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APPLICATION OF PHOSPHATE GLASS IN THE PRODUCTION OF FLOWERS AND VEGETABLES

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Abstract

This paper presents the results of the application of phosphate glass with the addition of Fe, Mn, Zn and Cu in the production of cockscomb (*Celosia plumosus L .*), impatiens (*Impatiens waleriana Hook.*), aubergine (*Solanum melongena L.*) and tomato (*Solanum esculentum* L). The experiment was conducted in the greenhouse of the Faculty of Agriculture in Belgrade during the years of 2012 and 2013. The chosen plants of flowers and vegetables were produced using modern cultivation systems, in polystyrene containers and polypropylene pots. For the production of flower seedlings the influence of the following glass doses were studied: 0, 1, 2, 3 g/l; and for the production of vegetable plant seedlings the doses of 0,1,2,3 and 4g/l of substrate were studied. The research examined the effect of the phosphate glass use on the following properties of flower and vegetable seedlings' development: height, plant weight, number of lateral branches, number of leaves, root weight. Research results showed a positive effect of phosphate glass application in the production of flower and vegetable seedlings. High quality seedlings were produced in the process, thus justifying its application.

Key words: *phosphate glass, doses, seedlings, flowers, vegetables*.

Introduction

The scientific challenge of the modern greenhouse production of flower and vegetable seedlings has a few directions: introducing renewable sources of energy and new techniques in concordance with climatic conditions, integrating crops, introducing and designing sustainable irrigation systems as well as strategies of sustainable soil fertility and substrate quality. The modern production of flower and vegetable seedlings increasingly uses the new so-called alternative substrates or the existing ones improved by new components (Boyer et. al., 2007; Vujošević, 2012). Since there is no *universal* substrate for all cultivated seedlings (Samadi, 2011), it is necessary to pay attention to the substrate's physical, chemical and biological characteristics while preparing it. Thus, the selection of the substrate with the appropriate composition is crucial for the production of quality seedlings (Latimer, 1991; Kallo et.al., 1985; Argo, 2004). As reported by other authors (Landis et.al., 1990; Heiskanene, 1993; Reinikainen, 1993), the components for substrate preparation should be easily available, of small specific weight, easy to manage and that their use ensures the uniformity of plants. Today, various materials are used for this purpose, but the advantage is given to those materials which not only bring to the the increase of crop yield but also protect the environment, as stated by *Nikolić et al., 2011.* As pointed out by all the above mentioned authors, the aim is to reduce production costs, which directly leads to the reduction of the final products' price. The past research on the application of glass as a possible component have shown that, due to its amorphous structure, glass has the characteristics which make it a suitable material, capable of participating in the biological processes of living organisms.

As reported by Tošić et al. (2002), their chemical activity in the processes happening in contact with various solutions helps to design and produce new materials which are effective not only for the growth and development of living organisms but also for the environment protection.

The main advantage of glass lies in the flexibility of its chemical structure, which enables the structure changes without altering the kinetics and the mechanism of dissolution process. In addition, special significance (*Nikolić et al., 2011*) applies to the rate of isolating the components from these materials which can be equalled to the rates of consumption by plants, which eliminates the possibility of accumulation or shortage. The pioneer research to date and the obtained results about the application of glass in the production of seedlings of some flower and vegetable cultures, given by *Nikolić et al., 2012 and 2013; Vujosević et al., 2012* and *2013* have confirmed its positive influence on the growth and development of plants and thus the necessity of further research.

In order to follow the new tendencies of the modern greenhouse production of flower and vegetable seedlings, we have chosen for the subject of this research the consideration of the justifiability of the application of phosphate glass with the addition of Fe, Mn, Zn and Cu, as the new alternative component in the substrates for the production of flower and vegetable seedlings.

