

Original Research

GROWTH PARAMETERS RESPONSE OF *Ocimum basilicum* 'Genovese' TO PHOSPHATE GLASS AS AN ALTERNATIVE FERTILIZER

DOI: 10.5937/EcoTER26471R

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Abstract

The potential of phosphate glass as a fertilizer was evaluated through its effect on the growth of *Ocimum basilicum* 'Genovese' under controlled greenhouse conditions. A pot experiment was conducted over eight weeks using a factorial design with two substrate types differing in nutrient availability (P—nutrient-poor and F—nutrient-rich) and three fertilizer application rates (0, 1, and 2 g/kg substrate). Plant height and number of fully developed leaves were monitored as key growth parameters and expressed as relative values compared to the respective substrate controls. Results showed that plant response depended strongly on substrate type while the effects of fertilizer were limited reflecting the dominant influence of substrate type and opposing fertilization responses among substrates. In the nutrient-poor substrate, phosphate glass enhanced growth, increasing both height and leaf number, indicating that growth was initially nutrient-limited. In contrast, in the nutrient-rich substrate, fertilization reduced growth, suggesting adverse effects of excessive nutrient availability. Statistical analysis using the Kruskal–Wallis test confirmed significant differences among treatments. Overall, phosphate glass shows promise as a controlled-release fertilizer, particularly in nutrient-deficient systems, highlighting the importance of optimizing application rates in accordance with substrate conditions.

Keywords: phosphate glass, *O. basilicum* 'Genovese', fertilizer, nutrients.

INTRODUCTION

Sustainable agriculture represents one of the key challenges of modern society, given the need to ensure sufficient food production for a growing population while simultaneously preserving natural resources and the environment. The intensive use of conventional mineral fertilizers, although contributing to high yields, is often associated with negative environmental impacts such as eutrophication of water bodies, soil degradation, and

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greenhouse gas emissions. Consequently, increasing attention is being directed toward the development of alternative solutions that enable efficient nutrient supply to plants while minimizing environmental harm. In this context, particular emphasis is placed on fertilizers with controlled nutrient release, which reduce losses due to leaching and improve nutrient use efficiency [1,2].

Phosphate glass fertilizers represent a promising class of materials capable of meeting these requirements. Their structure enables gradual and controlled release of nutrients, which is directly related to the composition and structure of the glass network. In contrast to conventional fertilizers, which dissolve rapidly and may lead to nutrient losses, phosphate glasses provide a more prolonged and uniform nutrient supply. Furthermore, the ability to incorporate various macro- and micronutrients into the glass matrix allows precise tailoring of fertilizer composition to meet specific crop requirements. Another significant advantage of these materials lies in their reduced environmental impact, as controlled nutrient release lowers the risk of soil and water contamination. Owing to these characteristics, phosphate glass fertilizers represent an innovative approach in the development of sustainable agrochemical products and hold considerable potential for application in modern agriculture [3–7].

Phosphate glass fertilizers function through the controlled dissolution of a glass matrix in aqueous environments. When in contact with soil moisture, the glass undergoes hydration followed by ion exchange and gradual breakdown of P–O–P bonds, leading to the release of nutrient ions into the surrounding medium. The dissolution rate depends on the glass composition, particularly the degree of network connectivity and the presence of modifying cations, which regulate the mobility of ions and the stability of the structure [8,9].

An important feature of these materials is their responsiveness to plant demand. During periods of active growth, increased water uptake and root activity enhance local moisture and ion exchange processes, promoting faster dissolution and nutrient release. In contrast, as the growing season ends and plant activity decreases, the driving forces for glass dissolution—such as water flux and ion gradients—are reduced. As a result, nutrient release slows down, minimizing unnecessary losses and improving overall efficiency [10,11].

The aim of this research was to investigate the effect of phosphate glass as a fertilizer on the growth and development of *Ocimum basilicum* ‘Genovese’ under greenhouse conditions. The impact of different fertilizer doses was analyzed in two types of substrates differing in nutrient content. Plant growth was evaluated based on plant height and leaf number, supported by statistical analysis of the obtained results.

