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Response of three kinds of winter ornamental plants to *mycorrhiza* fungus

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ABSTRACT

The study aimed to investigate the effects of mycorrhizal inoculation on the growth and development of three plant species: *Petunia hybrida*, *Antirrhinum majus*, and *Dianthus chinensis*, as well as soil heavy metals. The study measured various parameters such as shoot fresh weight, root fresh weight, flower number, root length, plant height, flower diameter, leaves number, and petiole length. Results showed a significant increase in shoot fresh weight 10.74 g, root fresh weight 1.77 g, flower number 18.33, plant length 18.73 cm, and flower diameter 4.3 cm, as compared to the control. A similar trend was observed in *Antirrhinum majus*, where mycorrhizal inoculation resulted in significantly higher values for foliage fresh weight 37.43 g, root fresh weight 10.47 g, flower number 19, root length 22.67, plant height 75.67, and leaves number 34, as compared to the control. In *Dianthus chinensis*, mycorrhizal inoculation resulted in significantly higher values for shoot fresh weight 36.83 g, root fresh weight 6.17 g, flower number 16.67, root length 15.33 cm, and petiole length 2.2 cm, as compared to the control. The study also investigated the effect of mycorrhizal inoculation on leaf growth and development and found that it had a positive effect on leaf area, length, width, and aspect ratio. Furthermore, the study measured the concentration of various heavy metals in the soil and found that mycorrhizal inoculation had a significant effect on the concentration of some elements in the soil. These findings highlight the potential benefits of mycorrhizal inoculation in plant growth and development.

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استجابة ثلاثة أنواع من نباتات الزينة الشتوية لفطر الميكوريزا

سازار سامي نورالدين ، صبيحه صلاح الدين مصطفي ، اسماء سيد احمد
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الخلاصة

هدفت الدراسة إلى معرفة تأثير التلقيح بالمايكورايزا على نمو وتطور ثلاث انواع مختلفة من نباتات الزينه الشتويه ونسب العناصر الثقيلة في التربة المزروعة بهذة النباتات وكانت النباتات هى *Petunia hybrida* , *Antirrhinum majus* و *Dianthus chinensis.* تم قياس الخصائص المورفولوجيه :- مثل الوزن الطري للمجموع الخضري ، الوزن الطرى للمجموع الجذري ، عدد الأزهار ، طول الجذر والنبات ، وقطر الزهرة ، وعدد الأوراق ، وطول السويقة. أظهرت النتائج زيادة معنوية في الوزن الطري للمجموع الخضرى 10.74 غم والوزن الطرى للجذر 1.77 غم وأعداد الأزهار 12.3 وطول الجذر 18.78 سم وطول النبات 73 سم وقطر الزهرة 4.3 سم مقارنة بالكنترول لنبات *Petunia hybrida* . ولوحظ اتجاه مماثل في *Antirrhinum majus*، حيث أدى التلقيح بالمايكورايزا إلى قيم أعلى بكثير للوزن الطرى للمجوع الخضرى 37.43 غم ، والوزن الطرى للجذر 10.47 غم ، وعدد الأزهار 19 ، وطول الجذر 22.67سم ، وطول النبات 75.67سم ، وعدد الأوراق 34 ، مقارنةً بالمقارنة. في *Dianthus chinensis* ، أدى التلقيح بالمايكورايزا إلى قيم أعلى معنويًا للوزن الطرى للمجوع الخضرى 6.83 غم ، والوزن الطرى للجذر 3.17 غم ، وعدد الأزهار 16.67 ، وطول الجذر 15.33 سم ، وطول السويقة 2.2 سم ، مقارنةً بالكنترول و تحققت الدراسة أيضًا من ان التلقيح بالمايكورايزا له تأثير على نمو الأوراق وتطورها ووجدت أن لها تأثيرًا إيجابيًا على مساحة الاوراق وطولها وعرضها ونسبة العرض إلى الارتفاع. علاوة على ذلك ، قامت الدراسة بقياس تراكيز المعادن الثقيلة المختلفة في التربة ووجدت أن التلقيح بالمايكورايزا كان له تأثير معنوي على تركيز بعض العناصر في التربة حيث ادى الى نقص ملحوظ في كل من الكوبلت ، النيكل ، النحاس ، الزنك والزرنيخ .