Research material and methods

The research is based on the one-year experiments conducted during the years of 2012 and 2013 in the greenhouse of the Faculty of Agriculture in Belgrade. Two species of annual flowers were studied: *Impatiens walleriana Hook.*- impatiens *fam. Balsaminaceae*, *«Xtreme red »* series, *Goldsmith seed* and *Celosia plumosa L. fam. Amaranthaceae* - cockscomb, PanAmerican Seed. Two vegetable species were also examined: tomato - *Solanum esculentum L*. hybrid Nada F1- *fam. Solanaceae* and aubergine - *Solanum melongena L. fam. Solanaceae,* experimental series 'line15' of The Institute for Vegetable Crops in Smederevska Palanka. The seed sowing was performed in polypropylene TEKU containers type 144/4,5. The commercial sowing substrate *Floragard B-fine* was used for seed sowing. After the first two pairs of permanent leaves had appeared (4-5 weeks after the sowing), the plants were transplanted into round polypropylene TEKU 9-cm pots, while the tomato plants were transplanted into 15-centimetre pots. For the transplantation and further cultivation of the seedlings we used the commercial substrate *Floragard Medium Course* while adding the phosphate glass of the following chemical structure (the percentage represents the rate of oxide in the mass): P_2O_5-68,14%, K_2O-21,92%, CaO-1,609%, MgO-1,409%, SiO_2-2,87%, ZnO-0,838%, CuO-0,899%, Fe_2O_3-1,707%, MnO-0,682% with the granulation < 0,5mm. The plants were transplanted and separated into groups treated by the following glass doses: for vegetable plants - 1. control - 0 g/l of substrate; 2. 1g/l of substrate; 3. 2g/l of substrate; 4. 3g/l of substrate and 5. 4g/l of substrate; and for flower plants - 1.control- 0 g/l of substrate; 2. 1g/l of substrate; 3. 2g/l of substrate; 4. 3g/l of substrate. The production of seedlings was performed with daily monitoring the environmental conditions necessary for the undisturbed growth and development of the plants (day and night temperatures, relative humidity and substrate moisture). The selection of the initial seedlings for the transplantation into pots was done randomly. Transplantation was performed manually. At the end of the production cycle, the influence of the applied phosphate glass on the level of development of the seedlings was studied through the following parametres: height (cm), plant weight(g), number of lateral branches, number of leaves and root weight(g).

Statistical analysis: The results of the experiments and the results of their statistical analysis are represented in tables and graphs. The results of the Shapiro-Wilk's W test showed that the experimental data for the observed characteristics in all samples were not distributed according to the model of the normal distribution. The observed characteristics in all samples were not homogenous and that the variances of the analyzed groups were not homogenous. That is why the study of the effects of the applied glass doses was conducted using non-parametric tests. The comparison of the simultaneous effect of different glass doses on the examined characteristics of the seedlings' quality was performed according to the results of discriminant analysis, and the degree of separation of the two plant groups treated by different glass doses was determined according to the levels of significance of the squared Mahalonobis distance. The research on the different effects of different glass doses' application on separate characteristics of the seedlings' quality was conducted using the Kruskal-Wallis test for all treatments and the Mann-Whitney U test for two treatments. Statistical analysis of the results obtained in the experiment was carried out using software STATISTICA v. 6 (StatSoft, Inc., Tulsa, OK, USA).

