm. During the growing season the moisture was hold 70% of the water capacity (22.4%); in the initial phases, the moisture was hold in 55% of water capacity (12.3%). Calculations for that purpose are performed using the gravimetric method.

2.6 The experiment scheme and observations

The experiment was conducted in a randomized block with four repetitions.

POT –1 Control

POT –2 NPK (148:75:60) (kg/ha a.s. N, P and K)

POT –3 (Z – 600 kg/ha)

POT –4 (Z – 1200 kg/ha)

POT –5 (Z – 600 kg/ha + NPK – 148:75:60)

POT –6 (Z – 1200 kg/ha + NPK – 148:75:60)

POT –7 (Z – 5 % of soil weight)

During the growing season of plants, several phenomenological and biometric measuring have been performed. The plants were cut at the maturity time, 2 cm above ground level, stored in paper containers and dried for 15 h at 60°C temperature. After that, plant material was ground, sieved and stored in the glassy vessels.

2.7 Analytical methods

The processed soil samples were analyzed for pH-H₂O and pH-KCl, CaCO₃, particle size distribution, CEC, available P, exchangeable K and free Fe (on the samples < 2-mm), total carbon and nitrogen, and for total Ca, Fe, Cu, Mn and Zn and mobile Fe, Cu, Mn and Zn concentrations in the soil, and for total P, K, Ca, Fe, Cu, Mn and Zn concentrations in plant. Soil pH (2.5:1) was measured by pH-meter, on suspension in KCl 0.01M and distilled water; carbonates by calcimeter; particle size distributions by the Pipette method; CEC by BaCl₂ 1N, pH 7 extraction; available phosphorus by Olsen method; exchangeable potassium by CH₃COONH₄, its extraction and concentrations was measured by the flame-photometer; total carbon by Tjuri method and total nitrogen by Kjeldahl method; total Ca, Fe, Cu, Mn and Zn in soil by oxalat-NH₄ extraction and their concentrations were measured by flame-photometer; mobile Fe, Cu, Mn and Zn in soil by CH₃COONH₄ 1N, HNO₃ 0.4, H₂SO₄ 0.1, EDTA 0.1M – KCl 0.1N extraction respectively, and their concentrations were measured by atomic absorption; total P, K, Ca, Fe, Cu, Mn and Zn in plant by H₂SO₄ and HClO₄ extraction and their concentrations were measured by atomic absorption; dry matter by drying up the plant samples in biological thermostat at temperature 70°C. Analyses were carried out in the Institution of Soil Study, Tirana (Albania).

3. RESULTS AND DISCUSSION

3.1 Effect of zeolitic material in indexes of dry plant matter (Relative Agronomic Efficiency)

Relative Agronomic Efficiency (RAE) is referred to quantity in weight of dry plant material. As it can be seen in the table (Tab.3, Fig.3), the productivity of dry plant matter, studied for four cuttings, is greater in all the treatments (from 2.39 g/pot - V7, to 4.32 g/pot - V5) than that of the control variant (1.82 g/pot) (Beqiraj & Goka 2005). Relative Agronomic Efficiency (RAE) of zeolitic material, used as pure zeolite or in combination with fertilizer,

Table 3. Weight of plants (g.dry matter/pot) for four harvest

	P1	P2	P3	P4	Total	RAE
V1- control	0.74	0.4	0.39	0.29	1.82	48.02
V2	1.78	1.11	0.62	0.28	3.79	100.00
V3	1.55	1.11	0.59	0.09	3.34	88.13
V4	1.45	1.07	0.61	0.26	3.39	101.50
V5	2.04	1.1	1.04	0.14	4.32	127.43
V6	1.64	0.94	0.88	0.08	3.54	81.94
V7	0.84	0.65	0.77	0.13	2.39	67.51

