



Effects of the Zeolitic Tuff on the physical characteristics of Haplic Luvisol and the quality of fruits on apple orchards

Sámuel JAKAB¹

email: jakab.bocskai@rdslink.ro

András JAKAB²

email: delivery@yousendit.com

¹Department of Horticulture,
Faculty of Technical and Human Sciences,
Sapiientia University, Tg. Mureş, Romania

²Jakab és Társai Environmental Services and Trade Ltd,
Gödöllő, Hungary

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Abstract. An experiment with the volcanic zeolite tuff of Mirşid (Romania) on a slightly haplic luvisol of an orchard was performed, in order to improve its physical properties as well as to investigate if any influence on the nutrition of the plants (Jonathan apple trees) could be observed. The grinded zeolite tuff (granulation of 1-3 mm) was applied before planting, being incorporated at a depth of 20-25 cm under furrow in the following dosages: 0-30-45-60 t/ha. During the four years of experiment the water-stable structural aggregates in the upper 20 cm layer increased by 24%. The zeolite volcanic tuff had a favourable effect on the N maintenance and brought about the increase of mobile K content in the soil by 2-3 times. It had also a favourable effect on the main nutrients (N,P,K,Ca) in leaves and fruits, inducing a light increase of Fe in leaves and a higher one in the fruit (34%). A moderate increase of sugars, acids and vitamin C in fruits was also noticed. The fruits showed a better storage capacity during the winter period.

Keywords: water-stable aggregates, quality of fruits, storage capacity

1 Introduction

A frequent problem in the intensive orchards situated on heavy, fine-textured soils is the unfavourable physical state of the soil, which starts with the deterioration of its structure. The initial favourable crumb or the granular structure becomes angular blocky, which damages the air and water regime of the soil, causing water stagnation from time to time. As a consequence, the plants' water supply, release and assimilation of nutrients are hindered.

There are several possibilities to prevent the above mentioned phenomenon. One of these is to increase the amount of water-stable aggregates of the soil, in other words the stabilization of the soil structure. Many types of structure stabilizer chemicals – mainly polyacrilates – are known to yield good results. As our aim is to prevent the addition of new chemicals to the soils of the orchard – the soils have already been overloaded by chemicals –, we are looking for an environmentally neutral, easily accessible mineral substance; this should be found abundantly in the nature and our country, having as many favourable influences to the physical state of the soil and to the quality of fruits as possible.

A naturally occurring chemical complying with the above requirements is the volcanic zeolite tuff of Mirșid (Northeastern part of Romania). Our choice was not accidental. Based on the relevant literature the Japanese were doing soil melioration by adding zeolite tuff as early as the 19th century [1, 2, 3]. Several zeolite products have been used in Hungary and Bulgaria to improve the structure, texture, air and the water regime, reaction of the soils, as well as to stimulate the plant [1, 4, 5]. The best Rhine, Tokaj and Eger wines, the well-known Georgian tea, the high quality tobacco from the Rodope Mountains, and the best sweet-smelling roses of Tundzsa Valley derive from soils developed on volcanic zeolite tuffs [6].

Although Romania has important reserves of volcanic zeolite tuff, their agricultural use is insignificant. Aurelia Lăpușan and co-workers (1974) [7]. have studied the effect of zeolite tuff on clover yield, Ruxandra Bogaci et al. experienced a better absorption of potassium and magnesium by oats and *Dactylis glomerata* in the Perșani Mountains [3] while Calancea et al. report about the favourable effects of zeolite tuff on potato and maize yield [8].

2 Materials and Methods

Our experiment was performed on a pseudogleyed haplic luvisol of an apple orchard in order to improve its physical properties as well as to investigate if any favorable influences on the nutrition of the Jonathan apple trees could be

obtained.

The upper 50 cm of the soil profile is characterized by the following parameters:

- $\text{pH}_{\text{H}_2\text{O}}$ 5.6
- humus 1.49%
- CEC 16.9 me/100g
- PAL 10.5 ppm
- KAL 166.0 ppm
- clay ($\phi < 0.002\text{mm}$) 26,5%.

