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THE EFFECT OF PHOSPHORUS NUTRITION AND MYCORRHIZATION ON GROWTH, FLOWERING AND MACRONUTRITIONAL STATUS OF GERANIUM (*Pelargonium* × *hortorum* L.H. BAILEY) [1]

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Introduction

Many bedding plants are mycorrhiza-dependent. Plants with mycorrhizae are potentially more effective at mineral element and water acquisition and can grow better under stress conditions [AUGÉ 2001]. The technique employed for bedding plant propagation by cuttings does not allow the formation of mycorrhizae, because rooting substrates are usually sterilized or devoid of arbuscular mycorrhizal fungi (AMF). It was shown earlier that mycorrhization of some bedding plants is significantly reduced by high P concentration [KOIDE et al. 1999]. Since the AM fungi are dependent on host photosynthesis, substantial amount of assimilates produced in leaves is required for growth of fungus [JAKOBSEN, ROSENDAHL 1990]. Carbohydrate limitation may inhibit growth rate of host plants [FITTER 1991]. On the other hand, inoculation of cuttings during rooting in greenhouses may be beneficial for further growth of bedding plants in outdoor conditions.

The aim of this work was to investigate the effects of phosphorus nutrition and AMF inoculation on growth, flowering, and nutritional status of geranium (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange') during cultivation on ebb-and-flow benches.

Material and methods

Rooted cuttings of geranium were used for the experiments. The cuttings were planted into sphagnum peat : perlite medium (3 : 1,v/v), pH 6.1. The sub-

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strate was inoculated by adding 1 dm^3 mixture of osteospermum (*Osteospermum ecklonis* (DC.) NORL.) root pieces and substrate inoculated earlier with Endorize – TA AMF inoculum, containing a mixture of different *Glomus* species (Biorize Sarl, France) to 10 dm^3 of inoculated peat substrate. The substrate was not sterilized. The peat used in this experiment was devoid of AM fungi as confirmed by the absence of colonization with the non-inoculated treatments. Mycorrhizal infection was estimated at the end of cultivation, after staining the roots with trypan blue [PHILLIPS, HAYMAN 1970].

The plants were cultivated under glass from May 27th to July 18th. The night ventilation set-point in the greenhouse was kept at 16°C, the day ventilation set-point at 22°C. Plants were fertigated by subirrigation (ebb-and-flow benches, Clauhan Projekt A/S, Denmark). The nutrient solution contained: N-NO_3 12.08, K 5.49, Ca 3.1, Mg 0.76, S 1.1 ($mmol \cdot dm^{-3}$), and Mn 10, Fe 22, B 22, Cu 0.5, Mo 1, Zn 3 ($\mu mol \cdot dm^{-3}$). Two P treatments of 0.28 and 1.40 $mmol \cdot dm^{-3}$ were applied. Electrical conductivity (EC) and pH of the nutrient solutions were 1.8 $S \cdot m^{-1}$ and 6.0, respectively, regardless of P treatment.

At the beginning of flowering whole plants were harvested. Fresh and dry weights of upper parts, plant height, shoot number, number of days from planting to flowering, numbers of flower buds and flowers and root colonization by AMF were determined.

Leaf nutrient contents and chemical properties of growing media were determined as described earlier [TREDER et al. 1998].

The treatments were statistically analyzed by the analysis of variance and means were compared with the Duncan's multiple range test at 95% level of significance.

Results and discussion

A month after inoculation the inoculated plants were infected with mycorrhizal fungi. The control plants had no root infection. The mycorrhizal fungal colonization of the plants that were fertilized at 0.28 mmol $P \cdot dm^{-3}$ was 83% while those fertilized at 1.40 mmol $P \cdot dm^{-3}$ was 77%. At the end of culture the plants were similar in appearance. The growth responses to P and mycorrhizal inoculation were small (Tab. 1). A higher P level slightly increased fresh weight and height of inoculated plants, but did not affect non-inoculated ones. Mycorrhization slightly decreased the height of plants grown at a lower P level, but did not affect the height of plants grown at a higher P level. Typical symptom of P deficiency – a reddish coloration of leaves due to the increased anthocyanin production [SHUMAN 1992] were not observed on plants grown at 0.28 mmol $P \cdot dm^{-3}$. The effect of P level and mycorrhization on flowering of geranium is presented in Tab. 2. The non-inoculated and inoculated plants grown at 1.40 mmol $P \cdot dm^{-3}$ had more flower buds, than those grown at 0.28 mmol $P \cdot dm^{-3}$. No effect of mycorrhization on flowering of geranium was observed.