MATERIALS AND METHODS

In order to synthesize phosphate glass fertilizer, a batch was formulated using the following raw materials: $(\text{NH}_4)_2\text{HPO}_4$, K_2CO_3 , CaCO_3 , SiO_2 , MgO , ZnO , and MnO_2 . After prior drying, the components were homogenized in a mortar to obtain a uniform glass mixture. The prepared batch was subsequently melted in a Nabertherm G100/9 electric furnace at 1230 °C for 1 h. The molten mass was then cast onto a steel plate and allowed to cool under ambient conditions. The obtained phosphate glass was ground in an agate mortar

and stored in a desiccator until further use. The glass was physicochemically characterized, and its chemical durability was also examined in distilled water and in a 2% citric acid solution (commonly used under laboratory conditions to simulate the root environment). A detailed characterization and chemical durability of this glass have been presented in our previous studies [8,9]. The chemical composition of the glass was determined using gravimetric analysis for silicon (Si) and spectroscopic methods. Specifically, atomic absorption spectroscopy (AAS) with a PERKIN ELMER 703 instrument was used to analyze Ca, K, Mg, Cu, and Zn, while UV/VIS spectroscopy with a PHILIPS 8610 spectrophotometer was used for phosphorus determination.

To assess the effect of the phosphate glass fertilizers on *O. basilicum* 'Genovese' performances in two different commercially available substrates, Plagron Pro Mix (labelled as poor in nutrients- P) and Florabella (labelled as rich in nutrients - F), a pot experiment was performed in the greenhouse conditions for 8 weeks. The Florabella substrate contains black and white sphagnum peat, clay, compost, wood fibers, and 1.5 kg/m³ of NPK fertilizer (12:12:17.2); pH = 5.5–6.5; electrical conductivity = 45 mS/m. Plagron Pro Mix is an organic blend of white and black peat and worm castings. Its composition is: 60% white peat, 30% black peat, and 10% worm castings; pH (H₂O) = 6.5–7.5; electrical conductivity: 0.5–0.8 mS/cm; dry matter content 37%, organic matter content: 75%. The experiment was conducted as a factorial design with two substrate types (P and F) and three fertilizer levels (0, 1, and 2 g/kg substrate). Each treatment consisted of 5 replications, resulting in a total of 30 pots. Each pot contained five plants.

O. basilicum 'Genovese' seeds were obtained from commercial supplier „SemeSemena” d.o.o. and were soaked in 3% H₂O₂ for 10 minutes for disinfection and rinsed with distilled water prior to seeding. Ten seeds were sown per pot; upon emergence, seedlings were thinned to five individuals per pot, selecting those with the most uniform size and vigor for further treatment.

During experimental period temperature was set to 25/16 °C during a day/night cycle of 16/8 h. Relative air humidity was kept around 40%, and the artificial light was provided by multiply T5 fluorescent tubes with luminous flux of 2000 lm. Soil moisture was kept on 80% of field capacity during the experiment.

Plant height is measured from the soil surface to the highest apical meristem using digital caliper with 0.02 mm accuracy. Number of leaves is determined by counting fully expanded leaves. Plant growth parameters were expressed as relative values (%) with respect to the control of each substrate, which was set to 100%. Kruskal-Wallis test was applied for statistical analysis of variance and analyses were conducted in Statistica Statsoft 8.0 package.

RESULTS AND DISCUSSION

The chemical composition of the glass whose effect on *O. basilicum* 'Genovese' plants was investigated in our present study is presented in Table 1.

Table 1 The chemical composition of the phosphate glass

	Oxides						
	P ₂ O ₅	K ₂ O	CaO	MgO	ZnO	SiO ₂	MnO
mol%	45.4	25.6	14.5	9.3	1.2	3.1	0.9
wt.%	62	23.2	7.8	3.6	1	1.8	0.6

Plant height and number of leaves recorded during the experiment are presented in Figures 1–4. Height of plants in treatments with P substrate was ranging 10.5–16.1 cm, while the height of basil in treatments with F substrate reached twofold values, ranging from 22.1 to 33.9 cm. Number of leaves in in treatments with P substrate ranged from 8–14, whereas number of leaves in treatments with F substrate ranged from 30–52. Slight increase in both plant height and number of leaves was observed in P1 and P2 in comparison to their control (PK), whereas opposite trend was observed in F1 and F2 treatments in comparison to their control (FK).

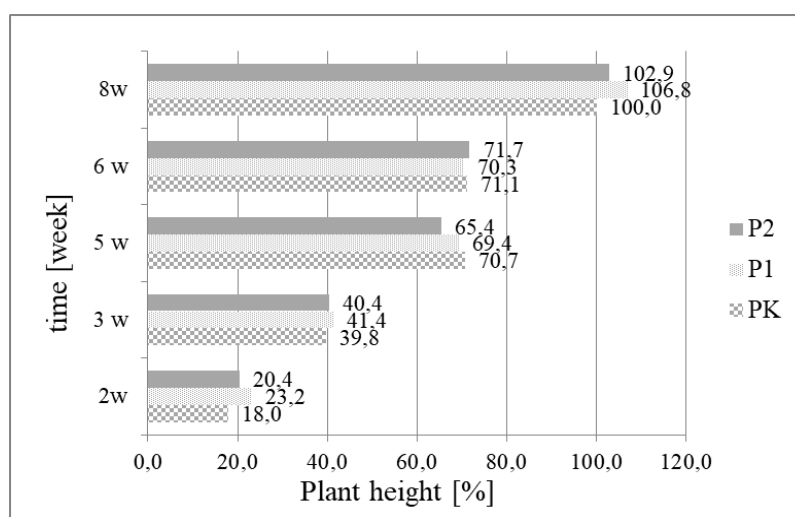


Figure 1 Height of *Ocimum basilicum* 'Genovese' reached during the experiment in substrate P (data are shown as relative percentages).

