RESPONSE OF THREE ORNAMENTAL PLANT SPECIES TO INOCULATION WITH ARBUSCULAR MYCORRHIZAL FUNGI DEPENDING ON COMPOST ADDITION TO PEAT SUBSTRATE AND THE RATE OF CONTROLLED RELEASE FERTILIZER

Bożena Matysiak and Grzegorz Falkowski

Research Institute of Pomology and Floriculture
Pomologiczna 18, 96-100 Skierniewice, POLAND
e-mail: Bozena.Matysiak@insad.pl

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ABSTRACT

The influence of arbuscular mycorrhizal fungi (AMF) inoculation, compost addition to peat substrate, and controlled release fertilizer (CRF) on mycorrhizal colonization, nutrient acquisition, and growth of *Physocarpus opulifolius*, *Spiraea japonica* and *Potentilla fruticosa* was investigated in a container experiment. The AMF treatments consisted of a commercial inoculum Endorize-Mix and non-inoculated (non-AMF) control. Compost was mixed with peat at different rates (0, 10 and 20% v/v). The CRF was applied at 100 and 50% of the manufacturer's recommended rate. Shoot fresh weights of all three species were affected by mycorrhizas the first year they were grown in containers. Differences between AMF and non-AMF plants were less significant in the second year. In the first year, species growth response to AMF inoculation was positive for *P. fruticosa,* which was not dependent on CRF rate and compost addition to substrate. Species growth response to AMF inoculation ranged from neutral to negative in the first year for *P. opulifolius* and *S. japonica* depending on the CRF rate and compost addition to substrate. Mycorrhiza development was generally supported by increasing the rate of compost in peat substrate and suppressed under the recommended rate of CRF. AMF inoculation affected P content in plant tissue of all species, with a higher P content in AMF than in non-AMF plants, regardless of the rate of CRF. However, the increased level of mycorrhizal colonization caused by AMF inoculum and higher phosphorus content in the leaves of all tested species did not correspond with higher biomass of plants. The greater participation of compost was in peat substrate, the more phosphorus and potassium contained all tested species. Shoot nitrogen content was not affected by AMF nor compost addition to peat substrate.

Key words: *Physocarpus, Potentilla, Spiraea,* arbuscular mycorrhiza, compost, controlled release fertilizer, nursery production, organic horticulture

INTRODUCTION

Mycorrhizal technology seems to be a promising field for the nursery industry because of the known growth benefits that plants may obtain from mycorrhizal fungi. Inoculation of horticultural crops with arbuscular mycorrhizal fungi (AMF) often increases the survival and growth rates of plants and cuttings in greenhouses and natural conditions (Crews et al., 1978; Lovato et al., 1995), improves the acclimatization of *in vitro* micropropagated plants (Vestberg et al., 2002) and promotes earlier flowering and fruiting (Lovato et al., 1995). Mycorrhizal plants are more efficient in the uptake of specific nutrients (Smith and Read, 1997) and more resistant to abiotic stresses and diseases caused by soil-borne pathogens (Liu et al., 2004). AMF inoculation of plants grown in containers offers the possibility of reducing fertilizers and pesticide applications. There is also the possibility of incorporating mycorrhiza in nursery production. With AMF inoculation, ornamental shrubs or trees transplanted from the nursery into the landscape have greater stress resistance, survivability and regrowth. For these reasons, AMF are gaining popularity as "biofertilizers", "bioprotectors" and "biocontrol" agents. The industry of mycorrhizal inoculum production is enjoying worldwide expansion.