Table 1; Tabela 1

The effects of P level and mycorrhizal inoculation on the growth of geranium (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

Wpływ poziomu P i mikoryzacji na wzrost pelargonii rabatowej (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

P level Poziom fosforu ($mmol \cdot dm^{-3}$)	Mycorrhizal inoculation Mikoryzacja	Fresh matter of plants Świeża masa rośliny (g)	Dry weight of plants Sucha masa rośliny (g)	Height of plants Wysokość rośliny (cm)	Shoot number Liczba pędów
0.28	–	59.3ab	8.3a	29.1b	3.6ab
	+	55.5a	7.6a	26.2a	3.3a
1.40	–	61.8ab	7.8a	30.4b	4.3c
	+	65.7b	8.5a	29.1b	4.0bc
Significance; Istotność					
P level; Poziom P		xx	n.s.	xxx	xxx
Mycorrhizal inoc.; Mikoryzacja		n.s.	n.s.	xxx	xx
P level x mycor.; Poziom P x mikor.		n.s.	x	n.s.	n.s.

The means followed by the same letter(s) do not differ at $\alpha = 0.05$; n.s., x, xx, xxx – non significant or significant at $\alpha = 0.1, 0.05, 0.001$, respectively; Średnie oznaczone tymi samymi literami nic różnią się istotnie przy $\alpha = 0,05$; n.s., x, xx, xxx – nieistotne lub istotne przy odpowiednio $\alpha = 0,1, 0,05, 0,001$.

Table 2; Tabela 2

The effects of P level and mycorrhizal inoculation on the flowering of geranium (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

Wpływ poziomu P i mikoryzacji na kwitnienie pelargonii rabatowej (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

P level Poziom fosforu ($mmol \cdot dm^{-3}$)	Mycorrhizal inoculation Mikoryzacja	Number of days to flowering Liczba dni do zakwitania	Number of undeveloped inflorescences Liczba nierozwinietych kwiatostanów	Number of open inflorescences Liczba rozwiniętych kwiatost.
0.28	–	47.6a	2.9a	1.8a
	+	48.5ab	2.7a	1.7a
1.40	–	48.4ab	4.3b	1.4a
	+	50.1b	3.9b	1.4a
Significance; Istotność				
P level; Poziom P		n.s.	xxx	n.s.
Mycorrhizal inoc.; Mikoryzacja		x	n.s.	n.s.
P level x mycor.; Poziom P x mikoryz.		n.s.	n.s.	n.s.

Explanations see Table 1. Objaśnienia jak w tabeli 1

The enhanced host plant acquisition of mineral nutrients, especially P, as a result of mycorrhization is very well documented [MARSCHNER, DELL 1994]. In geranium cultivated on ebb-and-flow benches mycorrhizal plants took up more P than non-inoculated ones (Tab. 3). A higher P concentration in nutrient solution resulted also in its better uptake and consequently increased P content in leaf tissue in both non-inoculated and inoculated plants. The leaf content of nitrogen was not affected neither by P nutrition nor by mycorrhization. At a higher P

level, both inoculated and non-inoculated plants had less Ca in leaves. Inoculation with AMF decreased K and Ca contents and increased Mg content of leaves. The lower potassium content in the shoots of inoculated plants can be explained by the reduction in root surface area and a relatively low K transport by hyphae [GEORGE et al. 1992]. Reports on the possible uptake of Ca and Mg by hyphae are contradictory, increased and decreased uptake of these elements in mycorrhizal plants comparing to non-inoculated ones was observed [GEORGE 2000]. Such conflicting results may be related to specific properties of AMF isolates or to experimental conditions.

Table 3; Tabela 3

The effects of P level and mycorrhizal inoculation on the mineral element content of geranium leaves (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

Wpływ poziomu P i mikoryzacji na zawartość składników mineralnych w liściach pelargonii rabatowej (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

P level Poziom fosforu (mmol·dm^{-3})	Mycorrhizal inoculation Mikoryzacja	Mineral element content (g·kg^{-1} dry matter) Zawartość składników mineralnych (g·kg^{-1} suchej masy)				
		N	P	K	Ca	Mg
0.28	–	40a	1.1a	35b	19d	1.3a
	+	38a	2.1b	29ab	13c	1.8b
1.40	–	38a	2.0b	33b	11b	1.2a
	+	36a	4.1c	23a	9a	2.1b
Significance; Istotność						
P level; Poziom P		n.s.	xxx	x	xxx	n.s.
Mycorrhizal inoc.; Mikoryzacja		n.s.	xxx	xxx	xxx	xxx
P level x mycor.; Poziom P x mikoryz.		n.s.	xxx	n.s.	xx	n.s.