It has to be noted that the clay content increases with depth, to a horizon with pellic character, where the maximum clay content is 50%.

The moderate acid reaction of the soil shows low calcium content, which together with a moderate humus content, independently of any human influence, give an explanation on the unfavourable state of the soil structure.

The soil was amended by grinded volcanic zeolite tuff (granulation of 1-3 mm) originating from Mirşid, near Zalău, having a zeolite content of 74%.

The zeolites represent a specific group of the hydrated aluminium silicate, containing Ca, K, Mg, Fe and Na. Due to their high cation-exchange capacity they are able to adsorb and continuously release water, other molecules and certain cations. Consequently, zeolites may be used for soil improvement.

The percentile chemical composition of the zeolite we used was: Loss of ignition (L.I.) 8.12; SiO_2 69.65; Al_2O_3 12.58; CaO 3.52; K_2O 3.10; Fe_2O_3 1.18; Na_2O 0.80; MgO 0.52; TiO_2 0.29. It was also containing negligible quantities of trace elements.

Location of the experiment and treatment

The experiment was performed at a Jonathan/MM106 apple orchard near Târgu Mureş, with a planting density of 4×2 m. Four treatment variants of the soil with zeolite tuff were performed in four repetitions as follows:

- no treatment (control)
- 30 t/ha
- 45 t/ha 60 t/ha

Scheme of the experiment

1	3	4	2
2	4	3	1
3	1	2	4
4	2	1	3

The grinded zeolite tuff (granulation of 1–3mm) was applied before planting, being incorporated at a depth of 20–25 cm under furrow. Grass (*Lolium perenne*) was seeded in 3 m wide stripes between the rows, and the cut grass was used as cover over 1 m wide bands along the rows.

3 Results and discussions

The effect of the volcanic zeolite tuff on the physical state of the soil was reflected by the improvement of the soil structure, estimated by the increase of the water-stable aggregates. Compared with the untreated soil, at the end of the four year experimental period the zeolite tuff treatment induced a significant increase of the water-stable aggregates in the upper 20 cm of the soil as follows: by 7.5–15.5% in the upper 10 cm and by 13–24% in the layer between 10–20 cm (Table 1). Only the 30 t/ha dosing did not result in a significant increase of the water-stable aggregates in the upper 10 cm layer.

Table 1: Quantitative change of soil’s water-stable aggregates of the soil due to the zeolite volcanic tuff

Handling	Depth			
	0–10 cm		10–20 cm	
	Watter-stable-%	Difference	Watter-stable-%	Difference
0t/ha (control)	26,5	–	17,8	
30 t/ha	28,5	+ 1,7	22,2	+ 4,2***
45 t/ha	29,9	+ 3,4**	20,1	+ 2,3***
60 t/ha	30,6	+ 4,1***	22,1	+ 4,3***

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

The lower increase in all four variants of the water-stable aggregates in the upper 10 cm of the soil is the consequence of lower amounts of grinded zeolite tuff being mixed with the soil during the 20–25 cm deep ploughing on the one hand, and on the other hand the higher compaction rate of the soil and the structural damages caused by agricultural equipment.

The importance of the water-stable aggregates consists in the fact that they are less influenced of heavy rains and they are not easily decomposed in their elemental structural particles. As a result, the water stagnation is diminished, and the air and water regime of the soil becomes better.

The volcanic zeolite tuff proved to have a favourable effect on the nitrogen maintenance (an increase of 27–40%) and brought about the increase of the mobile potassium content in the soil by 2–3 times, as well as a moderate increase of the majority of other analyzed nutrients. It also influenced positively the main nutrient content (nitrogen, phosphorus, potassium, calcium) in leaves and fruits, inducing a light increase of the iron in leaves and a higher increase in the fruits (Table 2).