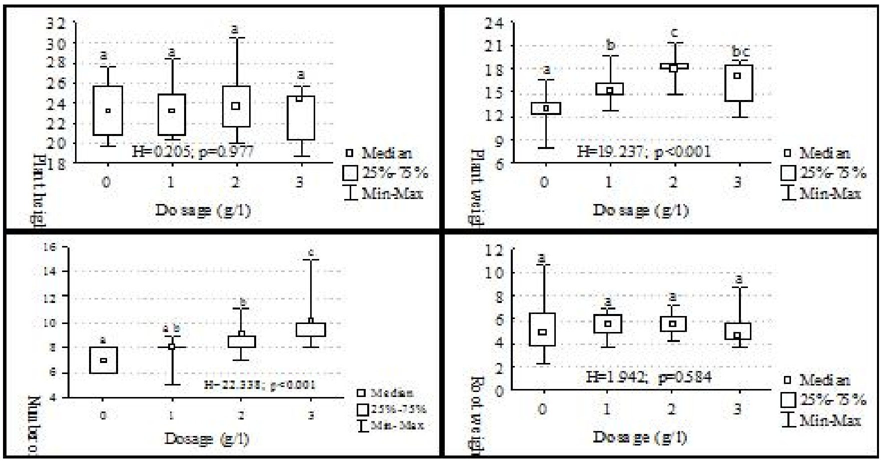
Results and discussion

The discriminant analysis determined that the use of different doses of phosphate glass caused statistically very significant differences if the characteristics of the studied *Celosia plumosa* seedlings ($F= 4.856$; $p<0.001$) were simultaneously observed. The characteristics of the studied seedlings of *Celosia plumosa* obtained by using the glass doses of 2 g/l and 3 g/l were very significantly different from the seedlings' characteristics obtained without the use of glass (0g/l). In addition, the glass quantities of 2g/l and 3g/l had a significantly different influence on the studied characteristics of the seedlings. Also, the use of these doses had a very significantly different effect from the use of 1g of glass/l of substrate (Table 1). The difference of the total quality of the obtained *Celosia plumosa* seedlings by using different glass doses was the consequence of the the glass effect on the above-plant weight and number of lateral branches (Graph 1).

Table 1: The significance levels of the differences between the examined glass doses' effects on the characteristics of the *Celosia plumosa* and *Impatiens walleriana* seedlings' development on the basis of the squared *Mahalanobis* distance

Dosage (g/l)	Celosia plumosa			Impatiens walleriana		
	Dosage (g/l)			Dosage (g/l)		
	1	2	3	1	2	3
0	0.100	**<0.001**	**<0.001**	0.739	0.089	0.313
1		**0.042**	**0.002**		**0.029**	0.075
2			**0.021**			0.256

The results of the Kruskal-Wallis test (H and p, Graph 1) showed that the average plant weight and number of lateral branches statistically very significantly depended on the used dose of glass. On the other hand, the glass dose did not affect the average height and root weight of the *Celosia plumosa* seedlings. The obtained results corresponded to the results acquired in the research (*Vujošević et al., 2011*) on the influence of phosphate glass in the production of marigold, where glass doses did not have a statistically significant influence on the height of seedlings and root weight Comparing the differences of the effects of two by two glass doses on the average above-ground biomass using the *U*-test (Table 2 and Graph 1), it was determined that the use of the glass with 1g/l of substrate significantly changed the plant weight, and the use of bigger doses (2g/l and 3g/l) had a very significant influence when compared to the non-use of glass. The effects of 1g/l and 2g/l doses on the plant weght were statistically significantly different.



Graph 1: The effects of the application of different glass doses on the seedlings’ characteristics *Celosia plumosa*

Note: The same letters were used to mark the treatments with the same effect

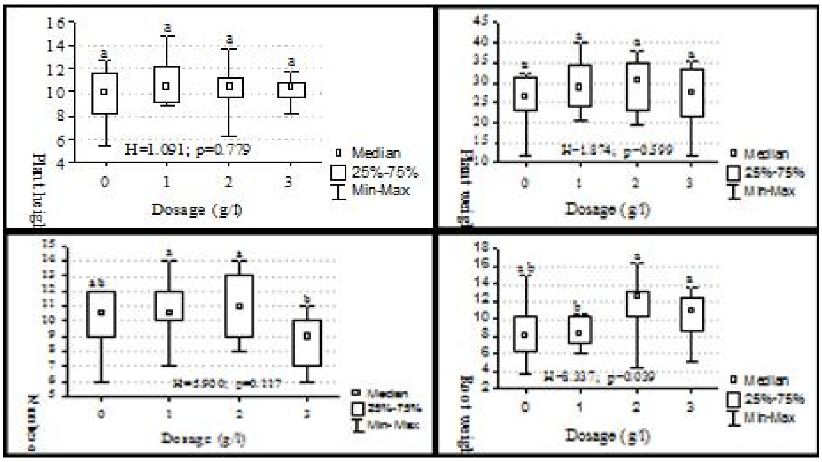
The number of lateral branches obtained by applying the maximum studied glass dose (3g/l) was statistically very significantly different from the number of lateral branches obtained by not applying glass or by applying the 1g/l dose, and significantly different from the number obtained by applying 2g/l. The number of branches obtained by applying 2g/l was very significantly different from the number of branches obtained by not applying glass (Table 2).
The obtained results concerning the plant weight and number of formed lateral branches of *Celosia plumosa* seedlings also corresponded to the before-mentioned research (Vujosević et al., 2012), according to which the glass application dose of 1 or 2g/l had the most favourable influence on the plant weight and number of lateral branches of *Tagetes patula* seedlings. When it comes to the *Celosia plumosa* seedlings, the 2g/l dose should have the advantage because it is a type of flowers from the medium long vegetation period of seedlings (8-10 weeks) so the need for food is greater than for the flowers from the group of short vegetation period of seedlings, such as marigold - *Tagetes patula* (6-8 weeks).