Increased trends towards organic production in horticulture including the ornamental nursery, seems to be highly conductive for mycorrhizal usage (Gosling et al., 2006). For instance, a greater proportion of inorganic controlled release fertilizers (CRF) than soluble fertilizers are now being used, CRF are beneficial for mycorrhizal associations. Under high temperature container production, *Ipomea carnea* grown with AMF in substrate amended with CRF at recommended rates did better than with CRF alone (Carpio et al., 2005). This is highly relevant to the nursery industry which predominantly uses CRF rather than soluble fertilizers. Sphagnum peat moss (*Sphagnum spp*. L.) is a commonly used substrate in container nursery production. Moreover, the use of peat is viewed critically because it is a limited natural resource. The European Union and organic growers' associations support the strong reduction of peat in growth substrates in the coming years and support using alternative products such as compost. Using peat-compost substrates may be advantageous to achieve rapid plant growth in containers, but the effects on mycorrhizal colonization are not well understood (Linderman and Davies, 2001; Corkidi et al., 2004; Gaur and Adholeya, 2005). Some studies suggest that peat-based substrates are not as favourable as growing media containing soil, for the development of mycorrhizal colonization (Linderman and Davies, 2004). Peat has been found to inhibit AMF colonization, but this effect could be reduced by adding 25% soil or sand to the substrate. It has also been reported that some compost amendments may suppress mycorrhizal colonization and activity of AMF. The opposite results were obtained by Perner et al. (2007), which showed that compost added to the peat in quantities of 20 and 40% support AMF colonization of *Pelargonium* plants. On the other hand, compost as a nutrient source for plants may require other nutrients as soil amendments to meet the demands of the plants. Addition of rhizosphere microorganisms as AMF that cannot be found within compost-peat substrates may help plants to mobilize and acquire nutrients from the substrate (Davies et al., 2000; Linderman and Davies, 2003; Amaya-Carpio et al., 2009).

The first objective of this study was to find out whether AMF inoculation is beneficial for ornamental deciduous shrubs grown in containers in standard nurseries. The second objective was to examine the influence of peat-compost substrates and rate of CRF on mycorrhiza formation, and the resulting mycorrhizal contribution to plant N, P, K uptake and growth.

MATERIAL AND METHODS

The experiment was executed in the Research Institute of Pomology and Floriculture in Skierniewice during the two successive seasons of 2008 and 2009. Rooted cuttings of *Physocarpus opulifolius* L. (Maxim.) ‘Diabolo’, *Potentilla fruticosa* L. ‘Gold Drop’ and *Spiraea japonica* L. ‘Pruhoniciana’ were used in the experiment. Plants were cultivated outdoors in containers filled with sphagnum peat substrate from the Baltic region (pH 5.5-6.0, Klasmann) with an addition of 0, 10 or 20% compost (see below). The outdoor cultivation in containers was done according to standard nursery practice. In 2008, plants were potted into 1.5 dm^{-3} pots and the next year they were transplanted into 3.0 dm^{-3} containers. Plants were watered as needed during rain-free weather *via* sprinklers located over above the canopy of the plants.

The experiment was a 2 × 3 × 2 factorial, arranged in a completely randomized design with five replications. The three factors were two controlled release fertilizer (CRF) rates (3 and 1.5 g dm^{-3}), three compost (COM) rates (0, 10 and 20%, v/v) and two arbuscular mycorrhizal fungi (AMF) treatments. The AMF treatments consisted of a commercial inoculum Endorize-Mix and non-inoculated (non-AMF) control. Endorize-Mix (Agrauxine, France) inoculum containing *Glomus mosseae*, *G. intraradices* and other, unspecified *G. spp*. was added directly on roots during planting at a rate according to the supplier’s recommendation (2.5 g per plant). Osmocote Standard 5-6 M (16N-11P-11K-3Mg + microelements) was used as CRF at 100%

(3 g dm^{-3}) and 50% (1.5 g dm^{-3}) of the manufacturer's recommended rate. Commercially available compost (Eko-Kompost, Ekokonsorcjum Efekt, Poland) obtained from yard waste and shredded trees and bushes was used. Compost contained (in % d.w.) 2.4 N total, 0.01 N-NH_4, 1.39 P_2O_5, 3.16 K_20, 7.06 CaO, 1.24 MgO, 0.12 Na_2O and pH was 8.71.

