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ZEOLITE AS A COMPONENT OF SUBSTRATE IN CULTIVATION OF ORNAMENTAL PLANTS – *Catharanthus roseus* (L.) G. Don AND *Gazania rigens* var. *rigens* (L.) Gaertn.

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Abstract. In Poland, zeolites are relatively rare substrates. These are natural aluminosilicate minerals with excellent sorptive and iron exchange properties. Mixing substrates with zeolite improved the physical and chemical properties of the media such as total porosity or water holding capacity. The research was aimed at assessing the usefulness of zeolite in the production of *Catharanthus roseus* and *Gazania rigens* var. *rigens* seedlings. For sowing the following substrates were used: 1. deacidified peat, 2. substrate ready for sowing AURA of Hollas, 3. peat + fine zeolite 1:1, 4. peat + fine zeolite 3:1, 5. peat + coarse zeolite 1:1, 6. peat + coarse zeolite 3:1. The Azofoska fertiliser was added to all substrates at a dose of 2 $g \cdot dm^{-3}$. At the second stage of the experiment, seedlings from each variant were planted in three substrates including: I. deacidified peat, II. peat with the addition of 20% fine zeolite, III. peat with the addition of 20% coarse zeolite. Addition of zeolite to the substrate for sowing improves seedling root development, while limiting the growth of shoots of *Gazania rigens* var. *rigens*. Plants of *Gazania* sown on substrates with zeolite – regardless of the type of substrate used for further cultivation – produce more flower buds than plants from other substrates. The least favorable for the growth and flowering *Catharanthus roseus* effect the substrate with fine zeolite in an amount of 20%; plants have been lower had fewer leaves, and definitely less flourish.

Key words: bedding plants, flowering, growth, medium, seeds, zeolite fraction

INTRODUCTION

The substrate for growing plants should be permeable and characterise the porosity, which gives plants adequate amount of air in the root zone. The basic substrate in the

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cultivation of ornamental plants is sphagnum peat. It is also the main component of garden substrates. There should also be introduced other mineral [Treacy and Higgins 2001, Polat et al. 2004] and organic [Moyin-Jesu 2007, Dobrowolska 2010, Mohammadi Torkashvand and Kaviani 2014] substrates, which due to its characteristics will improve relations between water and air to grow potting substrates.

In Poland, zeolites are relatively rare substrates. These are natural aluminosilicate minerals with excellent sorptive and ion exchange properties [Gworek and Sucharda-Kozera 1999] in the form of granules of various sizes. A characteristic feature of zeolites involves the occurrence of empty spaces in their internal structure with a diameter of 0.7 to 0.9 nm, which form a system of channels filled with water molecules [Chohura 2007]. Owing to their properties, they can absorb heavy metals and radioactive elements, among other things [Campbell and Davies 1997]. Zeolite has ability to sorption of heavy metals such as Cd, Cr, Ni and Pb from contaminated their substrates [Kapetanios and Loizidou 1992], as well as the retention of harmful salts NaCl and Na_2SO_4 [Noori et al. 2006]. Often this capacity increases with the percentage participation of the zeolite in substrate.

Mixing substrates with zeolite improved the chemical and physical properties of the media such as total porosity or water holding capacity. Addition of zeolite reduce K^+ leaching from the substrate [Jayasinghe et al. 2010]. Zeolite used as an additive to fertilizers increases nutrient components retention such as N, K, Ca, Mg and microelements which improves soil quality. Zeolite had additive effect on retention of the components in the root zone and increased their availability to the plants during cultivation. The use of zeolites limits the movement of nutrients in the deeper layers of the soil, especially in sandy soils and causes less their damages [Nowak 2000, Polat et al. 2004, Ahmed et al. 2010].

Due to the high porosity and crystalline structure zeolites have the ability to store water up to 60%. Absorption and vaporization of water at the same time does not destroy the structure of the zeolite crystals. However, the large weight of the zeolite, and therefore expensive transport of the substrate may be an obstacle to the propagation of zeolite as horticultural substrate [Cervelli et al. 1994].

The aim of this study was to evaluate several substrates, including substrates with zeolite on seed germination and further growth and development of *Catharanthus roseus* and *Gazania rigens* var. *rigens* seedlings. The research was aimed at assessing the usefulness of zeolite in the production of this plants.