Table 2. The levels of significance between average plant caracteristics of flowers seedlings *Celosia plumosa and Impatiens walleriana* on the basis of *U*-test

Spacies	Caracteristics	Dosage	Dosage		
			1 g/l	2 g/l	3 g/ l
Celosia plumosa	Plant height (cm)	0 g/l	≈1.000	0.791	0.734
		1 g/l		0.705	0.970
		2 g/l			0.734
	Plant weight (g)	0 g/l	**0.013**	**<0.001**	**0.007**
		1 g/l		**0.005**	0.326
		2 g/l			0.131
	Number of lateral branches	0 g/l	0.065	**0.003**	**<0.001**
		1 g/l		0.129	**0.001**
		2 g/l			**0.016**
	Root weight (g)	0 g/l	0.821	0.545	0.705
		1 g/l		0.940	0.290
		2 g/l			0.131
Impatiens walleriana	Plant height (cm)	0 g/l	0.273	0.623	0.623
		1 g/l		0.705	0.623
		2 g/l			
	Plant weight (g)	0 g/l	0.345	0.199	0.545
		1 g/l		0.940	0.650
		2 g/l			0.450
	Number of Lateral	0 g/l	0.618	0.299	0.153
		1 g/l		0.760	**0.038**

	branches	2 g/l			**0.044**
	Root weight (g)	0 g/l	0.762	0.059	0.082
		1 g/l		**0.028**	**0.041**
		2 g/l			0.257

The method of discriminant analysis was used to study the simultaneous effect of the application of different doses of phosphate glass on all the examined characteristics of *Impatiens walleriana* seedlings. The obtained results showed that the applied glass caused differences, but that they did not have any statistical significance; the results of the group test (F=1.654; p<0.075). The characteristics of *Impatiens walleriana* seedlings differed only when the 1 or 2g/l glass dose was used (Table 1). The results of the Kruskal-Wallis test (H and p, Graph 2) pointed out that the average root weight of *Impatiens walleriana* seedlings significantly depended on the used glass dose, while this dose did not affect the other examined characteristics of the seedlings. The comparison of differences of the glass doses' influence on the average plant weight roots of *Impatiens walleriana* seedlings using the U-test (Table 2 and Graph 2) showed that the use of 2g/l and 3g/l glass changed the average root weight significantly. When these glass doses were applied, the average weight of the seedlings' roots showed statistically significant difference in comparison with the root weight obtained by the application of 1g/l glass dose.

