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RETENTION OF IONS BY VOLCANIT SAND USED IN HYDROPONIC CULTURES

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Abstract

Volcanic sands were treated with nutrient solutions for a period of six weeks and were washed with deionized water (until constant conductivity) for several weeks. These basaltic materials had been used in commercial hydroponic cultures for 6-, 5-, 4-, and 1 year, while another, as control, had not been used before. The activity of the materials on the NH_4^+-, NO_3^--, $H_2PO_4^-$-, K^+-, Ca^{++}-, Mg^{++}, and Na^+contents of the nutrient solution was examined. All material had retention of NH_4^+ and $H_2PO_4^-$, and released K^+, Ca^{++}, Mg^{++} and Na^+. The non used material is the one which had the lowest activity in the nutrient solution composition. The pH of the material decreased about 1 unit (from 8 to 7). The NH_4-Acetate extractable Ca^{++}, Mg^{++}, and Na^+ and the $NaHCO_3$ extractable P increased after treatments. There was also a nitrification of the NH_4^+ retained, increasing the NO_3^- in the nutrient solutions except in the non-used material.

1. Introduction

Hydropony as a technique in commercial cultures is developed principally by using a substrate, as inert as possible, for the growth of the roots and the support of the plants.

Granulated volcanic material (lapilli) is aboundant and has been widely used in the hydroponic cultivation of tomatoes (Perez-Melian et al 1977), lettuce (Perez-Melian et al 1977), cucumber (Perez-Melian et al 1977), flowers (Sachs, 1969) (Zeid et al, 1972), etc..., there being a lower ddaily irrigation number than needed by nonporous gravel (Perez-Melian et al, 1977).

Blesa et al (1972, 1976) have investigated phonolitic and basaltic materials, pointing out that the phonolite material disintegrated when used in soilless cultures and showed considerable activity on the nutrient solution. The basaltic material, however, showed a strong resistence to disintegration and little activity on the nutrien solution.

The continuous use of basalt material as substrate in hydropony produces a little disintegration, shown by a decrease in the occlusive porosity (Luque et al, 1976) and it could affect its properties.

The subject of this paper is to know the effect that the period of use in hydropony could produce on the properties of basalts in relation to the chemical composition of the nutrient solution, since the control of the nutrient solution is essential for the best growth of the plants.

2. Material and Methods

Five basalt materials taken from hydroponic commercial installations were studied. The material had been used for 6, 5, 4 and 1 year, and a material not previously used which will be called "control". All the materials were between 6 and 0,5 mm in diameter.

Plastic containers with a drainage system were filled with 2-1 of previously weighed volcanic material. The pots were covered with polyethilene film to avoid evaporation. Each material was replicated four-fold.

Each container was then washed with deionized water until a stable conductivity in the washing water was reached (this took aproximately one week for all the materials).

The treatments were carried out with a nutrient solution which was composed of the following: NO_3^- = 14.0 ; $H_2PO_4^-$ = 3.8 ; $SO_4^=$ = 7.6 ; K^+ = 7.6; Ca^{++} = 10.2; Mg^{++}= 3.8 meq/l. The pH of the nutrient solutions was kept at 5.0± 0.2.

The period of treatment was of six weeks and the nutrient solution was changed weekly. The pots were kept completely flooded overnight and were flooded and emptied several times during the day. At the end of six weeks the washing with deionized water began, the washing water being changed each week until a steady conductivity was reached between two changes (about five weeks).

At the end of each week the nutrient solutions and the washing water were analyzed to know the variations produced by the materials.

The NO_3^- was determined colorimetrically by the phenoldisulfonic acid method. The H_2PO_4 was determined colorimetrically by the molibdo-vanadate method. The NH_4^+ was determined by vacuum distillation using an Afora-Bonat apparatus and valuing it with 1/70 N Hcl (Lachica et al, 1965). The Na^+ and K^+ were determined by flamephotometry and Ca^{++} and Mg^{++} by atomic absorption.

At the beginning and the end of the treatments the materials used were analyzed in order to observe the possible variations in their properties.