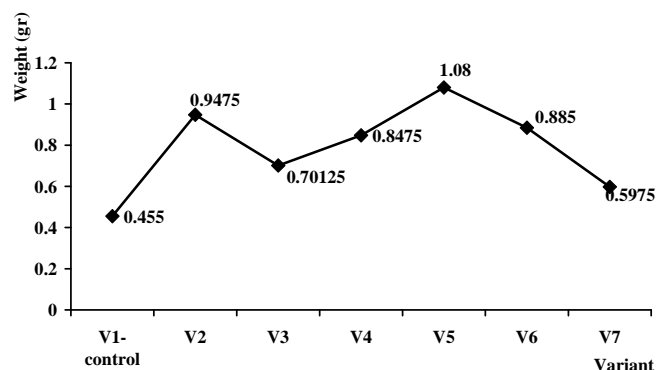


Figure 3. Variation of weight of dry plant matter by variant

considering the productivity of dry matter in pot V2 (NPK) as 100%, was ranged as follows: V7 (67.51%) < V6 (81.94%) < V3 (88.13%) < V2- NPK (100%) < V4 (101.50 %) < V5 (127.43%).

Comparing treatments with pure zeolite, the highest value of RAE belongs to the dose of 1200 kg/ha zeolite (RAE=101.5%), while the smallest one is for the dose of 5% zeolite of soil mass (RAE=67.50%). On the other hand, considering the treatments of zeolite combined with NPK, it is evident a greater value of RAE (127.43%) in the pot V5 (600 kg/ha zeolite + NPK -127.43%). This treatment is considered as the best variant for a higher efficiency in production of dry plant matter. This means that zeolite added to fertilizers promotes significantly a greater value of this production. So, it is sure, the best performance of V5 variant is dedicated to zeolite presence.

The zeolite concerns the most important plant nutrients such as nitrogen (N) and potassium (K), and also calcium, magnesium and microelements. Consequently this leads to a more efficient use of N and K fertilizers by reducing their rates for the same yield, by prolonging their activity or finally, by producing higher yields (Polat et al, 2004). Zeolites, porous minerals with high cation-exchange capacity, can help control the release of plants nutrients in agricultural systems (Pond & Mumpton, 1984).

The correlation between treatments and RAE index, are proved by means of different mathematical functions (lineal, logarithmic, polynomial, exponent and exponential) (Tab. 4). As shown in the table, the best correlation between them fits polynomial one with correlation coefficient: $R^2 = 0.7171$ and regress equation: $y = -5.6551x^2 + 47.443x + 11.121$.

Table 4. Correlation coefficients (R^2) between treatments and RAE

Correlation form	Regress equation	Correlation coefficient
Lineal	$y = 2.2018x + 78.983$	$R^2 = 0.0345$
Logarithmic	$y = 14.818\ln(x) + 69.743$	$R^2 = 0.157$
Polynomial	$y = -5.6551x^2 + 47.443x + 11.121$	$R^2 = 0.7171$
Exponent	$y = 64.872x^{0.2152}$	$R^2 = 0.216$
Exponential	$y = 73.166e^{0.0354x}$	$R^2 = 0.0583$

3.2 Effects of zeolitic material in indexes of essential nutrients in plant (efficiency of essential nutrients).

In table 5 there are given the total contents of P, K, Ca, Mn, Cu, Zn, and Fe in overground part of Lolium.

Table 5. Chemical composition of the lolium plant

	P ₂ O ₅	K ₂ O	CaO	Mn	Cu	Zn	Fe
	%			mg/kg			
	Second cut						
V1-control	0.416	1.494	0.219	160	416	952	248
V2	0.221	1.711	0.178	108	288	906	128
V3	0.536	2.00	0.178	92	288	954	114
V4	0.281	2.31	0.185	100	256	970	144
V5	0.281	1.600	0.206	92	224	100	190
V6	0.266	1.735	0.206	88	224	984	234
V7	0.202	1.650	0.212	112	202	100	234
	Third cut						
V1-control	0.392	2.04	0.209	152	384	101.6	274
V2	0.376	1.156	0.225	120	320	118.4	194
V3	0.606	1.421	0.233	152	384	107.6	552
V4	0.409	1.615	0.225	144	352	101.6	440
V5	0.433	1.439	0.214	128	384	104.6	248
V6	0.349	1.711	0.238	128	280	110	426
V7	0.338	1.446	0.243	144	320	938	732

Considering the third harvest, significant increase of P, K, Ca, Zn and Fe content was obtained in plants of different variants, where only zeolite and its combinations with NPK is used, comparing with variants without zeolite (V1 and V2). The content of these elements in the second harvest is probably influenced by soil. In this harvest the selective influence of zeolite has appeared only for P, K and Zn. In figure 4 is illustrated the variation of P₂O₅ content in dry plant matter, in the second and third harvest. In both harvests, the highest value of P₂O₅ was obtained in variant V3.