Table 2: Effect of the zeolite volcanic tuff on mineral composition of leaves and fruit

Treatment	N%	P%	K%	Ca%	Fe _{ppm}	Mn _{ppm}	Zn _{ppm}	Mo _{ppm}
L E A V E S								
0 t/ha	2,19	0,16	1,69	0,94	119	72	31	0,14
30 t/ha	2,42*	0,22**	1,81***	0,98*	124 ns	101***	36 ns	0,19**
45 t/ha	2,52**	0,22**	1,86***	1,14***	125 ns	92***	44**	0,16 ns
60 t/ha	2,46**	0,20*	1,85***	1,22***	134**	89***	36 ns	0,15 ns
F R U I T								
0 t/ha	0,15	0,023	0,25	0,012	2,60	0,77	1,79	0,012
30 t/ha	0,20**	0,028*	0,29 ns	0,018*	3,45***	0,87*	1,54**	0,014 ns
45 t/ha	0,20**	0,031**	0,36**	0,017*	2,93**	0,82 ns	1,29***	0,018**
60 t/ha	0,22***	0,029*	0,36**	0,016 ns	3,40***	0,70 ns	1,60*	0,016*

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

It is particularly important to mention the absorption of potassium, calcium and manganese in the leaves and the concentration of iron in the fruits. These have a positive effect on the colouring of the fruits, chlorophyll and proteins formation, resistance against metabolic diseases as well as provide a better storage of the fruits too.

The nutrients concentration in the leaves and fruits in the variants treated with zeolite tuff are equal to or approach the optimum levels as mentioned in the literature (cf. Sass 1980), except for the potassium in the leaves that exceeds the upper optimum limit. Such a high concentration of the potassium in the leaves may be an advantage in dry periods of the year, inasmuch as it diminishes the loss of water of the plants by evapotranspiration.

A moderate increase of carbohydrates, acids, and vitamin C in fruits was also observed (see Table 3) in the 45 and 60 t/ha dosing variants. The sugar/acid ratio was constant in all variants.

Table 3: Effect of the volcanic zeolite tuff on the apple's carbohydrate, acid and C-vitamin content

Handling	Red. sugar		Total sugar		Acidity		C-vitamin		Sugar/ acidity
	g %	δ	g %	δ	g %	δ	g %	δ	
0 t/ha	9,6	12,6	0,87		2,9		14,4		
30 t/ha	9,2	- 0,4 ns	11,5	- 1,1 ns	0,92	+ 0,05 ns	3,5	+ 0,6 ns	12,4
45 t/ha	10,5	+ 0,9 ns	13,5	+ 0,9 ns	1,01	+ 0,14 ns	2,9		13,3
60 t/ha	11,7	+ 2,1 ns	15,1	+ 2,5 ns	1,05	+ 0,17 ns	4,1	+ 1,2 ns	14,3

ns insignificant

The storage capacity of the fruits during the winter period increased significantly by approx. 11-15% in cellars. This is important when the farmers do not dispose of modern cooling equipment.

During the four years of experiment the volcanic zeolite tuff did not show any influence on the growth of the plants.

Table 4: Effect of the zeolite volcanic tuff on the storage of apples

Handling	Healthy fruits from 100 1. April	Difference
0t/ha (control)	69	—
30 t/ha	80	+ 11**
45 t/ha	84	+ 15***
60 t/ha	83	+ 14***

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

4 Conclusion

Our experiment proves unambiguously that volcanic zeolite tuffs can be used to improve the physical condition of the soil with air and water regime deficiency. The improvement of the physical condition of the soil has been evaluated by the significant quantitative increase of the water-stable aggregates in the upper 20 cm. The higher quantity of water-stable aggregates induced

a higher non-capillary porosity and – as a consequence – the air and water regime of the soil became better.

Based on our results, the recommended quantity of zeolite tuff in similar climatic and soil conditions is about 45-50 t/ha, but it may vary according to the quantity of clay. For soils rich in clay the doses may be of 60 t/ha or higher.

The zeolite tuff had a favourable effect on the nitrogen maintenance and caused the increase of mobile potassium content in the soil by about 2–3 times. It also had a favourable effect on the main nutrients (N, P, K, Ca) in the leaves and fruits, inducing a light increase of the iron in leaves and a higher increase in the fruit (34%). A moderate increase of sugars, acids, and vitamin C in fruits was also noticed. The fruits showed a better storage capacity during the winter period.

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