MATERIAL AND METHODS

The research was performed at the Research Station of the Chair of Horticulture (14°31'E and 53°26'N) in years 2009–2010. *Catharanthus roseus* 'Burgundy Punch' and *Gazania rigens* var. *rigens* 'Kiss Mahogany' constituted the plant material. The experiment was started from 10th of March in the first year of research and 14th of March in the second year of research. The seeds were sown into previously prepared substrates, made on the basis of raised peat and zeolite in two fractions: FFZ – fine fraction of zeolite – 0.3–0.5 mm, CFZ – coarse fraction of zeolite – 1–2.5 mm). The basic chemical properties of peat and substrate ready for sowing are presented in Table 1. The following substrates were used: 1. sphagnum peat (deacidified to the level of pH 6,0), 2. substrate ready for sowing AURA of Hollas, 3. peat + FFZ 1:1, 4.

peat + FFZ 3:1, 5. peat + CFZ 1:1, 6. peat + CFZ 3:1. After preparation of substrates the pH all of them was adjusted to the level 6,0. The Azofoska (N 13.6, P_2O_5 6.4, K_2O 19.1, MgO 4.5, B 0.045, Cu 0.180, Fe 0.17, Mn 0.27, Mo 0.040, Zn 0.045) fertiliser was added to all prepared substrates (apart from substrate ready to sowing) at a dose of 2 g·dm^{-3}.

Table 1. The basic chemical properties of sphagnum peat and ready substrat for sowing AURA used in the study (average from years)

	pH (in H_2O)	Content (mg·dm^{-3})						Salinity (g NaCl·dm^{-3})
		$N\text{-}NO_3$	P	K	Ca	Mg	Cl	
Sphagnum peat	3.6	21	74	14	121	39	58	0,47
Ready substrat for sowing AURA	5.5	181	131	402	1646	172	18	1,86

Table 2. The effect of substrates on growth and flowering of *Catharanthus roseus* 'Burgundy Punch' (synthesis of years)

Trait	Substrates for planting	Substrates for sowing						
		1*	2	3	4	5	6	mean
Height of plants (cm)	peat	23.3 ac	21.2 bf	23.3 ac	23.8 a	23.4 ab	21.1 cf	22.7 A
	peat + FFZ 20%	20.8 ef	22.4 ae	19.5 f	20.2 f	21.0 df	19.6 f	20.6 B
	peat + CFZ 20%	22.4 ae	22.6 ae	23.0 ae	21.0 df	24.6 a	23.2 ad	22.8 A
	mean	22.2 A	22.0 A	21.9 A	21.6 A	23.0 A	21.3 A	–
Diameter of plants (cm)	peat	24.6 ac	23.7 ad	24.2 ac	23.9 ac	22.2 bf	22.4 af	23.5 A
	peat + FFZ 20%	23.4 ae	22.9 af	22.4 af	20.5 ef	20.2 f	20.6 df	21.7 B
	peat + CFZ 20%	23.8 ac	24.4 ac	25.1 ab	22.7 af	25.5 a	21.8 cf	23.9 A
	mean	23.9 A	23.6 A	23.9 A	22.4 AB	22.6 AB	21.6 B	–
Number of leaves (pcs.)	peat	93.2 a	87.4 ac	78.0 df	79.6 ce	81.8 be	68.6 gi	81.4 A
	peat + FFZ 20%	70.2 fh	66.6 gj	62.0 hj	59.4 j	60.9 j	62.3 hj	63.6 B
	peat + CFZ 20%	89.3 ab	89.1 ab	79.4 ce	74.4 eg	82.8 be	86.3 ad	83.6 A
	mean	84.2 A	81.0 A	73.1 B	71.1 B	75.2 B	72.4 B	–
Number of flower buds (pcs.)	peat	25.4 ac	22.9 be	22.9 be	29.1 a	28.1 ab	20.5 cg	24.8 A
	peat + FFZ 20%	14.8 g	16.8 fi	18.1 di	13.0 i	14.6 hi	17.1 ei	15.7 C
	peat + CFZ 20%	23.8 ad	23.0 bd	18.5 di	21.9 cf	23.4 ad	19.3 dh	21.6 B
	mean	21.3 A	21.0 A	19.8 AB	21.3 A	22.0 A	18.9 B	–
Number of flowers (pcs.)	peat	21.0 ab	19.2 ac	23.2 a	21.1 ab	18.0 ad	14.0 ce	19.4 A
	peat + FFZ 20%	14.4 ce	12.4 de	12.9 de	12.3 de	12.2 e	11.3 e	12.6 B
	peat + CFZ 20%	14.3 ce	15.8 be	14.7 ce	14.2 ce	14.5 ce	14.0 ce	14.6 B
	mean	16.6 A	15.8 AB	16.9 A	15.9 A	14.9 B	13.1 C	–