For P treatment, plant height showed slight increase in fertilized treatments (Figure 1), particularly in later stage of the experiment (weeks 6 and 8) in comparison to the control (up to 106.8% for P1 treatment). Number of leaves developed at week 2 in P substrate was identical for all treatments, indicating uniform seed emerging (Figure 2). Up to week 6, control plants had the highest number of developed leaves in comparison to fertilized treatment, but by the end of experiment that trend changed favouring the development of leaves in both fertilized treatments, particularly P2 (109.5%).

In the F substrate, plant height shows slight responsiveness to fertilization (Figure 3), with the control performing better than both fertilized treatments in later stages of the experiment (week 6 and 8), indicating that nutrient availability was already sufficient for optimal growth. Particular reduction of growth height is notable in P1 treatment (93.8%). The differences were more pronounced in number of leaves (Figure 4), where at the later stages of the experiment control outperformed both treatments, particularly F2 (100% in FK in comparison to 74.2%).

This phenomenon indicates that nutrient availability is already sufficient in control pots and that additional fertilization could have detrimental effects to the vegetative growth.

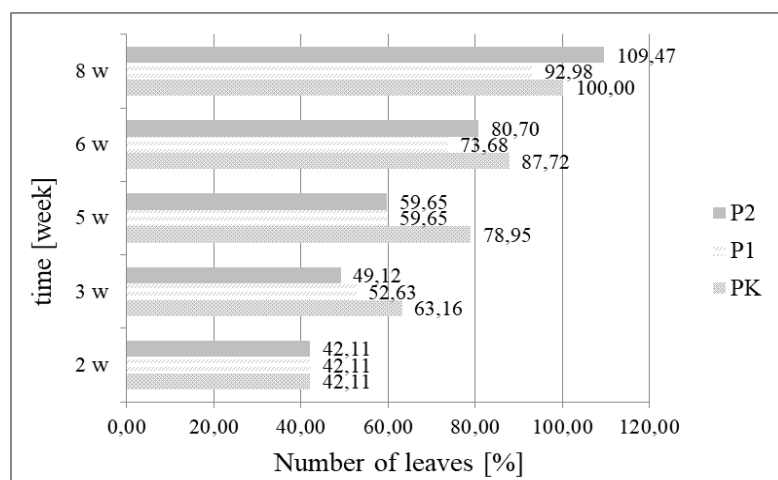


Figure 2 Number of leaves of *Ocimum basilicum* 'Genovese' reached during the experiment in substrate P (data are shown as relative percentages).

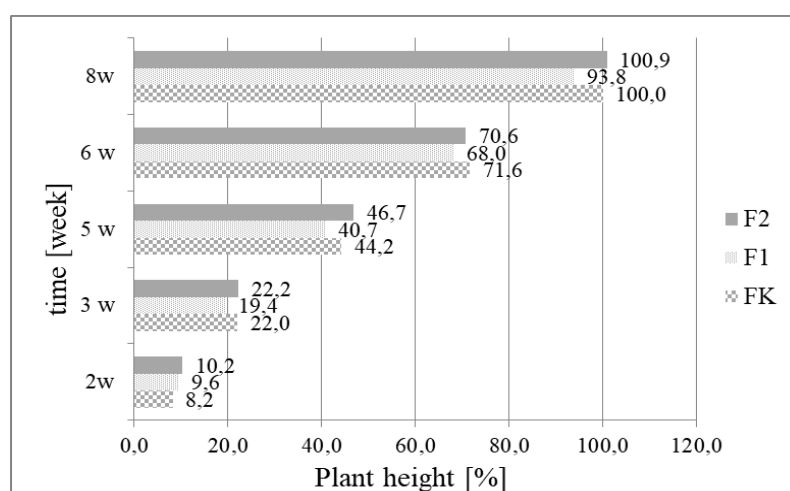


Figure 3 Height of *Ocimum basilicum* 'Genovese' reached during the experiment in substrate F (data are shown as relative percentages)

Non-parametric Kruskal-Wallis test showed the significant differences among measured vegetative growth parameters (Table 2). During the early growth stages (week 2) differences among plant height and leaf numbers among treatments were not statistically significant, revealing that initial growth was predominantly supported by seed reserves. During later growth phases (weeks 3–8) significant differences between plant height and leaf number among the treatments were observed. However, analysis of plant height and number of leaves showed no statistically significant differences among fertilizer treatments ($F = 0.0134$, $p = 0.9867$ and $F = 0.3609$, $p = 0.6998$, respectively), which can be explained by dominant effect of substrate type and opposing responses to fertilization observed in different substrates.