Explanations see Table 1; Objaśnienia jak w Tabeli 1

Table 4; Tabela 4

The effects of P level and mycorrhizal inoculation on chemical characteristic of growing medium at the end of geranium culture (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

Wpływ poziomu P i mikoryzacji na właściwości chemiczne podłoża po zakończeniu uprawy pelargonii rabatowej (*Pelargonium* × *hortorum* L.H. BAILEY 'Tango Orange')

P level Poziom fosforu (mmol·dm^{-3})	Micorrhizal inoculation Mikoryzacja	pH	Salt concentration Stężenie soli (g·dm^{-3})	Macroelement content Zawartość makroelementów (mg·dm^{-3})				
				$N\text{-}NO_3$	P	K	Ca	Mg
0.28	–	7.1a	1.7b	350a	33a	696a	1066a	72a
	+	6.9a	2.2c	457b	35a	753b	1054a	73a
1.40	–	7.2a	1.4a	353a	106c	647a	1027a	74a
	+	7.1a	1.8b	437b	90b	745b	1102a	88a
Significance; Istotność								
P level, poziom P		n.s.	xxx	n.s.	xxx	n.s.	n.s.	n.s.
Mycorrhizal inoc.; Mikoryzacja		n.s.	xxx	xxx	xx	xx	n.s.	n.s.
P level x mycor.; Poz. P x mik.		n.s.	xxx	n.s.	xxx	xx	n.s.	n.s.

Explanations see Table 1; Objaśnienia jak w Tabeli 1

P level and mycorrhization did not affect significantly the pH of growing media (Tab. 4). Usually the pH of soil is decreased under a direct influence of hyphae [LI et al. 1991]. Measurements of total soluble salts in the growing medium at the end of cultivation of geranium showed that both AMF and P level significantly affected salt accumulation in growing medium (Tab. 4). Higher amont of total soluble salts in AMF inoculated media can be due to a lower K acquisition of mycorrhizal geranium and as a result a higher content of K in growing medium at the end of cultivation. A higher N content of the growing medium inoculated with AMF can obviously also affect total soluble salts, but cannot be explained by a lower N acquisition in leaves of AM plants. The differences in chemical characteristics of a lower layer of growing media could be due to different growth and distribution of root system of AMF inoculated and non-inoculated plants. Lower amount of total soluble salts in media fertilized with a higher P is also difficult to explain. The mineral element contents of root system and other organs (except fully developed leaves) and extraradical hyphae were not determined, so the total amounts of mineral elements taken up from different media are unknown. Mycorrhizal inoculation did not affect Ca, and Mg contents of the growing media. A higher level of P in nutrient solution increased P content in the growing media, but it did not affect other macro-nutrients determined.

Conclusions

1. High percentage of geranium root colonization by AMF during cultivation on ebb-and-flow benches is possible under both, low (0.28) and high (1.40) mmol·dm P levels in the nutrient solution.
2. The effect of mycorrhization on growth and flowering of geranium cultivated on ebb-and-flow benches under a high fertility level is negligible.
3. Inoculation with AMF changes the macronutritional status of geranium leaves.

References

AUGÈ R. M. 2001. *Water relations, drought and vesicular-arbuscular mycorrhizal symbiosis.* Mycorrhiza 11: 3 –42.

FITTER A.H. 1991. *Costs and benefits of mycorrhiza: Implications for functioning under natural conditions.* Experientia 47: 350–355.

GEORGE E. 2000. *Nutrient uptake,* in: *Arbuscular mycorrhizas: physiology and function.* Kapulnik Y., Douds D.D. Jr. (Eds), Kluver Academic Publishers, Dortrecht-/Boston/London: 307–343.

GEORGE E., HÄUSSLER K.U., VETTERLEIN D., GORGUS E., MARSCHNER H. 1992. *Water and nutrient translocation by hyphae of Glomus species.* Ca. J. Bot. 70: 2130–2137.

JAKOBSEN I., ROSENDAHL L. 1990. *Carbon flow into soil and external hyphae from roots of mycorrhizal cucumber plants.* New Phytol. 115: 77–83.

KOIDE R.T., LANDHERR L.L., BESMER Y.L., DETWEILER J.M., HOLCOMB E.J. 1999. *Strategies for mycorrhizal inoculation of six annual bedding plant species.* HortScience 34: 1217–1220.