* – explanations: 1 – deacidified peat, 2 – substrate ready for sowing, 3 – peat + FFZ 1:1, 4 – peat + FFZ, 3:1, 5 – peat + CFZ 1:1, 6 – peat + CFZ 3:1; ** – means marked with the same letter do not differ significantly

The seeds were sown into boxes in an amount of 100 pieces of both tested taxon for each of substrate. After sowing the seeds, the substrate was sprayed with a fungicidal agent Previcur 607 SL in concentration 0.15%, covered with perforated film to retain the moisture and placed in a greenhouse with a medium-high air temperature 18–20°C. During the experiment, the rate of emergence (germination) and number of the seedlings were observed; in the fourth week of the cultivation, morphological features of the young plants were measured: height of seedlings (*Catharanthus*), length of leaves (*Gazania*), number of leaves and the length of roots. There were measured 25 randomly selected seedlings from each variant (5 replications × 5 plants).

At the second stage of the experiment, seedlings from each variant were planted into pots of 10 cm and capacity 0.5 dm^{-3} in three substrates including: I. deacidified peat, II. peat with the addition of 20% FFZ, III. peat with the addition of 20% CFZ. The Azofoska fertiliser was added to all substrates at a dose of 5 $g \cdot dm^{-3}$. Doses of fertilizers was determined on the basis of earlier research conducted with other bedding plants [Janicka, Dobrowolska 2012].

Table 3. The effect of substrates on growth and flowering of *Gazania rigens* var. *rigens* 'Kiss Mahogany' (synthesis of years)

Trait	Substrates for planting	Substrates for sowing						
		1*	2	3	4	5	6	mean
Width of the leaf rosette (cm)	peat	28.6 ab**	30.4 a	27.1 bd	28.3 ab	27.7 bc	27.9 ac	28.3 A
	peat + FFZ 20%	28.2 ab	28.2 ab	23.4 f	27.9 ac	27.8 ac	28.3 ab	27.3 A
	peat + CFZ 20%	26.5 cd	25.8 de	24.7 ef	27.4 bd	28.7 ab	28.1 ac	26.9 A
	mean	27.8 A	28.1 A	25.1 B	27.9 A	28.0 A	28.1 A	–
Number of leaves (pcs.)	peat	55.8 g	56.2 g	69.5 a	60.9 df	62.1 de	67.2 ab	61.9 A
	peat + FFZ 20%	44.3 i	48.3 hi	44.9 hi	49.0 h	65.5 ac	60.2 dg	52.0 B
	peat + CFZ 20%	57.2 fg	61.3 cf	57.7 eg	64.8 bd	59.8 eg	66.9 ab	61.3 A
	mean	52.4 C	55.3 BC	57.3 B	58.2 B	62.4 A	64.8 A	–
Number of flower buds (pcs.)	peat	8.9 eg	9.7 be	11.1 ac	8.9 eg	9.4 cf	7.9 gh	9.3 A
	peat + FFZ 20%	7.9 gh	7.7 h	9.1 cf	7.9 gh	11.7 ab	12.2 a	9.4 A
	peat + CFZ 20%	8.6 fh	8.9 eg	9.3 cf	9.7 be	9.0 df	11.0 ad	9.4 A
	mean	8.4 B	8.7 AB	9.8 A	8.8 AB	10.0 A	10.3 A	–
Number of flowers (pcs.)	peat	1.8 c	1.6 de	1.1 fg	1.3 df	1.6 de	3.1 a	1.8 A
	peat + FFZ 20%	1.2 eg	1.9 c	1.7 cd	1.0 fg	0.8 g	1.2 eg	1.3 B
	peat + CFZ 20%	1.1 fg	1.6 de	1.2 eg	1.0 fg	1.8 c	2.6 b	1.6 AB
	mean	1.4 BC	1.7 B	1.3 BC	1.1 C	1.4 BC	2.3 A	–

* – explanations: 1 – deacidified peat, 2 – substrate ready for sowing, 3 – peat + FFZ 1:1, 4 – peat + FFZ, 3:1, 5 – peat + CFZ 1:1, 6 – peat + CFZ 3:1; ** – means marked with the same letter do not differ significantly

After planting young plants were preventively sprayed with Previcur and then placed on tables in an unheated plastic film-covered tunnel at distances of 10 × 10 cm. In the period from 11 to 14th of April in both years of the research, plants in pots were placed on 120 cm-wide beds, at distances of 20 × 15 cm. Regardless of the year of the research, the experiments were ended between the 16th and 20th of July.