الكلمات المفتاحية: نباتات الزينة الشتوية ، فطر المايكورايزا

INTRODUCTION

Ornamental plants, particularly winter ornamental plants, are of particular interest when studying the effects of mycorrhizal colonization. These plants are commonly used in landscaping and horticulture and play an important role in the aesthetic and ecological value of gardens and green spaces. The response of winter ornamental plants to mycorrhizal colonization can have significant implications for their growth and survival, as well as for the overall health of the ecosystem in which they are found. This introduction will provide an overview of the research on the response of winter ornamental plants to mycorrhizal colonization and its potential implications for horticulture and ecology. In the past 20 years, the use of Arbuscular Mycorrhizal symbiosis as a biostimulant in horticultural crops has significantly risen due to their ability to improve production and stability while being environmentally sustainable (Rouphael *et al.*, 2015). The relationship between plants and mycorrhizae is a symbiotic one that has been studied for decades. Mycorrhizae are fungi that form a symbiotic relationship with the roots of plants, providing the plant with essential nutrients and water while receiving photo-synthetically produced sugars in return (Fortin & Melchert, 2015). The fungus can grow to the cortex, but cannot to grow arbuscules. The causing hyphal colonization of the cortex in mutant plants does not provision cooperative gaining of phosphate and copper by the plant (Reddy DMR *et al.*, 2007). Inoculation with *Glomus fasciculatum* led to an increase in the growth of *Ocimum* *basilicum* plant and also to an increase in the content of volatile oil. According to many researches, it has been found the positive effects of AMF on enhancing the root system and enhancing the uptake of both macro and micronutrients through improved transport and solubilization. The results showed that there is a significant effect on increasing the systemic city of ornamental plants to absorb phosphorus and other elements, which therefore has a role in the growth and its response to the formation of flowers (Rydlova & Püschel, 2020) . Phosphorus and nitrogen are essential macronutrients for plant growth and development. The symbiotic relationship between *Petunia hybrida* and mycorrhizae has been established to enhance plant growth by facilitating the exchange and uptake of these key nutrients. Studies have shown that mycorrhizal colonization results in an increase in phosphorus and nitrogen availability to the host plant, leading to improved growth and overall health. The mutualistic nature of the association between *Petunia hybrida* and mycorrhizae highlights the significance of this relationship in optimizing plant nutrient acquisition and overall growth (Nouri *et al.*, 2014). Studies have investigated the impact of mycorrhizal colonization on the growth of *Antirrhinum majus* and have demonstrated mixed results. While some studies have found no significant effect on plant growth, others have demonstrated a significant impact on the longevity of flowers when used in cut arrangements. Specifically, the presence of mycorrhizae has been shown to significantly extend the vase life of *Antirrhinum majus* flowers. This indicates that while the relationship between mycorrhizae and this plant may not significantly impact growth, it can have a significant impact on the ornamental value of the plant (Besmer & Koide, 1999). The study confirmed that the pollination of mycorrhiza has an effective role in increasing the number of *Dianthus chinensis* flowers (Gaur & Adholeya, 2005). As for the plant *Dianthus chinensis* the microrhiza has an effect on raising the rate of relative water content inside the plant and increasing the light absorption capacity of the plant (Huang *et al.*, 2022).

This research aims to study the effect of microrhiza inoculation on winter ornamental plants in terms of flower numbers, other morphological characteristics and its impact on Mycorrhiza effect on reducing heavy metals with these plants to reach the chief goal, with ecofriendly ornamental plants cultivation.

MATERIALS AND METHODS

This investigation was carried out from Autumn 2020 to Spring 2021 in Gerdarash field. The experimental site is located at Grdarasha research station college of Agricultural Engineering Sciences/ Salahaddin University, located at (Latitude36˚07´10.44˝N Longitude 44˚00´50.52˝ E).

Plants used in the experiment:

Winter ornamental plant seeds (*Petunia hybrida*, *Antirrhinum majus* and *Dianthus chinensis*) were obtained from Holland. These were planted on the 15th of October 2020 in seedling trays. They were planted in seedling trays for a month to obtain seedlings, they were transferred to a 10 cm deep soil along with a surface of round plastic pots diameters and 25cm in height. Each pot was filled with 3kg of peat moss, sand, and a clay mixture soil at a rate of (2:1:1). The chemical and physical properties of this soil mixture before planting are shown in table (1) Also, heavy metals were measured in the soil before planting are shown in table (2), The heavy metals in the soil were measured using an instrument portable ED-XRF spectroscopy

Table 1: The physical and chemical analysis of initial soil mixture:

The Physical Analysis		The chemical analysis								
Sandy- loam soil		Organic Matter	Total N	Total P	K	Fe	Zn	Cu	pH	Ec
Sand	65.00%	%	%	%	%	mg/kg				Ds/m
Clay	20.00%	1.250	0.421	0.031	0.711	3.65	92.28	1.30	7.4	1.60
Silt	15.00%									

Table 2: Heavy metals in soil before planting

Mn (PPM)	Fe (%)	Co (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Pb (ppm)
337.97	3.65	12.61	289.84	34.33	92.28	3.78	0.66	0.46	1.46

Source of Mycorrhiza inoculum

Mycorrhizal inoculum was obtained from Sustainable Agricultural Technologies, Inc. company, Mycorrhizal inoculum ingredients: Endomycrrhizal fungi, *Glomus intraradices, Glomus mosseae, Glomus aggregatum, Glomus etunicatum and* 10^4 per g.