In the beginning of September 2008 and 2009 shoots were cut 5 cm above ground and shoot fresh weight was measured. For *S. japonica* and *P. opulifolius,* the Chlorophyll Content Index (CCM-200, Opti-Sciences) was recorded before harvesting the crops. Inflorescences of *S. japonica* (in June) and flowers of *P. fruticosa* (in September) were counted. For the investigation of mycorrhizal colonization, a 3 g fresh subsample was randomly taken from the root system of each plant species. These samples were cleared by heating with 10% KOH in a 90 °C water bath for 10 min then acidified with 10% HCl. Roots were stained for 2 hours using 0.1% trypan blue in lactoglicerol at 80 °C, than de-stained for 24 hours. Mycorrhizal fungus colonization in the root system (%) was determined according to the method of Trouvelot et al. (1986). Foliar sample of plants for nitrogen, phosphorus and potassium content determination were taken in September 2009, then were dry-ashed and analyzed. Nitrogen was determined by the Kjeldahl method, phosphorus photometrically and potassium was determined with an atomic absorption spectrophotometer.

Data were subjected to analysis of variance. Significance of differences between means was determined with Duncan's Multiple Test at $p = 0.05$.

RESULTS

Plant growth

As expected, because of taxonomic and growth rate diversity, *P. opulifolius* (Tab. 1)*, P. fructicosa* (Tab. 2) and *S. japonica* (Tab. 3) responded differently to: CRF rate, compost addition to peat substrate and AMF. For all species, reduced rate of CRF (1.5 g dm^{-3}) compared to the recommended (3 g dm^{-3}) significantly diminished shoot fresh weight in both the first and second year of the plants grown in containers. *P. opulifolius* and *P. fruticosa* were also lower, *P. fruticosa* and *S. japonica* bloomed less abundantly and furthermore, leaves of *P. opulifolius* and *S. japonica* contained less chlorophyll. All these results demonstrated that decreased quantity of CRF did not cover plant demand for mineral nutrients. On the other hand, compost had a positive effect on the growth and development of all plant species. The compost was derived from organic debris generated from urban green areas. Compost was used as an additive to sphagnum peat, as a substrate for growing in containers. The highest fresh weight of shoots was achieved while a higher rate of CRF was used. Regardless of the CRF rate, plants of *S. japonica* grown in peat substrate enriched with compost, bloomed abundantly in both the first and second year of cultivation. *P. fruticosa* grown in substrate

T a b l e 1. Significance levels of main effects and interactions between controlled release fertilizer (CRF) rate, compost rate (COM) of arbuscular mycorrhizal fungi (AMF) inoculation and effects of these factors on shoot fresh weight, plant height, Chlorophyll Content Index, root mycorrhizal colonization and nutrient element concentration in leaves of *Physocarpus opulifolius* 'Diabolo' grown in containers