As shown in figure 5, the increase of Ca content in plant was accompanied by the corresponding decrease in K content, probably due to the cation exchange reactions in the zeolite. The highest content of Mn and Cu, determined in V1– control variant, may be dedicated to the rate of selectivity for cations $Zn^{2+} < Cu^{2+} < Pb^{2+}$ of Munella zeolite. So, Zn element can be up taken by plant more easily than Cu (fig. 6) which is probably fixed in porous structure of zeolite (Tab.5). Various cations interact

differently with various zeolite framework and their associated electrical fields. This consideration explains why zeolites display different affinities for cations and forms the theoretical basis of their cation selectivity sequence (Pansini 1996). The behaviour of metals is primarily governed by their retention and release reactions of solute with soil matrix.

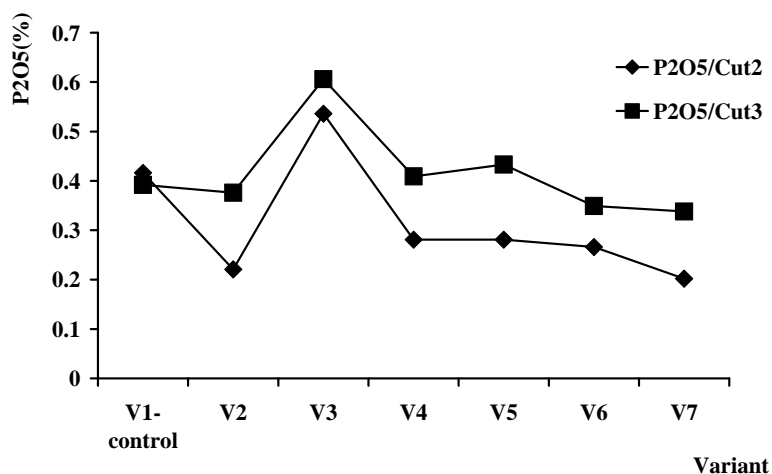


Figure 4. Variation of P₂O₅ content in dry plant matter, in second and third harvest

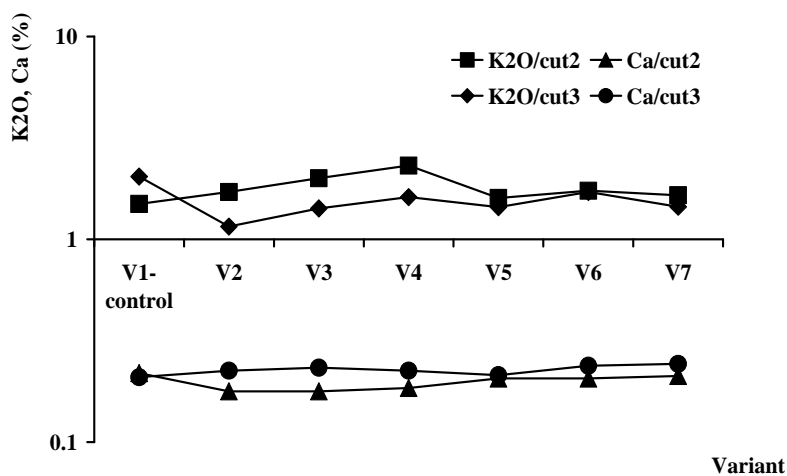


Figure 5. Variation of P₂O₅ (%), second and third harvest, in dry plant matter.

The highest content of Mn in the variant V1 may be due to high binding capacity of Fe - Mn oxides and aluminosilicates for metals. Thus, the immobilizing capacity of MnO₂ was higher than that of other metals. These effects were assumed to be related to immobilization of metals due to formation of insoluble metal-organic complexes and increased cation exchange capacity (CEC) (Singh & Oste, 2001).