Transplants

After germinating the seeds and obtaining seedlings, they were transferred to pots. During transportation, the roots were inoculated as follows: touch dam root to inoculum so a small amount sticks to roots or sprinkle into planting holes using ¼ tsp under each cutting ,2 tsps. for potted transplant, ½ Oz /inch for stem caliper planting.

Experiment design and statistical analysis:

This study was conducted to study response of some winter ornamental plants to Mycorrhizae colonization. The experiment was designed as a complete randomized design (CRD) with three replicates in factorial experiment. In this experiment nest analysis and Duncan was used and the statistical analysis was carried out by using SAS. The total experimental units included: 3* 2* 3= 12.

Experimental parameters:

Shoot and root fresh weight(g), flower numbers, root length(cm), plant length (cm), flower diameter (cm), leaves number, petiole length (cm), for measurement of the leaf area, leaf length, leaf width, aspect ratio by using Digital Leaf Area Meter (original manufacturer) Zhejiang top instrument co., ltd, model YMJ-C.

RESULT AND DISCUSSION

Data in Table 3and Fig (1,2 and 3) presented the effect of mycorrhizal inoculation on the growth and development of three plant species: *Petunia hybrida*, *Antirrhinum majus*, and *Dianthus chinensis*, as compared to their respective controls. The parameters measured include foliage fresh weight, root fresh weight, flower numbers, root length, plant length, flower diameter, leaves number, and petiole length. The results indicated that mycorrhizal inoculation has a positive effect on plant growth and development in all three kinds. In *Petunia hybrida*, mycorrhizal inoculation resulted in a significant increase in shoot fresh weight 10.74 g, root fresh weight1.77g, flower numbers12.3, root length18.78cm, plant length73 cm, and flower diameter 4.3 cm, as compared with control. A similar trend was observed in *Antirrhinum majus*, where mycorrhizal inoculation resulted in significantly higher values for foliage fresh weight 37.43g, root fresh weight 10.47g, flower numbers19, root length 22.67, plant length75.67, and leaves number 34, as compared to the control. In *Dianthus chinensis*, mycorrhizal inoculation resulted in significantly higher values for foliage fresh weight 6.83 g, root fresh weight 3.17g, flower numbers16.67, root length15.33cm, and petiole length 2.2cm, as compared with control.

Table 3: The impact of mycorrhiza inoculation on the morphological characteristics of three winter ornamental plants

Plant	Treatment	Shoot fresh weight(g)	root fresh weight(g)	flower numbers	root length (cm)	plant length (cm)	flower diameter (cm)	leaves number	petiole length (cm)
Petunia hybrida	Inoculation with Mycorrhiza	10.47 ± 0.09^{b}	1.77 ± 0.69^{c}	12.33 ± 6.33^{ab}	18.67 ± 4.18^{ab}	74 ± 0.58^{a}	4.33 ± 0.17^{a}	26.33 ± 0.33^{b}	3.67 ± 0.33^{b}
Petunia hybrida	Control	5.67 ± 0.33^{bc}	0.9 ± 0.1^{c}	4.33 ± 0.33^{b}	7.33 ± 0.88^{d}	41.67 ± 0.88^{b}	3 ± 0^{b}	29.33 ± 4.84^{ab}	2.67 ± 0.33^{b}
Antirrhinum majus	Inoculation with Mycorrhiza	37.43 ± 3.61^{a}	10.47 ± 0.47^{a}	19 ± 0.58^{a}	22.67 ± 1.86^{a}	75.67 ± 3.48^{a}	3 ± 0^{b}	34 ± 3.46^{ab}	7.67 ± 2.19^{a}
Antirrhinum majus	Control	7 ± 0.58^{bc}	1.7 ± 0.61^{c}	6.67 ± 0.33^{b}	$11 \pm 1c^{d}$	43.33 ± 1.86^{b}	2 ± 0^{c}	38 ± 2.65^{a}	7 ± 0.58^{a}
Dianthus chinensis	Inoculation with Mycorrhiza	6.83 ± 0.93^{bc}	3.17 ± 0.23^{b}	16.67 ± 1.86^{a}	15.33 ± 0.88^{bc}	24.67 ± 0.33^{c}	2 ± 0^{c}	37.67 ± 3.18^{a}	2.2 ± 0.12^{b}
Dianthus chinensis	Control	3.23 ± 1.09^{c}	1.03 ± 0.09^{c}	7.67 ± 0.67^{b}	$12.33 \pm 0.33b^{cd}$	19 ± 0.58^{d}	1.9 ± 0.1^{c}	24.33 ± 1.86^{b}	1.53 ± 0.24^{b}