When the plants achieved their full ornamental value, the morphological features of the plants were measured: height of plants, diameter of plants (*Catharanthus*), width of the leaf rosette (*Gazania*), the number of leaves, the number of buds and the number of flowers. The experiments were conducted in a total randomisation system as one-factor and two-factors ones in 5 replications. There were 5 plants in 1 replication. The results of the measurements of morphological features were analysed statistically using a one-factor and two-factor variance analysis in the Statistica 10 software. Tukey's test was used for the verification of statistical significance between the means at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The type of substrate used for sowing affected in an non-uniform way the dynamics of emergence and the percentage of germinating seeds of Madagascar Periwinkle and Treasure Flower. According to some authors, Rydenheim [2007] and Yilmaz et al. [2014], adding zeolite to the soil positively affects the emergence of cucumber and the later development of seedlings. Beneficial influence of zeolite can be an effect of high soil moisture – owing to strong absorbing capacity, water retention ability, and a better use of nutrients [Fotouhi Ghazvini et al. 2007]. This assumption was not confirmed in our research. The fastest germination of Madagascar Periwinkle seeds was observed in peat soil, i.e. already 3 days after sowing, and the first occurring seedlings were stated in soils with CFZ addition only after 6 days (fig. 1). According to Yilmaz et al. [2014], using zeolite as a uniform soil limits the emergence of cucumber. In the performed research increasing zeolite volume in the soil was decisive in decreasing the percentage of germinating seeds. In the case of Madagascar Periwinkle, this percentage in soil composed of peat and FFZ 3:1 v/v was the highest and equalled 100.0% ; the smallest percentage was in soil composed of peat and CFZ 1:1 v/v – 76.5%. Treasure Flower seeds started germinating earlier and emerged more uniformly than Madagascar Periwinkle seeds, and the percentage of germinating seeds varied between 89.5% in the case of ready-made sowing bed to 100.0% in the case of soil prepared on the base of peat and FFZ 3:1 v/v. Also, increasing the percentage of CFZ to 1:1 v/v in the sowing bed, caused a lag and prolongation of emergence phase in these species (fig. 2).

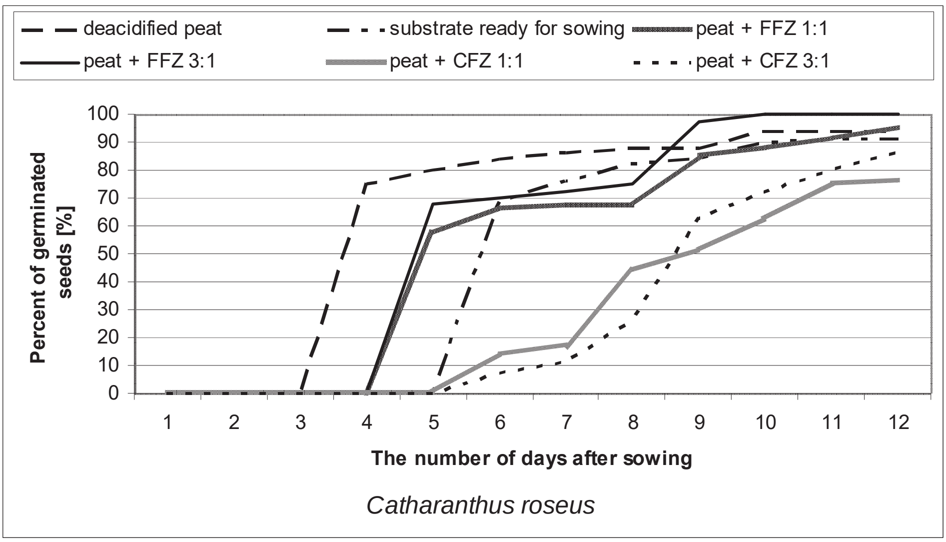


Fig. 1. The effect of substrates on germination of *Catharanthus roseus* ‘Burgundy Punch’ seeds (average of years)