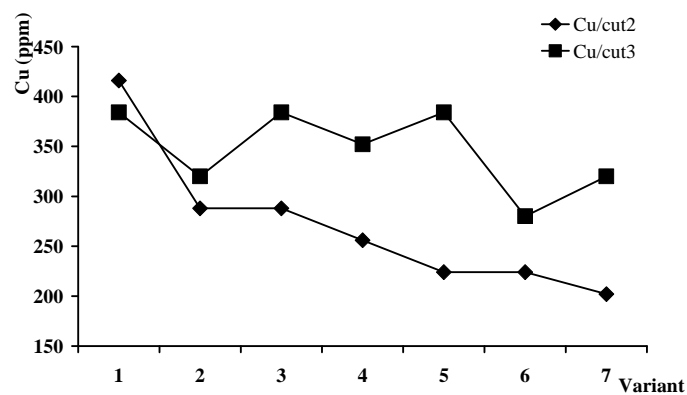


Figure 6. Variation of Cu (ppm), second and third harvest, in dry plant matter

3.3 Effect of zeolitic material in indexes dry root matter

As it is shown in table 6, all the variants showed a higher index of dry root matter with respect to control variant V1.

Table 6. Weight of roots (dry matter/pot in g)

	V1 Kontroll	V2 Trajtim NPK	V3 Trajtim M1	V4 Trajtim M2	V5 Trajtim M1 +NPK	V6 Trajtim M2 +NPK	V7 Trajtim M3
P1	1.94	2.86	2.24	6.28	3.21	3.42	2.75
P2	1.52	2.89	1.53	4.06	4.11	3.42	2.17
P3	2.57	2.46	2.35	5.73	4.3	4.2	3.64
P4	1.82	3.26	3.6	5.91	2.98	3.62	3.57
Mes.	1.96	2.87	2.43	5.49	3.65	3.66	3.03

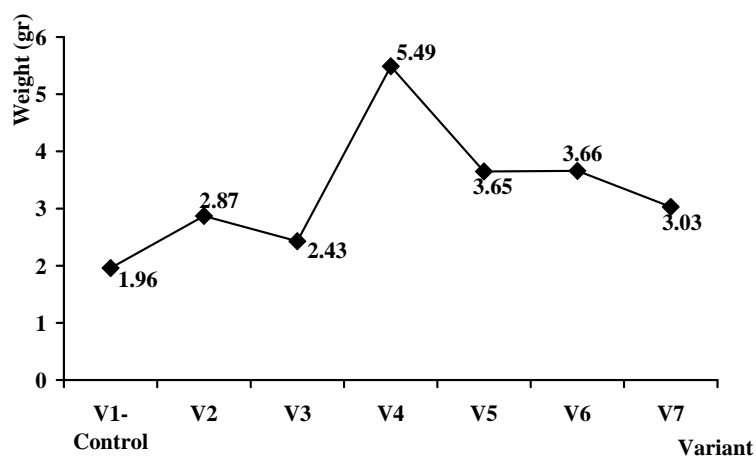


Figure 7. Variation of dry root matter (g) in variants

Among the treatments (zeolite and/or NPK), the greatest amount of dry root matter (5.49gr/pot) was obtained in variant V4 (treatment with 1200 kg/ha zeolite), whereas the smallest one (2.87 gr/pot) is obtained in variant V2 (control). The increase of amount of zeolite applied from 6 kv/ha (V3) to 12 kv/ha (V4), caused the increase of dry root matter 2.2 times. On the contrary, the further increase of quantity (5% of soil weight) in the variant V7 caused a decrease of quantity of dry root matter up to 55% (Fig. 7).

In variants where zeolite was used combined with NPK (V5 & V6), the index of dry root matter is higher than in variants treatment only with NPK (V2). These results suggest an increase of efficiency of fertilizer as a result of their combination with zeolitic material.

3.4 Effect of zeolitic material in soil quality.

In table 7 are given data which present soil quality analysed at the end of the experiment.