Factor		Shoot fresh weight [g]		Plant height [cm]		Chlorophyll Content Index		Mycorrhizal colonization [%]		Element content [g (kg DW)$^{-1}$]		
		2008	2009	2008	2009	2008	2009	2008	2009	N	P	K
Significance level												
CRF		** [a]	**	**	**	**	NS	NS	**	**	*	**
COM		**	**	NS	NS	NS	**	**	**	NS	**	**
AMF		**	NS	NS	**	NS	NS	**	**	NS	*	NS
CRF × COM		**	NS	*	NS	**	NS	NS	NS	NS	**	NS
CRF × AMF		**	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
COM × AMF		**	NS	NS	NS	NS	NS	NS	**	NS	*	NS
CRF × COM × AMF		NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
CRF [g dm^{-3}]												
3.0		125 b [b]	748 b	38.5 b	65.5 b	28.0 b	31.7	6	18 a	29.4 b	2.7 b	20.2 b
1.5		104 a	459 a	34.4 a	51.4 a	23.2 a	30.4	7	36 b	23.3 a	2.5 a	16.9 a
COM [%]												
0		101 a	525 a	36.1	58.0	25.8	33.4 b	6 a	26 b	26.9	2.3 a	14.8 a
10		123 b	628 b	37.4	58.0	24.4	30.6 a	3 a	17 a	26.0	2.5 b	19.3 b
20		120 b	657 b	35.9	59.4	26.7	29.3 a	13 b	38 c	26.1	3.1 c	21.4 c
AMF												
-		120 b	610	36.4	60.0 b	26.2	31.0	1 a	11 a	26.0	2.5 a	18.4
+		109 a	597	36.5	56.0 a	25.1	31.1	17 b	46 b	26.6	2.7 b	18.7
CRF × AMF												
3.0	-	135 c	756	38.8	66.5	29.5 c	31.7	1	7	28.9	2.6	20.0
	+	115 b	740	38.2	64.5	26.5 b	31.7	16	33	29.8	2.8	20.4
1.5	-	105 a	464	33.9	53.5	22.8 a	30.3	1	15	23.2	2.4	16.8
	+	102 a	454	34.8	49.3	23.6 a	30.5	18	59	23.4	2.7	16.9
COM × AMF												
0	-	102 a	520	36.8	59.6	27.0	33.4	1	18 b	26.3	2.3 a	14.7
	+	100 a	530	35.3	56.4	24.6	33.3	17	35 c	27.5	2.2 a	15.0
10	-	135 d	638	37.8	58.3	25.7	31.3	0	1 a	25.8	2.3 a	19.1
	+	110 b	619	37.0	57.6	23.1	29.9	10	49 cd	26.2	2.7 b	19.6
20	-	124 c	672	34.5	62.0	25.8	28.3	4	22 b	26.0	3.0 c	21.4
	+	117 bc	643	37.2	56.7	27.5	30.2	27	55 d	26.1	3.2 c	21.5

[a] NS, * and **, non-significant and significant $P<0.05$, 0.01, respectively
[b] Numbers followed by different letters are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test

Table 2. Significance levels of main effects and interactions between controlled release fertilizer (CRF) rate, compost rate (COM) and of arbuscular mycorrhizal fungi (AMF) inoculation and effects of these factors on shoot fresh weight, plant height, flowering, root mycorrhizal colonization and nutrient element concentration in leaves of *Potentilla fruticosa* 'Gold Drop' grown in containers

Factor		Shoot fresh weight [g]		Plant height [cm]		Number of flowers per plant		Mycorrhizal colonization [%]		*Element content* [g (kg DW)$^{-1}$]		
		2008	2009	2008	2009	2008	2009	2008	2009	N	P	K
Significance level												
CRF		** [a]	**	*	*	**	NS	NS	NS	**	**	**
COM		**	**	**	**	**	NS	**	*	NS	**	**
AMF		*	NS	NS	NS	NS	NS	**	**	NS	**	NS
CRF × COM		*	*	NS	NS	NS	NS	**	NS	NS	NS	**
CRF × AMF		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
COM × AMF		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
CRF × COM × AMF		NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
CRF [g dm^{-3}]												
3.0		134 b [b]	407 b	26.3 b	40.7 b	32.5 b	83.5	16	64	27.4 b	3.0 b	12.9 b
1.5		105 a	305 a	24.8 a	37.5 a	17.2 a	75.7	20	71	24.4 a	2.8 a	11.3 a
COM [%]												
0		88 a	286 a	22.9 a	37.7 a	29.5 b	78.6	21 b	59 a	25.7	2.6 a	11.1 a
10		132 b	356 b	25.9 b	37.7 a	25.1 ab	79.4	5 a	60 a	25.9	2.9 b	12.4 b
20		137 b	424 c	27.8 c	42.0 b	20.1 a	80.9	34 c	82 b	26.1	3.2 c	12.8 b
AMF												
-		116 a	348	25.2	39.4	24.2	84.3	5 a	27 a	25.8	2.8 a	11.9
+		123 b	363	25.8	38.8	25.5	75.0	36 b	96 b	26.0	3.0 b	12.2
CRF × AMF												
3.0	-	132	410 c	26.2	41.1	31.0	87.2	5	27	27.5	2.9	12.8
	+	135	403 c	26.3	40.2	34.1	79.8	30	93	27.3	3.1	13.0
1.5	-	100	287 a	24.2	37.6	17.5	81.3	5	26	24.1	2.6	11.1
	+	110	323 b	25.3	37.5	16.9	70.1	42	99	24.6	3.0	11.5
COM × AMF												
0	-	83	264 a	22.7	37.5	27.2	85.5	7	13	25.5	2.5	10.8
	+	94	309 b	23.1	37.8	31.7	71.7	39	96	25.9	2.7	11.3
10	-	130	346 c	25.3	38.2	22.7	84.9	0	18	25.9	2.7	12.3
	+	134	367 c	26.5	37.1	27.4	73.9	17	95	26.0	3.1	12.5
20	-	134	435 d	27.6	42.4	22.8	82.4	17	54	26.1	3.1	12.7
	+	141	413 d	28.0	41.6	17.3	79.3	54	98	26.1	3.3	12.8