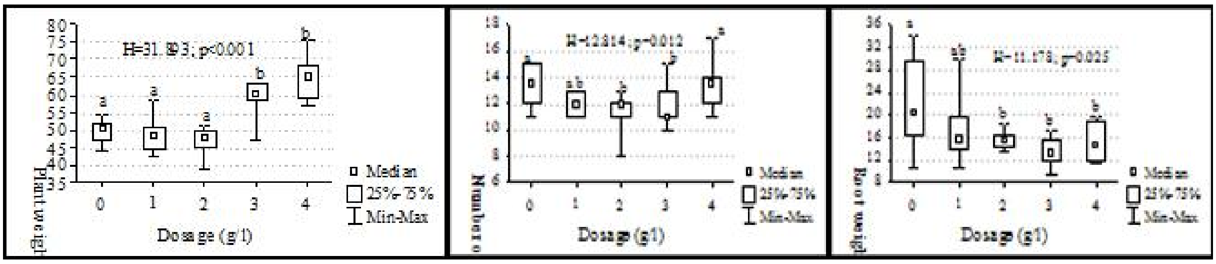


Graph 2: The effects of the application of different glass doses on the seedlings' characteristics *Impatiens walleriana*

Note: The same letters were used to mark the treatments with the same effect

Also, the application of the U-test proved that the apllication of 3g/l glass significantly changed the average number of lateral branches in relation to the number of lateral branches formed by using the smaller doses (1g/l and 2g/l). The favourable effect of bigger glass doses on the average root weight and number of the formed lateral branches of the *Impatiens walleriana* seedlings could also be attributed to its medium long vegetation of the seedlings (8-10 weeks) and the habitus itself (the appearance of the stem). Namely, this flower type is characterized by basal branching, while the primary stem is short. The quality of the obtained plants is measured by their network of branches not the height. When it comes to the studied quality characteristcs of vegetable seedlings, the use of different doses of phosphate glass showed statistically very significant effects; tomato (F=6.978; p=0.001) and aubergine (F=2.603; p=0.002). The results of the discriminant analysis pointed out that the use of different doses of phosphate glass had a statistically very significant influence on the studied quality characteristics of vegetable seedlings. With regard to tomato seedlings (*S. esculentum*), the use of 2g/l glass dose brought to the seedlings' quality which was

significantly different, and the use of 3g/l brought to very significantly different quality from the quality of the seedlings obtained without the application of glass, 0g/l (Table 3).
The application of 3g/l and 4g/l of phosphate glass had a statistically very significantly different effect from the application of 1g/l and 2g/l glass. The quality changes in seedlings made by using 1g/l or 2g/l glass were not significant, while the use of 3g/l and 4g/l glass brought to the statistically significantly different effects on the quality of tomato seedlings (Table 3 and Graph 3).



Graph 3: The effects of the application of different glass doses on the seedlings’ characteristics *Solanum esculentum*
Note: The same letters were used to mark the treatments with the same effect

More favourable effect of bigger glass doses could be explained by the fact that tomato was grown in the pots of bigger volume and that the plants were grown until the phase of fruit bearing. The obtained results corresponded to the results obtained in the research (*Vujosević et al., 2013*) on the effect of phosphate glass in the cultivation of peppers (*Capsicum annum*) where the applied glass dose of 3g/l had the most favourable effect on the quality of plants.

Table 3. The significance levels of the differences between the examined glass doses’ effects on the characteristics of the *Solanum esculentum* and *Solanum melongena* seedlings’ development on the basis of the squared *Mahalanobis* distance

Dosage (g/l)	Solanum esculentum				Solanum melongena			
	Dosage (g/l)				Dosage(g/l)			
	2	3	4	5	2	3	4	5
0	0.191	**0.020**	**<0.001**	**<0.001**	0,058	0,394	**0,033**	**0,004**
1		0.723	**<0.001**	**<0.001**		0,196	**0,048**	**<0,001**
2			**<0.001**	**<0.001**			0,390	**0,019**
3				**0.033**				0,221