Table 7. Main chemical properties of the soil at the end of the experiment

Variants	Humusi %	N-total %	P-intake mg/100 g.	K-excahng. mg/100	CEC mek/100g.	CaCO ₃ %	Cu-exchang. mg/kg	Mn-exchang. mg/kg	Zn-exchang. mg/kg
P3V1	0.7	0.06	0.77	4.33	10	8.1	0.683	11.24	3.54
P3V2	0.6	0.051	0.81	4.83	13.38	7.5	0.653	18.67	1.326
P3V3	0.6	0.054	0.67	4.00	11.84	8	0.576	11.57	1.17
P3V4	0.6	0.052	0.92	4.83	12.67	7.3	0.663	15.12	1.27
P3V5	0.7	0.058	0.95	4.17	12.757	6.9	0.673	12.14	1.432
P3V6	0.7	0.056	0.85	4.22	10.65	7.4	0.665	15.13	1.974
P3V7	0.7	0.055	0.21	4.31	9.55	7.4	0.679	12.56	1.45

Table 7. continue

Variants	Cu-total (ppm)	Zn-total (ppm)	Mn-total (ppm)	Fe--total (ppm)	Ca--total (ppm)
P3V1	40	63.2	0.071	4.67	4.36
P3V2	35.2	46	0.062	5.37	2.93
P3V3	41.3	52.3	0.068	4.57	5.33
P3V4	42.6	50.3	0.07	5.08	4.31
P3V5	28.8	49.2	0.064	5.37	3.04
P3V6	40.4	51.3	0.08	3.98	4.38
P3V7	25.6	49.2	0.067	3.08	3.42

Comparing the data before and after the experiment, the humus content decreases from 0.8% to 0.6-0.7%. The greatest decrease was obtained in variants V2, V3, V4, where zeolites (600 and 1200 kg/ha) and fertilizers (283 kg/ha NPK) are used separately. On the contrary, the lowest decrease of humus content was obtained in variants V5, V6 (zeolite + NPK), and in overdose treatment V7 (5% of soil weight).

The same tendency was observed for N (Fig. 8), too. It has been known that this phenomenon depends on the cultivation process of soil and mineralization of biogenic substances – re-mineralization process.

Mineralization of biogenic substances is part of the recycling process which occurs at any given time where organic materials are synthesized by plants and degraded by animals and microflora (Antinis et al, 2002).

Remineralization of soil using natural zeolite has been shown to cause a phenomenal growth of the microorganisms in the soil, increases nutrient intake of plants, reduces effects of soil acidity; prevents soil erosion and increases storage capacity of soil as well as contributing to building of precious humus complexes (Akinyemi, 2006). The main use of zeolites in agriculture is, however, for nitrogen capture, storage and slow release (Akinyemi, 2006), as it is our case.

A considerable decrease is determined for P-assimilated and K-exchangeable in soil because of plant uptake and zeolite adsorption properties, respectively. Such extremely changes are characteristic for sandy soils that are impoverished in these elements. Zeolites are useful in agriculture because of their high exchange capacity and their selectivity for potassium cations, their ability to increase the solubilization of phosphate minerals (Lai & Erbel, 1986; Chesworth et al., 1987), leading to improved phosphorous uptake and yields for plant (Barbarick et al., 1990). They can be used both as carriers of nutrients and as a medium for free nutrients. The influence of zeolite use in the P content in soil is more evident in the treatment V5 (600 kg/ha + NPK), compared to the K content in the treatment V4 (1200 kg/ha Z). Finally, the use of zeolite overdose (V7) has no significant influence in the contents of the above elements in soil.

The highest CEC (13.38 meq/100g) value of the soil belongs to the treatment V2 (NPK). On the other hand, the CEC shows a light increase from treatment V3 through treatment V4 to treatment V5 and a more evident decrease towards the treatments (V6, V7) with zeolite overdose. One must consider the environmental conditions that may change the nature and effectiveness of the zeolite such as: change in pH, redox conditions, microorganism activity and the amount of clay minerals (Stead et al, 2002).