[a, b]See Table 1

Table 3. Significance levels of main effects and interactions between controlled release fertilizer rate (CRF), compost rate (COM) and of arbuscular mycorrhizal fungi (AMF) inoculation and effects of these factors on shoot fresh weight, flowering, Chlorophyll Content Index, root mycorrhizal colonization and nutrient element concentration in leaves of *Spiraea japonica* 'Pruhoniciana' grown in containers

Factor		Shoot fresh weight [g]		Number of inflorescences		Chlorophyll Content Index		Mycorrhizal colonization [%]		Element content [g (kg DW)$^{-1}$]		
		2008	2009	2008	2009	2008	2009	2008	2009	N	P	K
Significance level												
CRF		** [a]	**	NS	**	**	**	**	**	**	NS	**
COM		**	**	**	**	NS	NS	**	NS	NS	**	**
AMF		*	NS	**	NS	NS	NS	**	**	NS	**	NS
CRF × COM		**	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
CRF × AMF		*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
COM × AMF		NS	NS	**	NS	NS	NS	*	NS	NS	NS	NS
CRF × COM × AMF		NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
CRF [g dm^{-3}]												
3.0		199 b [b]	419 b	1.1	33.9 b	13.3 b	16.2 b	9 a	67 b	20.2 b	2.4	15.4 b
1.5		128 a	216 a	1.1	26.4 a	8.6 a	14.2 a	40 b	50 a	17.7 a	2.3	14.1 a
COM [%]												
0		155 a	295 a	0.3 a	27.1 a	11.4	15.4	10 a	54	18.6	1.9 a	12.1 a
10		173 c	322 b	1.5 b	32.2 b	10.4	15.6	26 b	68	19.0	2.4 b	15.5 b
20		163 b	335 b	1.6 b	31.3 b	11.1	14.6	36 b	54	19.3	2.7 c	16.6 c
AMF												
-		166 b	313	1.4 b	30.3	10.7	15.5	10 a	46 a	19.0	2.2 a	14.5
+		161 a	322	0.8 a	30.0	11.2	14.9	39 b	71 b	18.9	2.4 b	15.0
CRF × AMF												
3.0	-	199 c	414	1.2	34.3	12.9	16.5	2	58	20.2	2.4	15.2
	+	200 c	424	1.0	24.4	13.7	15.9	20	76	20.3	2.4	15.5
1.5	-	133 b	212	1.5	33.6	8.5	14.5	23	34	17.8	2.2	13.8
	+	123 a	221	0.7	26.5	8.7	13.9	59	65	17.6	2.4	14.4
COM × AMF												
0	-	159	291	0.5 ab	26.3	10.6	15.5	3 a	45	18.6	1.9	12.2
	+	150	300	0.1 a	27.9	12.2	15.3	21 bc	62	18.7	1.8	12.1
10	-	174	322	1.3 cd	33.2	10.4	15.9	19 bc	52	19.3	2.3	15.1
	+	172	322	1.6 d	31.2	10.4	15.3	33 c	83	18.8	2.5	16.0
20	-	165	325	2.3 e	31.5	11.1	15.1	13 b	42	19.2	2.6	16.3
	+	161	345	0.8 bc	31.0	11.0	14.2	64 d	65	19.4	2.9	16.9

[a, b] See Table 1

supplemented with 20% compost, however, had fewer flowers in the first year. Moreover, the leaves of *P. opulifolius* plants grown in substrate with compost in the second year contained less chlorophyll than those grown without compost. This lower chlorophyll level was probably due to *P. opulifolius'* faster growth.