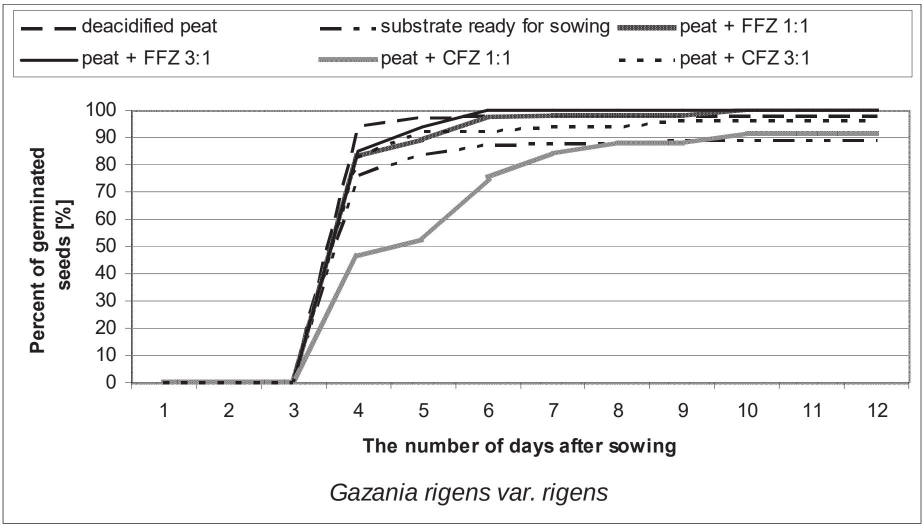
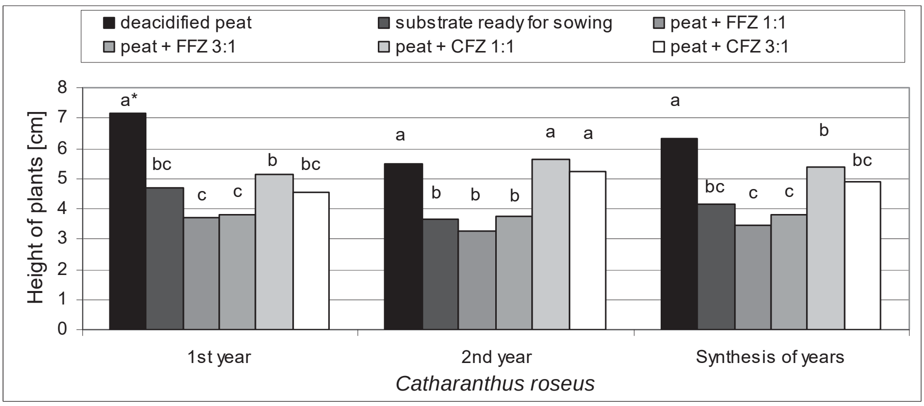


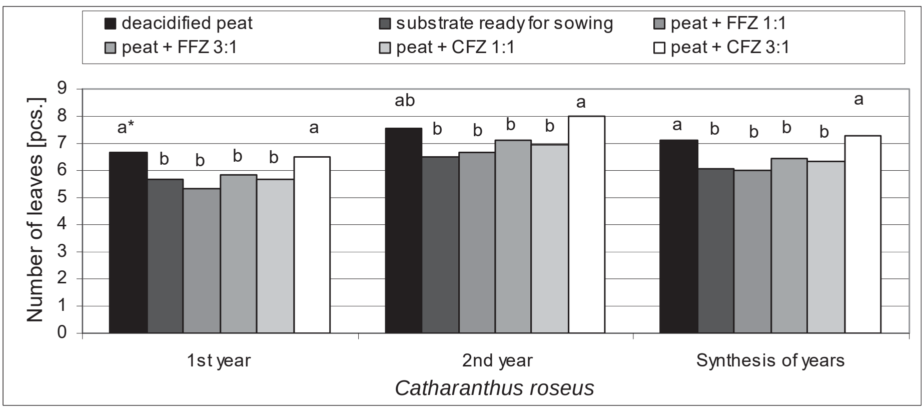
Fig. 2. The effect of substrates on germination of *Gazania rigens* var. *rigens* 'Kiss Mahogany' seeds (average of years)



* – means marked with the same letter do not differ significantly

Fig. 3. The effect of substrates on height of plants of *Catharanthus roseus* 'Burgundy Punch' seedlings (1st and 2nd year and synthesis of years)