The Na^+, K^+, Ca^{++} and Mg^{++} were determined after their extraction from the samples with 1N NH_4^+ = acetate at pH7 (Staff,1954). The phosphate was extracted with 1N Na HCO_3 at pH 8.5 (Olsen's method). The pH values were determined in aqueous extract 1:2.5 (w/v).

To calculate the retention or release of each one of the ions studied the following formula was used in each treatment:

$$T = \frac{C_n \times W_t + C_{n-1} \times W_r - C_a (W_t + W_r)}{\text{Weight of substrate (2K)}}$$

C_n = Concentration of the ion at new nutrient solution (meq/l)

C_{n-1} = Concentration of the ion in the preceding treatment (meq/l)

C_a = Concentration of the ion after treatment.

W_t = Amount of water used in the treatment (l)

W_r = Amount of water retained by substrate (l)

$T < 0$ = release of ions from the substrate
$T = 0$ = non activity
$T > 0$ = retention of ions by the substrate

3. Results

3.1. Activity of the volcanic materials on the content of the nutrient solutions.

3.1.1. Nitrogen

In the nutrient solutions nitrogen was incorporated in two forms: NH_4^+ and NO_3^+ . All the materials show retention of NH_4^+ which is fixed by the substrates since, when the washing with deionized water is carried out, NH_4^+ does not appear in any of the cases. The fixing of NH_4^+ is more intense in the materials which have been used over longer periods of time (Fig.1). The total a mount of NH_4^+ fixed is higher than that presented by silice sand and lower than that shown by pumice stone or vermiculite (Manshard, 1958).

All substrates release NO_3^- into the nutrient solutions except the non used materials wich retains it. The quantity of NO_3 released in the washing treatments with deionized water is lower than that released with nutrient solution treatments. All the materials generally show a certain amount of retention of net-nitrogen (NH_4^- retained - NO_3^- released) (Fig.1).

3.1.2. Phosphate

The materials retain $H_2PO_4^-$ from the nutrient but part of this $H_2PO_4^-$ is released when it is washed with deionized water (Figure 1).

The oldest materials retain very little phosphate and during the washing with deionized water release a quantity 2.5 times higher than that retained from the nutrient solution. As regards retention there are no significant differences between the control material and the others. However, the former releases the smallest amount in the washing treatments.

3.1.3. Potassium

All the materials retain K^+ in the treatments with nutrient solutions without following any correlation as regards the years of their use (Figure 2). In the washing treatments all the materials release K^+ and the quantity of K released increases according to the length of time that the materials have been previously used in hydropony.

3.1.4. Calcium, Magnesium and Sodium

The behaviour of volcanic materials as regards these three cations is similar. In every case whether they are treatments with nutrient solution or with deionized water there is a release of Ca^{++} , Mg^{++} and Na^+ (Figure 3). Nevertheless, the quantity released is much greater with nutrient solution than with deionized water (black area in Figure 3). In the three cases the control material is the one which shows the least activity on the nutrient solutions.

3.2. K^+, Ca^{++}, Mg^{++}, Na^+, P, and pH values in the volcanic materials before and after the treatments with nutrient solutions and the washing process.

The non-used material shows the lowest content of exchange cations before and after it has been treated with nutrient solution and washed. The content of K^+, Ca^{++}, Mg^{++} and Na^+ decreases in all the materials after the treatments except the K^+ in the non-used material (Table 1).

The phosphate extractable with sodium bicarbonate almost doubles in all the studied materials, except in the non-used in which it increases only slightly.

The values of pH decrease in all the materials almost one unit after the treatment with nutrient solutions and washing.

4. Discussion

The NH_4^+ is the only cation fixed by the volcanic materials. This fixation can occur mainly on the small exchange complex fraction shown by these materials by substituting the cations Ca^{++}, Mg^{++} and Na^+,since these three cations are released into the medium (nutrient solution or washing water) from all the materials. One part of NH_4^+ is again returned to the medium in the form of NO_3. This is to say that in these volcanic materials that have been used in hydropony there exists a process of nitrification by bacteria. The non-used material alone does not show nitrification since instead of releasing NO_3 it retains it, though in a very small quantity.