Shoot fresh weights of all three species were affected by mycorrhizas in their first year in containers, but differences between AMF and non-AMF plants were less significant the next year. In the first year, species growth response to AMF inoculation was positive for *P. fruticosa* independent of CRF rate and compost addition to substrate. In the first year, species growth response to AMF inoculation ranged from neutral to negative depending upon CRF rate and compost addition to substrate for *P. opulifolius* and *S. japonica*. The first year, shoot fresh weight of inoculated *P. fruticosa* was higher by 6% than non-AMF plants regardless of CRF rate and the addition of compost to the substrate. The next year AMF inoculum stimulated growth of *P. fruticosa* only when the peat substrate was not enriched with compost and at half the recommended rate of CRF. However, the shoot fresh weight of these plants was still much lower than plants grown in substrate amended with compost and with recommended CRF rate. For *P. opulifolius* and *S. japonica,* an AMF effect significantly interacted with CRF rate in the first growing season, however, the way of interaction for these species was different. AMF inoculum decreased shoot fresh weight of *P. opulifolius* only at recommended, while *S. japonica* only at a decreased rate of CRF. AMF inoculum also influenced negatively on the fresh weight of *P. opulifolius* in peat substrate enriched with compost.

AMF root colonization

Under standard nursery conditions, inoculation of ornamental plants grown in containers with Endorize-Mix produced mycorrhizal plants of all species. Colonization in the first year ranged from 17% in *P. opulifolius* (Tab. 1), 36% in *P. fruticosa* (Tab. 2), to 39% in *S. japonica* (Tab. 3) roots. The fine roots of the control, non-AMF plants at this time showed a much weaker colonization level and ranged from 1% in *P. opulifolius,* 5% in *P. fruticosa* to 10% in *S. japonica* roots. After the second year, the percentage of AMF colonized root of *P. opulifolius*, *P. fruticosa* and *S. japonica* increased to 46, 96 and 71% respectively. At this time 11, 27 and 46% of the roots of the control non-AMF plants were also colonized. The rate of CRF in different ways influenced the AMF root colonization. The recommended CRF rate (3 g dm^{-3}) compared to the decreased rate of inhibition of the root colonization of *S. japonica* during the first year and *P. opulifolius* during the second year of container growth, did not affect the roots of *P. fruticosa* and slightly enhanced mycorrhization of *S. japonica* during the second year. Addition of compost into peat substrate at a higher rate (20%) generally positively influenced AMF root colonization of *P. opulifolius*, *P. fruticosa* and *S. japonica* compared to plants grown without compost. This was true even though roots of *S. japonica* after the second year were highly AMF colonized, irrespective of the addition of compost.

Mineral contents in shoot tissue

For all species, N concentration in plant tissue was significantly higher when CRF rates were higher. No effect of AMF inoculation and compost addition to peat substrate was observed for this nutrient. Shoot P significantly increased with the rate of compost in peat substrate for all plants and significantly decreased with a decreased rate of CRF for *P. opulifolius* and *P. fruticosa.* AMF inoculation affected P content in plant tissue of all species. There was a higher P content in AMF than in non-AMF plants regardless of the rate of CRF. P concentration in shoots *P. opulifolius* was higher when mycorrhizal plants grew in a substrate with 10% compost, compared with substrate without compost. The potassium content was dependent on both the rate of CRF and compost and was not affected by AMF inoculum. Shoot K concentration was significantly higher when plants were grown in peat substrate enriched in compost as well as when grown with a higher rate of CRF.