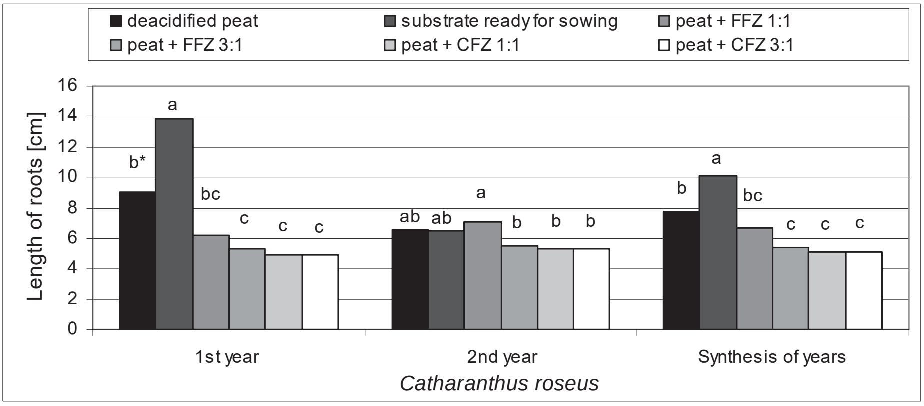
The evaluation of acquired seedlings indicated to an important influence of the type of sowing bed on studied morphological qualities of Madagascar Periwinkle's and Treasure Flower's young plants. Many authors, such as Rydenheim [2007], Janicka and Dobrowolska [2011] Mahboub Khomami [2011], Mohammadi Torkashvand [2012], Yilmaz et al. [2014], assume that zeolite soil additive in the amount from 10.0 to 50.0% improves those qualities, and at the same time positively affects the growth of plants. According to Yilmaz et al. [2014], using zeolite as a uniform soil for sowing negatively affects the height of seedlings as well as their fresh mass. In the first year of research – which is confirmed by annual average results – the highest plants of Madagascar Periwinkle were acquired from peat soil, equally second in height were seedlings growing in soils with CFZ additive (fig. 3). According to Mohammadi Torkashvand [2012], adding zeolite to soil decided about increasing the number of formed leaves in Dieffenbachia. In our studies, based on the synthesis of results, it was demonstrated that Madagascar Periwinkle plants formed most leaves while being sown on a peat soil which formed of peat and CFZ 3:1 v/v (fig. 4). Janicka and Dobrowolska [2011] are authors who in their experiments proved that zeolite used as an additive to peat soil in the proportion of 1:3 v/v, stimulates rooting of cuttings in coarse column, especially in forming roots longer than 3 cm. The length of Madagascar Periwinkle roots in our research was affected also by the type of soil used for sowing. In 2009, the longest roots – which is confirmed by annual average research results – were formed by seedlings growing in a ready-made sowing bed, however in 2010 – seedlings obtained in soil prepared from peat and FFZ 1:1 v/v, although they had not substantially differed from seedlings growing on peat and in a ready-made sowing bed according to discussed feature (fig. 5).



* – means marked with the same letter do not differ significantly

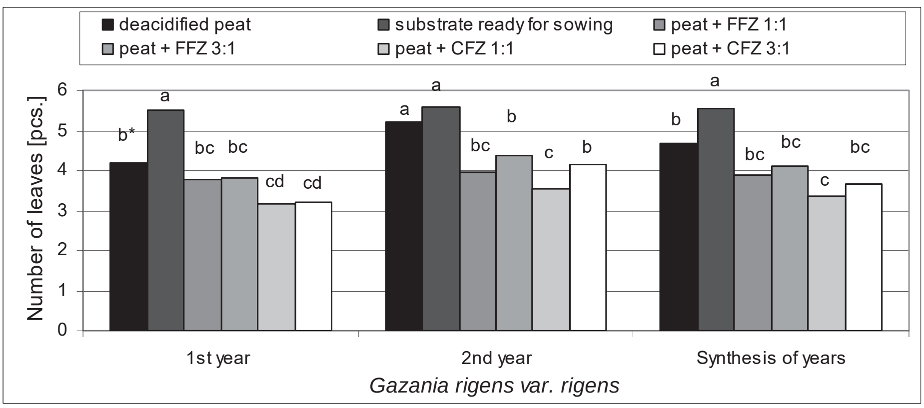
Fig. 4. The effect of substrates on number of leaves of *Catharanthus roseus* 'Burgundy Punch' seedlings (1st and 2nd year and synthesis of years)

Results of research performed by Bahadoran et al. [2012] indicate that zeolite added to soil increases the surface of leaves as well as their chlorophyll content. They confirm that also in their articles Abdi et al. [2006] and Nazari et al. [2007]. According to their opinion, it can be the result of better access to different nutrients and water by plants with zeolite use. These results were not confirmed in our research, because the ready-made sowing bed had an important influence on increasing the overall number of formed leaves by Treasure Flower seedlings (fig. 6). It was also shown that plants growing in this soil during the first year created significantly longer leaves than those obtained in soil with peat and zeolite 1:1 composition, and in the next year even longer from the ones cultivated on peat and FFZ 1:1 v/v bed (fig. 7). Based on the synthesis of results from a previous year, it was stated that the increase of Treasure Flower root length is positively affected by zeolite addition to the soil. Shortest roots were identified in seedlings obtained from peat soil (fig. 8). It is confirmed by authors Yilmaz et al. [2014], according to whom natural zeolite can be used for optimising germination and root formation.