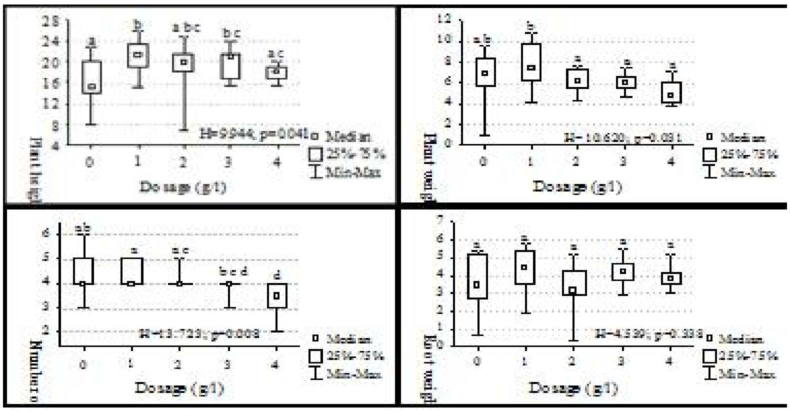
The results of analyzing the influence of glass doses on the plant weight of tomato seedlings, using the Kruskal-Wallis test (H and p, Graph 3), showed that the average plant weght of tomato seedlings statistically very significantly depended on the glass dose applied during the cultivation, while the average root weight and average number of leaves were statistically significantly influenced by the glass dose (Graph 3). The comparison of two by two doses of the applied glass, using the U-test, showed that the plant wieght obtained using 3g/l and 4g/l glass was statistically very significantly different from the plant weight obtained without using the glass or using a lower dose, 1g/l and 2g/l (Table 4 and Graph 3). The number of formed leaves obtained using 2g/l and 3g/l doses was statistically significantly different from the number of leaves formed when glass was not used. The number of leaves obtained when using the glass of 4g/l of substrate was statistically very significantly different from the number of leaves formed when using the 2g/l dose of glass, and significantly different from the number formed when applying the 1g/l and 3g/l doses (Table 4 and Graph 3).
In addition, the *U*-test pointed out that the root weight of tomato seedlings changed significantly when using 2g/l and 4g/l glass, and very significantly when using 3g/l in comparison with the root weight when the glass was not used (Table 4 and Graph 3).

The use of the 3g/l glass dose made a significant difference to the characteristics of aubergine seedlings, and the use of 4g/l a very significant difference in comparison with the situation when the glass was not used or when the minimum quantity was used (1g/l). The glass dose of 4g/l also had a very significantly different effect from the application dose of 2g/l (Table 3).
According to the results of the Kruskal-Wallis test (H and p, Graph 4), the average height and average plant weight were statistically significantly dependent on the applied glass dose, while the average number of leaves was statistically very significantly dependent. The results also stated that the applied dose of glass did not influence the average root weight

Table 4. The levels of significance between average plant parameters of vegetables seedlings *S. esculentum* and *S. melongena* on the basis of *U*- test

Spacies	Caracteristics	Dosage	Dosage			
			1 g/l	2 g/l	3 g/ l	4 g/ l
Solanum esculentum	Plant weight (g)	0 g/l	0.406	0.096	**0.001**	**<0.001**
		1 g/l		0.545	**0.001**	**<0.001**
		2 g/l			**0.001**	**<0.001**
		3 g/ l				0.082
	Number of leaves	0 g/l	0.067	**0.018**	**0.037**	0.969
		1 g/l		0.231	0.298	**0.040**
		2 g/l			0.719	**0.007**
		3 g/ l				**0.027**
	Root weight (g)	0 g/l	0.131	**0.028**	**0.007**	**0.028**
		1 g/l		0.705	0.070	0.307
		2 g/l			0.070	0.496
		3 g/ l				0.496
Solanum melongena	Plant height (cm)	0 g/l	**0.016**	0.199	**0.034**	0.140
		1 g/l		0.273	0.496	**0.028**
		2 g/l			0.596	0.256
		3 g/ l				0.089
	Plant weight (g)	0 g/l	0.427	0.450	0.326	0.070
		1 g/l		0.131	**0.028**	**0.008**
		2 g/l			0.705	0.054
		3 g/ l				0.070
	Number of leaves	0 g/l	0.740	0.562	0.169	**0.036**
		1 g/l		0.131	**0.015**	**0.003**
		2 g/l			0.088	**0.010**
		3 g/ l				0.148
	Root weight (g)	0 g/l	0.199	0.970	0.326	0.650
		1 g/l		0.070	0.545	0.212
		2 g/l			0.226	0.307
		3 g/ l				0.345

The U-test determined that the average height of plants significantly differed when applying the glass doses of 1g/l, 3g/l and 4g/l from the height obtained without using the glass. Also, the different height of the aubergine seedlings showed statistically significant difference if grown with the use of glass doses of 1g/l and 4g/l (Table 4 and Graph 4). When the glass doses of 3g/l and 4g/l were used, the plant weight of aubergine seedlings significantly differed (3g/l) and statistically very significantly differed (4g/l) from the plant weight obtained when the glass dose of 1g/l was used (Table 4 and Graph 4).