DISCUSSION

Our results indicate, that the commercial horticultural substrates such as sphagnum peat or mixture peat and compost support spontaneous mycorrhizal colonization of ornamental plants grown in containers under standard nursery practices. Broadleaved ornamental shrubs are cultivated in nurseries usually for two growing seasons. Depending on the plant species, up to 50% of the roots can be colonized by AMF during the plants 2 year nursery stay. The spontaneous colonization may occur at a very early stage of cultivation, even during the rooting process of the cuttings. At this stage, the young nursery stock is exposed to various rooting substrates (usually consisting of sand), which can by contaminated by hyphae and spores of AMF. Another reason for spontaneous root colonization can be attributed to the mode of cultivation in the nurseries. AMF can be easily moved from container to container by mycorrhizal roots growing outside the pots. Plants at the end of the growing season are brought together in order to protect them from frost during the winter. This is the general practice in nurseries. Fragments of mycorrhizal roots may remain in a nursery providing a source of inoculum to other plants. However, horticultural producers intending to grow mycorrhizal plants should use inocula containing selected species of mycorrhizal fungi. It is known that different species of mycorrhizal fungi affect various plants differently in different climatic and soil conditions (Carpio et al., 2003).

There are numerous reports on the genetic variation in plant responses to inoculation with mycorrhizal fungi (Parke and Kaeppler, 2000; Linderman and Davies, 2004). Our study involved ornamental shrubs produced in containers under standard nursery practices. The basis for the variation with three plant species of deciduous shrubs could be variation in the level of vegetative hyphal growth. Genetic variation of the host morphology and physiology also appear to interact, resulting in a given level of response. AMF inoculum only enhanced growth of *P. fruticosa* in the first growing season independent of CRF rate and compost addition to substrate. AMF inoculum was neutral to negative, depending on these factors for *P. opulifolius* and *S. japonica*. However, root mycorrhizal colonization of all species inoculated with AMF increased according to the increase of compost in peat substrate. This is significant for commercial nursery production, since compost added to peat at a 20% rate stimulated growth of all species and there was no decrease in mycorrhizal colonization when using this peat-compost substrate. The opposite occurred in the relationship between mineral fertilization intensity and root mycorrhizal colonization. Controlled release fertilizers release minerals gradually and there is much lesser risk of a high salinity substrate. Despite use of the recommended rate of CRF, it significantly decreased root mycorrhizal colonization of two plant species (*P. opulifolius* and *S. japonica*) compared to the reduced CRF rate. For all tested plant species, half the rate of CRF compared to the recommended rate negatively affected both shoot fresh weight and plant quality. The negative effect was determined by the number of flowers and chlorophyll content in leaves. Amya-Carpio et al. (2009) demonstrated a strong reduction in the mycorrhizal colonization of *Ipomea carnea* ssp. *fistulosa* plants fertilized with the recommended dose of CRF.

The contribution of AMF to plant nutrient uptake is often particularly evident in plants that are deficient in certain nutrients, mainly phosphorus. Mycorrhizal fungi are well known for their efficient P uptake. As discussed by Parke and Kaeppler (2000), P efficiency is reflected in the plant's ability to produce dry matter without the addition of P to the soil or growth medium in the absence of mycorrhizae. The results of our experiment show that inoculation with AMF increased both root mycorrhizal colonization and P content in the tissue of *P. opulifolius*, *P. fruticosa* and *S. japonica,* while no mycorrhizal effect on shoot N and K concentration was found. However, the increased level of mycorrhizal colonization caused by AMF inoculum and higher phosphorus content in the leaves of all tested species did not correspond with the higher biomass of plants. It is also believed by some, that there is no obvious growth enhancement from AMF inoculation. The cost of maintaining the mycorrhizal status could be offsetting the benefits derived from the association (Parke and Kaeppler, 2000).