When the treatments with nutrient solutions are carried out all the materials retain phosphate although after the washing processes a part of this phosphate is released into the washing water. The fixation of phosphate can be carried out by several processes, mainly by precipitation with the Ca^{++} in which these basaltic materials are rich having values from 10 to 12% (w/w) of CaO in their chemical composition (Blesa et al, 1972). However, the fixation of H_2PO_4 is weak and what is more the oldest material releases even more phosphate than it retains.

The fact that in all the materials (including that used for six years) the P extracted on concluding the treatments is greater than that extracted before could be related to the decrease of pH shown by all the materials and could mobilise the P fixed during the use of the substrates in hydropony.

We have already mentioned that the release of cations in all the materials could be an effect of the NH_4^+ which substitutes them. The decrease of the cation content conjointedly with the nitrification of the retained NH_4^+ causes the substitution of the cations with H^+ in the exchange complex which would cause a decrease of the pH of the materials (Table I.)

In the control substrate that had not previously been used there appears a retention of NO_5 and of K^+ which could be a consequence of biological activity that has been undetected in the rest of the materials. This could be because of the presence of nitrificant bacteria which are non-existent in the non-used material.

The non-used material is the only one that releases less potassium than it retains. Thus, it is the only one that has a net retention of K^+ (Table I.). Therefore it is also the only that shows an increase in the exchange K^+ after the treatments have been carried out.

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Table I- Values of K^+, ca^{++}, Mg^{++} and Na^{++} (extracted with 1N NH_4 Acetate at pH7), P values (extracted by Olsen methods) and pH values (1:2.5 (w/v) after half hour) of the volcanic materials before and after nutrient solutions and washing treatments.

Volcanic materials		K^+	Ca^{++}	Mg^{++}	Na^+	P	pH
		meq/100g				ppm.	
Years of use:							
6	before treatments...	0.31	2.51	0.79	0.54	12.8	7.8
	after treatments...	0.24	2.03	0.16	0.16	22.6	6.8
5	before treatments...	0.22	2.96	0.38	0.29	12.4	8.1
	after treatments...	0.19	1.78	0.00	0.22	26.4	7.0
4	before treatments...	0.25	2.44	0.36	0.28	14.3	8.0
	after treatments...	0.17	1.26	0.15	0.13	20.7	6.9
1	before treatments...	0.12	2.10	0.34	0.25	12.5	7.3
	after treatments...	0.16	2.00	0.12	0.19	23.3	7.1
C	before treatments...	0.06	1.18	0.00	0.16	9.4	7.7
	after treatments...	0.15	1.15	0.00	0.10	10.6	7.0