Graph 4: The effects of the application of different glass doses on the seedlings’ characteristics *Solanum melongena*

Note: The same letters were used to mark the treatments with the same effect

With the application of the 4g/l glass dose, the obtained number of leaves was statistically significantly different from the number of leaves when the glass was not used, and statistically very significantly different from the number of leaves obtained with the application of the glass doses of 1g/l and 2g/l (Table 4 and Graph 4).

Conclusion

The research results showed the positive and justified effect of the phosphate glass application in the production of flower and vegetable seedlings. The favourable glass doses could be singled out for the further cultivation of each species of flowers and vegetables. The glass dose of 1-2g/l of substrate proved as the optimal dose for the production of flower seedlings *Celosia plumosa* and *Impatiens walleriana.* Although the average height of flower seedlings is determined by the characteristics of the hybrid itself, and as such does not change statistically significantly by applying the studied glass doses, it was still greater when using the glass than when the plants were grown without the use of glass. The 2g/l glass dose had the optimal effect on the realized average plant weight of flower seedlings. The use of this dose brought to the plant weight of *Celosia plumosa* seedlings which was statistically very significantly bigger than the average plant weight obtained without the application of the glass or with the application of the 1g/l glass dose. Although the average plant weight of *Impatiens walleriana* did not show statistically significant increase with the application of the studied glass doses, the average plant weight was greater when the glass dose of 2g/l was applied. The application of 2g/l and 3g/l doses with *Impatiens walleriana* seedlings had a statistically significant influence on the increase of the average root weight when compared to the dose of 1g/l. In case of *Celosia plumosa* seedlings, the application of glass doses of 1 and 2g/l had the effect on the increase of their weight, yet not a statistically significant one. The application of the glass dose of 2g/l of substrate also had the most favourable effect on the average number of branches of *Impatiens walleriana* seedlings, and the bigger dose of glass application statistically significantly decreased the number of branches per plant. In case of *Celosia plumosa* the application of 3g/l glass dose ensured a better level of branching than the level of branching obtained without the application of glass or with the application of 1g/l and 2g/l dose. On the basis of the acquired results, the glass dose of 2g/l of substrate could be recommended as the optimum dose in the production of *Celosia plumosa* and *Impatiens walleriana* seedlings as the seedlings characterized by the medium long vegetation of the seedlings (8-10 weeks). With regard to vegetable seedlings, and *Solanum melongena*– aubergine, the application of the glass dose of 1g/l of substrate had the most favourable effect on the average height and average plant weight. The obtained average height of aubergine seedlings was statistically significantly bigger than the average height obtained without the application of the glass or with the use of the maximum researched dose of 4g/l. With regard to vegetable seedlings of *Solanum esculentum*–tomato, the application of the glass dose of 4g/l had the most favourable effect on the plant weight. With the application of this dose, the obtained average weight was statistically significantly bigger than the average weight obtained with the application of the glass dose of 2g/l of substrate. This more favourable influence of the bigger glass dose could be attributed to the period when the research ended (fruit-bearing phase). The application of phosphate glass had a positive effect on the development of the root system of vegetable seedlings. In case of both vegetable species, the applied glass dose of 1g/l brought to the statistically significant increase of its average weight in comparison with the researched doses (0g, 2g, 3g and 4g/l). The results of this research proved the justifiability of the further research on glass in the production of seedlings and other flower and vegetable species, with the aim of determining the optimum application doses, achieving maximum crop yield, obtaining healthy and safe food and protecting the environment.

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