Our studies have also shown that compost produced from organic materials of urban green areas can partially replace peat used as a substrate in the production of ornamental shrubs in containers. A compost amendment to the peat substrate showed a 10 to 20% beneficial effect on the growth of all plant species. This may be due to an increased P and K supply, as evidenced by the increased shoot P and K concentration in plants grown in the compost treatment. Another reason could have been the higher water-holding capacity of peat-based substrates, which have a high compost addition rate (Perner et al., 2007). The use of compost as an additive to peat substrate promoted the colonization of roots by AMF.

The conclusions to be drawn from this study are that varied growth response should be expected from inoculation with AMF on different plant species of deciduous shrubs. Another conclusion is that AMF inoculum can differently affect their level of mycorrhizal colonization. Variation in growth response is the result of the convergence of multiple factors of fungus and host plant genetics and the environmental conditions of the experiment. Whether the growth response to AMF is positive, neutral or negative, all AMF inoculated plant species contained more phosphorus in the shoots. We also conclude that compost addition to the peat substrate at the rate of up to 20%, positively affects the growth and development of *P. opulifolius*, *P. fruticosa* and *S. japonica*. This rate of a compost addition increased shoot P and K concentration and support AMF root colonization. Therefore, using compost seems to be a highly beneficial practice in organic horticulture.

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REAKCJA TRZECH GATUNKÓW ROŚLIN OZDOBNYCH NA INOKULACJĘ ARBUSKULARNYMI GRZYBAMI MIKORYZOWYMI W ZALEŻNOŚCI OD DODATKU KOMPOSTU DO PODŁOŻA TORFOWEGO I DAWKI NAWOZU O KONTROLOWANYM DZIAŁANIU

Bożena Matysiak i Grzegorz Falkowski

S T R E S Z C Z E N I E

Badano wpływ szczepionki mikoryzowej zawierającej grzyby arbuskularne AMF, dodatku kompostu do podłoża torfowego oraz dawki nawozu o kontrolowanym działaniu (CRF) na zasiedlanie korzeni przez grzyby mikoryzowe, pobieranie składników mineralnych oraz wzrost roślin *Physocarpus opulifolius*, *Potentilla fruticosa* i *Spiraea japonica* uprawianych w pojemnikach. W badaniach zastosowano komercyjną szczepionkę mikoryzową Endorize-Mix. Rośliny kontrolne nie były mikoryzowane. Kompost zmieszano z torfem w dawkach 0, 10 i 20% (v/v). Nawóz CRF stosowano w dawce zalecanej przez producenta (100%) i obniżonej o połowę (50%). Mikoryzacja wpływała istotnie na wzrost roślin w pierwszym roku uprawy w pojemnikach, ale reakcja poszczególnych gatunków była odmienna. Inokulacja roślin szczepionką mikoryzową stymulowała wzrost *P. fruticosa* niezależnie od dawki CRF i kompostu w podłożu torfowym. Z kolei w przypadku *P. opulifolius* i *S. japonica* oddziaływanie szczepionki mikoryzowej uzależnione było zarówno od dawki CRF, jak i udziału kompostu w podłożu torfowym i reakcja ta miała charakter neutralny lub negatywny. W drugim roku różnice między roślinami mikoryzowanymi i niemikoryzowanymi były mniej istotne. Zasiedlaniu korzeni przez grzyby mikoryzowe sprzyjał dodatek kompostu do podłoża torfowego i proces ten był hamowany przy zastosowaniu zalecanej dawki CRF. Wszystkie badane gatunki roślin inokulowane szczepionką mikoryzową zawierały więcej fosforu w liściach niż niemikoryzowane niezależnie od dawki CRF. Wraz ze wzrostem dawki kompostu zwiększała się zawartość fosforu i potasu w roślinach. Zawartość N w liściach nie była uzależniona ani od zastosowania szczepionki mikoryzowej, ani od dodatku kompostu do substratu torfowego.

Słowa kluczowe: *Physocarpus, Potentilla, Spiraea,* mikoryza arbuskularna, kompost, nawóz o kontrolowanym działaniu, ogrodnictwo ekologiczne, produkcja szkółkarska