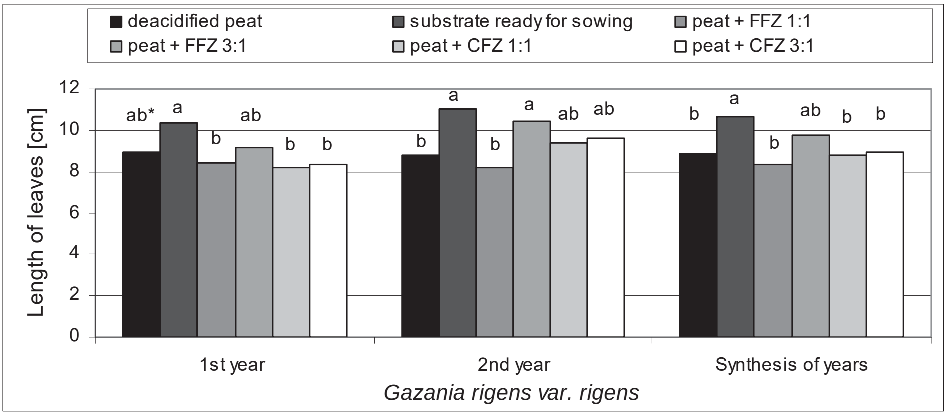
* – means marked with the same letter do not differ significantly

Fig. 5. The effect of substrates on length of roots of *Catharanthus roseus* 'Burgundy Punch' seedlings (1^{st} and 2^{nd} year and synthesis of years)



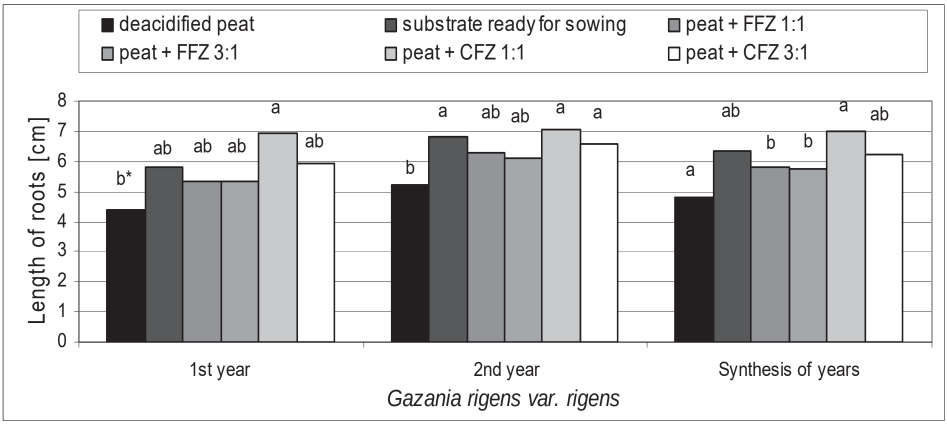
* – means marked with the same letter do not differ significantly

Fig. 6. The effect of substrates on number of leaves of *Gazania rigens* var. *rigens* 'Kiss Mahogany' seedlings (1^{st} and 2^{nd} year and synthesis of years)



* – means marked with the same letter do not differ significantly

Fig. 7. The effect of substrates on length of leaves of *Gazania rigens* var. *rigens* 'Kiss Mahogany' seedlings (1st and 2nd year and synthesis of years)



* – means marked with the same letter do not differ significantly

Fig. 8. The effect of substrates on length of roots of *Gazania rigens* var. *rigens* 'Kiss Mahogany' seedlings (1st and 2nd year and synthesis of years)

During further cultivation and after plant transplantation to new soil bed, it was stated that both sowing beds and their planting usage had an important influence on the morphological features of researched plants. It was indicated that among the soils used for planting, the analysed features of Madagascar Periwinkle were least favourably affected by soil with FFZ additive in the amount of 20%. Plants cultivated in this soil were shorter, had smaller diameter, fewer leaves, and they also formed fewer flower buds than plants obtained in other variants. Based on the synthesis of results, it was stated that zeolite additive in the soil limits the number of formed flowers. Other authors' research, Nazari et al. [2007] and Bahadoran et al. [2012], indicate that although zeolite additive in soil stimulates the growth of vegetative parts, it often does not affect the quantity of flowers, and often reduces it.