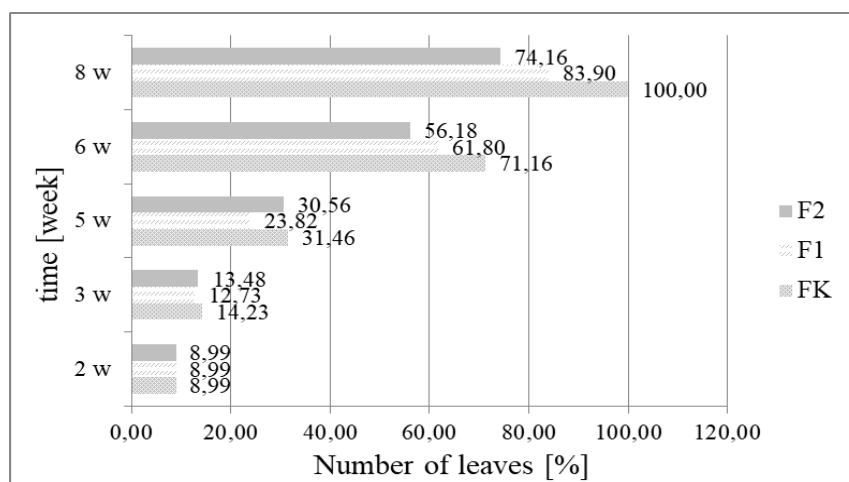


Figure 4 Number of leaves of *Ocimum basilicum* 'Genovese' reached during the experiment in substrate F (data are shown as relative percentages)

Table 2 Non-Parametric (Kruskal–Wallis) analysis of plant height and number of leaves in *O.basilicum* 'Genovese' during the experimental period (statistically significant differences are marked with *)

Experiment period [week]	Plant height		Number of leaves	
	KW-H F value	p-value	KW-H F value	p-value
2	15.958	0.007	0	-
3	18.850	0.002*	11.698	0.0392*
5	26.303	0.00008*	31.366	0.00001*
6	26.596	0.00007*	30.372	0.00001*
8	26.884	0.0006*	28.881	0.00002*

In the P substrate, the addition of phosphate glass fertilizer resulted in modest improvement in both plant height and leaf number, suggesting that vegetative growth was primarily limited by substrate conditions that initially had restricted nutrient availability. In contrast, in the F substrate, initially rich in nutrients, additional fertilization reduced vegetative growth. These findings highlight the need to optimize glass fertilizer dosage according to the initial substrate conditions during the *O. basilicum* 'Genovese' cultivation process. Additional investigations are needed to provide deeper insight into soil-fertilizer-plant chemical interactions as well as to identify physiological processes underlying observed plant responses.

CONCLUSION

In this study, the effect of phosphate glass as a fertilizer on the growth and development of *Ocimum basilicum* 'Genovese' under substrates with different initial nutrient status was investigated. The obtained results indicate that the effect of glass fertilizer application strongly depends on the nutrient availability of the substrate. In the nutrient-poor substrate, a slight improvement in vegetative growth was observed, reflected in increased plant height and leaf number, confirming the potential of phosphate glasses as a controlled-release nutrient

source. In contrast, in the nutrient-rich substrate, additional fertilization resulted in reduced plant growth, suggesting a possible negative effect of excessive nutrient availability and emphasizing the importance of proper dosage depending on cultivation conditions.

Statistical analysis showed that substrate type had a dominant influence on the observed growth parameters, while differences among fertilizer doses were not statistically significant, which can be explained by the opposing responses observed in different substrates. These findings confirm that the application of phosphate glass fertilizers requires careful adjustment to agroecological conditions in order to achieve optimal efficiency and avoid potential adverse effects.

The obtained results contribute to a better understanding of the application of glass fertilizers in sustainable agriculture, while also highlighting the need for further research. Future studies will focus on a more detailed investigation of the influence of glass composition, as well as the kinetics and mechanisms of its dissolution and nutrient uptake by plants, with the aim of optimizing their application and improving overall efficiency.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for financial support according to the contract with registration No. 451-03-33/2026-03/200023.

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