LI X.L., GEORGE E., MARSCHNER H. 1991. *Phosphorus depletion and pH decrease at the root-soil and hyphae-soil interfaces of VA mycorrhizal white clover fertilized with ammonium.* New Phytol. 119: 397–404.

MARSCHNER H., DELL B. 1994. *Nutrient uptake in mycorrhizal symbiosis.* Plant Soil 159: 89–102.

PHILLIPS J.M., HAYMAN D.S. 1970. *Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection.* Transactions of the British Mycological Society 55: 150–160.

SHUMAN L.M. 1992. *Mineral nutrition,* in: *Plant-Environment Interactions.* Wilkinson R.E. (Ed.) Marcel Dekker, Inc., New York, Basel, Hong Kong: 149–182.

TREDER J., MATYSIAK B., NOWAK J.S., NOWAK J. 1998. *The effect of different potting media on growth and mineral nutrient content of leaves of Ficus benjamina cultivated on ebb-and-flow benches.* Folia Hortic. 10: 85–93.

Key words: *Pelargonium* × *hortorum* L.H. BAILEY, mycorrization, P nutrition, macronutritional status of plant

Summary

Greenhouse experiments were conducted to evaluate the effects of arbuscular mycorrhizal fungi (AMF) and phosphorus nutrition on root colonization, growth, flowering and macronutrilional status of geranium cultivated on ebb-and-flow benches. One month after inoculation high percentages of root colonization by AMF under both, low (0.28) and high (1.40) mmol $P \cdot dm^{-3}$ levels in the nutrient solution were noted. Mycorrhization decreased slightly the height of plants grown at a lower P level, but it did not affect the height of plants grown at a higher P level. A higher P level increased slightly fresh weight and height of inoculated plants, but it did not affect non-inoculated ones. A higher P level also increased shoot and flower bud numbers in both non-inoculated and inoculated plants. Inoculated plants contained more P and Mg in leaves and less K and Ca than non-inoculated ones. A higher P concentration in the nutrient solution resulted in its higher content in both non-inoculated and inoculated plants. At the end of cultivation higher amountg total soluble salts and N and K contents in AMF inoculated media were measured. A higher level of P in the nutrient solution increased P content in the growing media and it did not affect other macronutrient content in the growing media, irrespectively of mycorrhization.

WPŁYW FOSFORU I MIKORYZACJI NA WZROST, KWITNIENIE I ODŻYWIANIE MAKROELEMENTAMI PELARGONII (*Pelargonium* × *hortorum* L.H. BAILEY)

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Słowa kluczowe: *Peargonium* × *hortorum* L.H. BAILEY, mikoryzacja, nawożenie fosforem, odżywianie makroelementami

Streszczenie

W doświadczeniach szklarniowych oceniano wpływ mikoryzacji i poziomu P w pożywce na kolonizację korzeni, wzrost, kwitnienie i odżywienie makroelementami pelargonii uprawianej na stołach zalewowych. Po miesiącu od inokulacji stwierdzono wysoki procent zasiedlenia korzeni przez grzyby mikoryzowe zarówno przy niskim (0,28 mmol·dm^{-3}) jak i przy wysokim (1,40 mmol·dm^{-3}) poziomie fosforu w pożywce. Mikoryzacja hamowała w niewielkim stopniu wzrost roślin uprawianych przy niskim poziomie P, ale nie wpływała na wzrost roślin uprawianych przy wyższym poziomie tego pierwiastka. Wysoki poziom P zwiększał świeżą masę i wysokość roślin inokulowanych, ale nie wpływał na wzrost roślin nieinokulowanych. Wysoki poziom P zwiększał także liczbę pędów bocznych i liczbę pąków kwiatowych, zarówno u roślin inokulowanych jak i nieinokulowanych. Rośliny inokulowane miały więcej P i Mg w liściach a mniej K i Ca niż rośliny nieinokulowane. Wyższy poziom P w pożywce powodował wzrost zawartości tego pierwiastka w liściach roślin inokulowanych i nieinokulowanych. W końcowym okresie uprawy wyższe stężenie soli i wyższa zawartość N i K stwierdzono w podłożach inokulowanych niż nieinokulowanych. Wysoki poziom P w pożywce powodował wzrost zawartości tego pierwiastka w podłożu, ale nie wpływał na zawartość innych makroskładników w podłożu, niezależnie od inokulacji.

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