In researches conducted by Chen et al. [2000] changes in the properties of the substrates after the introduction of the zeolite did not cause adverse effects on the plants, their biomass increased as compared to control plants. Substrates used for sowing did not significantly-affect the height of Madagascar Periwinkle plants in further cultivation. It was observed, however, that plants sowed in peat, ready-made sowing bed, and the mixture of peat and FFZ 1:1 v/v had a significantly larger diameters than plants whose seeds were sown over soil with CFZ 3:1 v/v additive. Madagascar Periwinkle plants sown in peat and to ready-made sowing bed also formed significantly more leaves than plants in other variants. CFZ additive unfavourably affected the number of formed flowers (independent of percentage in soil) and flower buds (in 3:1 v/v proportion with peat).

Substrates with the addition of zeolite had a beneficial effect on the growth of some pot plants, even if only a small amount of zeolite was added [Nowak 2000]. In the case of Treasure Flower, planting soil did not significantly affect the width of leaf rosettes and the number of flower buds, however, it affected other features. The fewest leaves of Treasure Flower plant were formed in soil with 20% FFZ additive. More flowers were stated in Treasure Flower planted on peat ground, and according to this feature, plants significantly differed only from plants cultivated in soil with FFZ additive in the amount of 20% (tab. 3).

Concerning the issue of soil beds used for sowing, the smallest leaf rosettes were observed in plants with seeds sown in the mixture of peat and FFZ 1:1 v/v. Soils with CFZ additive, regardless of proportions, were the most favourable in forming the number of leaves. In the bed composed of peat and CFZ 3:1 v/v, Treasure Flower plants formed the biggest number of flowers.

In the case of all evaluated features, a crucial interaction was found between the factors compared in the research. Soils with zeolite additive can be recommended for the cultivation of some decorative and agricultural crops [Cervelli 1994, Gul et al. 2005, Jayasinghe et al. 2010], however soil granulation or proportions require further research owing to its unequal influence on individual species.

CONCLUSIONS

1. Type of substrate used for seeding and planting has an effect on growth and development of *Gazania rigens* var. *rigens* and *Catharanthus roseus* seedling.

2. Addition of zeolite to the peat improves seedling root development, while limiting the number of leaves of *Gazania rigens* var. *rigens*.

3. Plants of *Gazania rigens* var. *rigens* sown on substrates with coarse zeolite – regardless of the type of substrate used for further cultivation – produce more flower buds than plants from other substrates.

4. Substrate ready for sowing affects better root development in *Catharanthus roseus* than other.

5. The least favorable for the growth and flowering *Catharanthus roseus* effect stated at the substrate with fine zeolite in an amount of 20%; plants have been lower had fewer leaves, and definitely less flower buds and flowers.

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ZEOLITY JAKO KOMPONENTY PODŁOŻY W UPRAWIE ROŚLIN OZDOBNYCH – *Catharanthus roseus* (L.) G. i *Gazania rigens* var. *rigens* (L.) Gaertn.

Streszczenie. W Polsce zeolity – naturalne glinokrzemiany o doskonałych właściwościach sorpcyjnych i jonowymiennych – są stosunkowo mało rozpowszechnionymi podłożami. Podłoża z dodatkiem zeolitu mają lepsze właściwości chemiczne i fizyczne: całkowitą porowatość czy zdolność zatrzymywania wody. Celem badań była ocena przydatności zeolitu do produkcji rozsady odmian *Catharanthus roseus* i *Gazania rigens* var. *rigens*. Do wysiewu nasion zastosowano następujące podłoża: 1. torf odkwaszony, 2. gotowe podłoże do wysiewu AURA firmy Hollas, 3. torf + zeolit drobny 1:1, 4. torf + zeolit drobny 3:1, 5. torf + zeolit gruby 1:1, 6. torf + zeolit gruby 3:1. Do wszystkich podłoży dodano nawóz Azofoska w dawce 2 g·dm^3. W drugim etapie doświadczenia rozsadę z każdego wariantu posadzono do trzech podłoży, które stanowił: I. torf odkwaszony, II. torf z dodatkiem zeolitu drobnego w ilości 20%, III. torf z dodatkiem zeolitu grubego w ilości 20%. Dodatek zeolitów do podłoża do wysiewu poprawia rozwój korzeni siewek gazanii przy jednoczesnym ograniczeniu wzrostu pędów. Rośliny gazanii, których nasiona wysiewano do podłoży z dodatkiem zeolitu – niezależnie od rodzaju użytego substratu do dalszej uprawy – wytworzyły więcej pąków kwiatowych niż pozostałe rośliny. Najmniej korzystne dla wzrostu i kwitnienia barwinka różowego było podłoże z dodatkiem drobnego zeolitu w ilości 20%; rośliny były niższe, miały mniej liści i zdecydowanie słabiej kwitły.

Słowa kluczowe: frakcja zeolitu, kwitnienie, nasiona, podłoże, rośliny rabatowe, wzrost

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