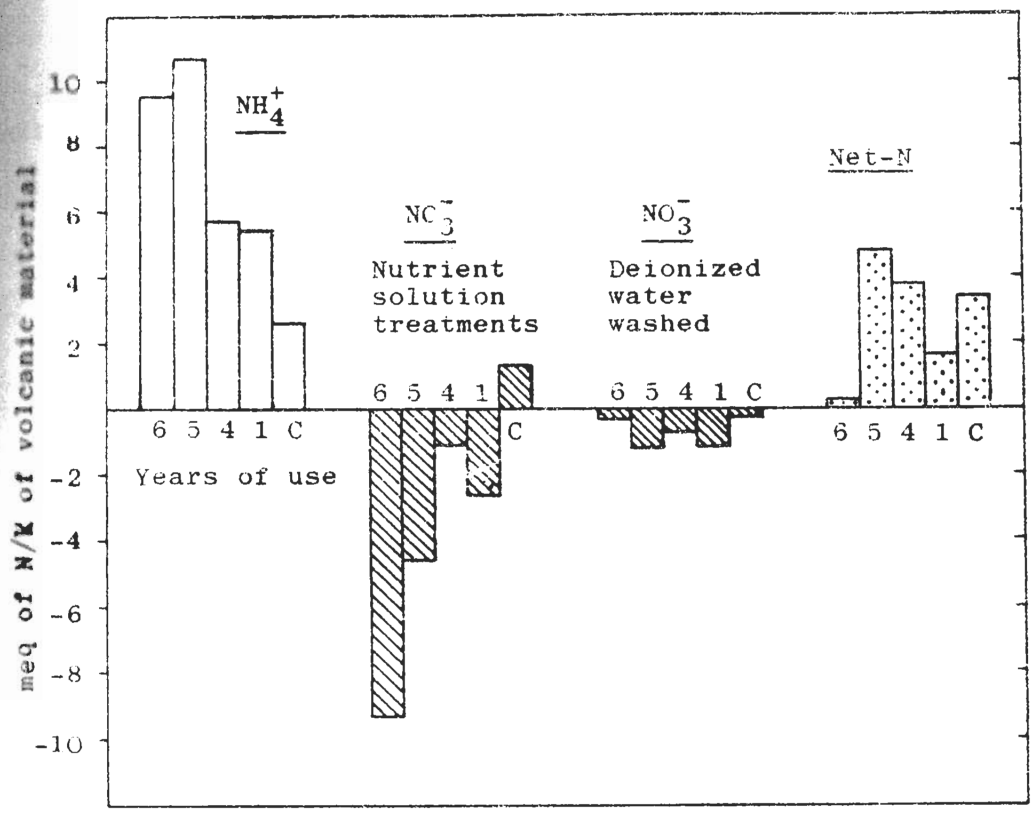

Figure 1 - Activity of the volcanic materials on the content of Nitrogen in the nutrient solution

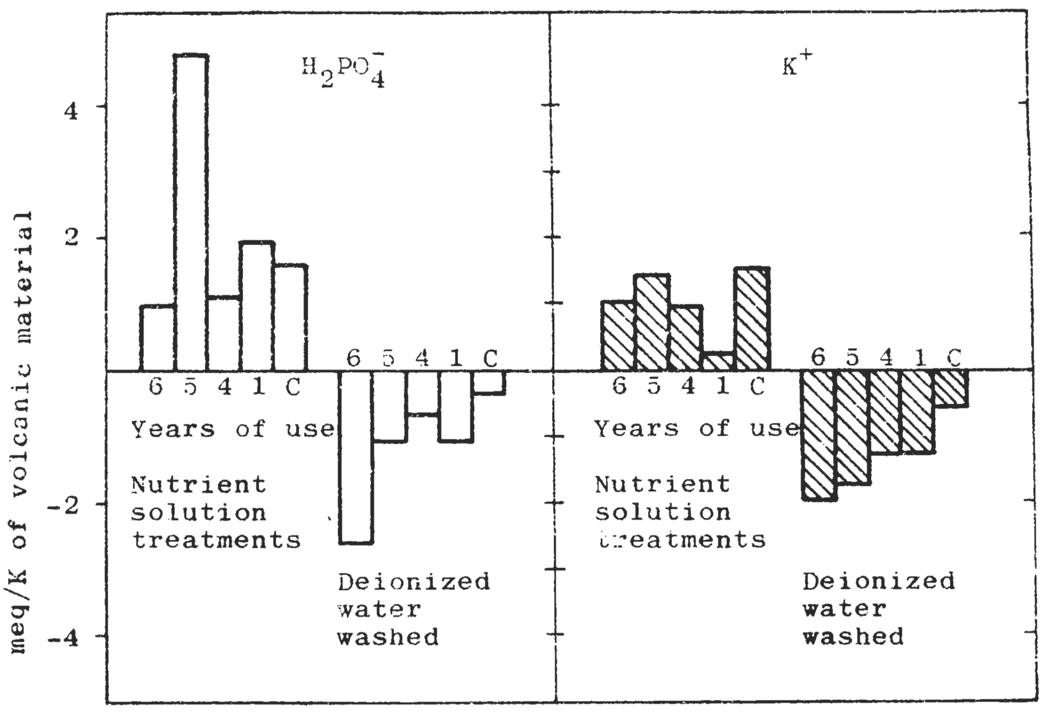

Figure 2 - Activity of the volcanic materials on the contents of $H_2PO_4^-$ and K^+ in the nutrient solution