In general, the contents of micro-elements in soil show a significant decrease at the end of the experiment. In particular, Cu (Fig.9), was observed in treatments V7 (5% Z of soil weight) and V5 (600 kg/ha Z + NPK); Zn was decreased in treatment V2 (NPK); Ca was decreased in treatment V2 (NPK) and V5 (600 kg/ha Z+NPK) Finally, small changes are observed for Mn and Fe contents.

The use of zeolite combined with fertilizer ensures equilibrium conditions of main indexes (humus, N, P, Cu, Mn and Fe), of soil fertility up to the end of the experiment.

On the other hand, its use helps to keep the soil aerated and to maintain the moist active for a long time. In addition, its use with fertilizer helps buffer soil pH levels, thus reducing the need for lime application (Polat et al, 2004). All treatments with zeolite were characterized by the best conservation of moisture and more healthy plants. Zeolitic material reduced the amount of water needed during watering (15.05.2004), from 90-100 ml (V2-NPK) to 50-65 ml in treatments V6 (1200 kg/ha Z

+NPK) and V5 (600 kg/ha + NPK), respectively. This was especially evidenced during the period July-August, that represents the most dry season of the year (39-41°C). That means big savings in irrigation water, or an increase in the area that can be irrigated with a given amount of water.

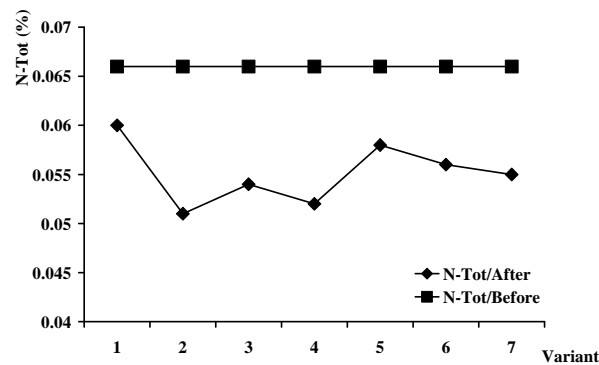


Figure 8. Content of N-Tot in soil before and after the experiment

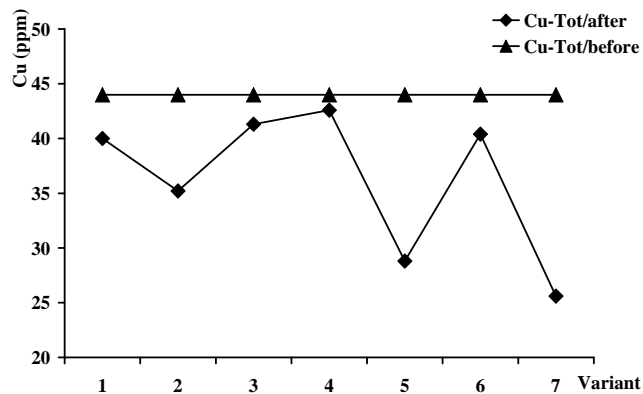


Figure 9. Content of Cu-Tot in soil before and after the experiment

4. CONCLUSIONS

The results indicate that:

Zeolites of Munella region are characterized by an optimal cation exchange capacity (CEC), which makes them useful in different agricultural practices.

The use of zeolites, pure or in combination with manure application increased significantly the fertility of soil, thus, resulting in faster growth, higher yield and better plant quality.

The presence of zeolites ameliorates the physical and chemical quality of soil and maintains the infiltration rates of soil and soil moisture. By way of its properties, zeolitic material can reduce nutrient loss due to leaching by increasing the retention of nutrients and slowly releasing them as needed by soil and plants.

The best performance of zeolite application was the treatment with 600 kg/ha

zeolite (101.50%) and treatment 600 kg/ha zeolite + NPK (127.43%).

The use of zeolite combined with fertilizer ensures equilibrium conditions for main indexes of soil fertility (humus, N, P, Cu, Mn and Fe), at the end of the experiment.

The report zeolite/fertilizer, in the combined treatments, must be carefully considered according to the case.

ACKNOWLEDGMENTS

This study was supported by the scientific program of the Politechnic University of Tirana.

REFERENCES

- Akinyemi, O.M.**, 2006. *The effects of soil amendments on the Efficiency of Agricultural Cropping System*. PhD. Thesis, Toronto.
- Allen E.R. & Ming D. W.**, 1995 *Natural Zeolites*, Brockport, New York, p. 447-490.
- Antinis A. Z., Arapolou D.P., Hahali M. & Zorpas G.**, 2002. *Compost quality and use from Sewage Sludge, Organic Fraction of Municipal Solid Waste and Natural Zeolite-Clinoptilolite*. Proceedings of the 10th Inter. Conf. of the RAMIRAN Network 2002. Published by FAO.
- Barbarick K.A., Lai T.M. & Erbel D.D.**, 1990. *Exchange fertilizer (phosphate rock plus ammonium-zeolite) effects on sorghum-sudangrass*. Soil Science Society of Amer. Journ., p. 911-916.
- Beccaluva L., Coltorti M., Premti I., Saccani E., Siena F. & Zeda O.**, 1994. *Mid-ocean ridge and suprasubduction affinities in the ophiolite belts from Albania*. Ofioliti, v. 19/1, p. 77-96
- Beqiraj E.**, 2005. *Karakterizimi mineralogjik e material i ceoliteve të Munellës. Efekti i ceoliteve në tokat ranore të Divjakës (Rast studimi)* (Phd thesis, p.183).
- Beqiraj E. & Gjoka F.**, 2005. *Zeolitic material of Munella: use in agriculture (preliminary investigations)*. XI BALKAN MINERAL PROCESSING CONGRESS. Tirana, 45-50.
- Capelletti P., Langella A. & de Genaro R.**, 1999. *Mineralogical and technical features of zeolite deposits from Northern Latium volcanic district*. Per Mineral., 68, p. 77-96.
- Chesworth W., van Straaten P., Smith P. & Sadura S.**, 1987. *Solubility of apatite in clay zeolite-bearing system: application to agriculture*. Appl. Clay. Sci., 2, p. 291-297.
- Collela C., de' Genaro M., Franco E. & Aiello R.**, 1982. *Estimation of zeolite content in Neapolitan Yellow Tuff, phillipsite in nearly monozelitic deposits*. Rend. Soc. Ital. Mineral. Petrol., 38, p. 1423-1427.
- Gjoka F & Cara K.**, 2003. *Soils of Albania*, 13 6p.
- Lai T.M., & Erbel D.D.**, 1986. *Controlled and renewable release of phosphorus in soils from mixtures of phosphate rock and NH₄exchanged clinoptilolite*. Zeolites, p.129-132.
- Mumpton F.A.**, 1984. *Natural Zeolites in Zeo-Agriculture: Use of Natural Zeolites, in Agriculture and Aquaculture*. (Westview Press, Colorado, p. 33-43.
- Mumpton F.A.**, 1976. *Natural Zeolites: a new industrial mineral commodity*. In: Natural Zeolites, Occurrence, Properties, Use, p. 3-27.
- Pansini M.**, 1996. *Natural zeolites as cation exchangers for environmental protection*. Mineral Deposita, p. 563-575.
- Polat E., Karaca M., Demir H. & Onus A.**, 2004. *Use of natural zeolite (clinoptilolite) in agriculture*. Jour. of Fruit and Ornam.Plant Research, vol. 2 (p.183-189).

- Pond W. G. & Mumpton F.A.**, 1984. *Zeo-Agriculture: Use of natural zeolites in Agriculture and Aquaculture* (Westview Press, Colorado, p. 296.
- Shallo, M.**, 1994. *Outline of the Albanian ophiolite*. Ofioliti, p. 19.
- Singh B. R.&Oste L.**, 2001. *In situ immobilization of metals in contaminated or naturally metal-rich soils*. Environ. Rev., NRC Canada.
- Stead K., Ouki S. & Ward N.**, 2002. *Natural zeolites-remediation for the 21 century?* 6th Intern. Conf. on the Occurrence, Prop. And Util. of Natural Zeolites, Greece.

Received at 21. 08. 2008

Revised: 06. 10. 2008

Accepted for publication: 15. 10. 2008