* For each parameter and the mean of three replicates ± SD, means not followed by the same letter are significantly different by Duncan's Multiple range test (P>0.05

Fig 1: Effect on mycorrhiza inoculation on some morphological traits on *Petunia hybrida*
A: *Petunia hybrida* (control)
B: *Petunia hybrida* Inculcated with Mycorrhiza

Fig 2: Effect on mycorrhiza inoculation on some morphological traits on *Antirrhinum majus*
A: *Antirrhinum majus* (control)
B: *Antirrhinum majus* Inculcated with Mycorrhiza

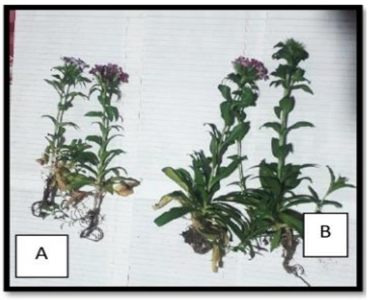

Fig 3: Effect om mycorrhiza inoculation on some morphological traits on *Dianthus chinensis*
A: *Dianthus chinensis* (control)
B: *Dianthus chinensis* Inculcated with Mycorrhiza

Results in Table 4 showed that the leaf area, length, width, and aspect ratio of three plant species, *Petunia hybrida*, *Antirrhinum majus*, and *Dianthus chinensis*, under two treatments, inoculation with mycorrhiza and control. The results suggest that mycorrhizal inoculation has a positive effect on leaf growth and development in all three species.

For *Petunia hybrida*, mycorrhizal inoculation resulted in a significantly larger leaf area (9.8 cm2) and higher leaf length (6.17 cm) and width (2.98 cm) compared to the control (4.76 cm2, 3.47 cm, and 1.93 cm, respectively). The aspect ratio of leaves in the mycorrhizal treatment (2.09) was also significantly higher than that in the control (1.8).

Similarly, for *Antirrhinum majus*, mycorrhizal inoculation resulted in a significantly larger leaf area (12.13 cm2) and higher leaf length (8.63 cm) and width (1.96 cm) compared to the control (5.39 cm2, 6.68 cm, and 1.74 cm, respectively). The aspect ratio of leaves in the mycorrhizal treatment (4.63) was also significantly higher than that in the control (3.96).

For *Dianthus chinensis*, mycorrhizal inoculation resulted in a significantly larger leaf area (8.43 cm2) and higher leaf length (5.31 cm) and width (1.77 cm) compared with control (5.59 cm2, 3.83 cm, and 1.47 cm, respectively). The aspect ratio of leaves in the mycorrhizal treatment (3.02) was also significantly higher than that in the control (2.64).

Table 4: Effect of mycorrhiza inoculation on some morphological traits of three winter ornamental plants leaves

Plant	Treatment	leaf Area	leaf length	leaf width	Aspect ratio
Petunia hybrida	Inoculation with Mycorrhiza	9.8 ± 0.21^{b}	6.17 ± 0.21^{b}	2.98 ± 0.17^{a}	2.09 ± 0.16^{c}
Petunia hybrida	Control	4.76 ± 0.89^{c}	3.47 ± 0.12^{d}	1.93 ± 0.02^{b}	1.8 ± 0.08^{c}
Antirrhinum majus	Inoculation with Mycorrhiza	12.13 ± 0.67^{a}	8.63 ± 0.84^{a}	1.96 ± 0.29^{b}	4.63 ± 0.85^{a}
Antirrhinum majus	Control	5.39 ± 0.11^{c}	6.68 ± 0.13^{b}	1.74 ± 0.25^{b}	3.96 ± 0.45^{ab}
Dianthus chinensis	Inoculation with Mycorrhiza	8.43 ± 0.76^{b}	5.31 ± 1.03^{bc}	1.77 ± 0.03^{b}	3.02 ± 0.61^{bc}
Dianthus chinensis	Control	5.59 ± 1.09^{c}	3.83 ± 0.2^{cd}	1.47 ± 0.15^{b}	2.64 ± 0.14^{bc}

* For each parameter and the mean of three replicates ± SD, means not followed by the same letter are significantly different by Duncan's Multiple rang test (P>0.05)

The Table 5 shows the results of a study on the effect of mycorrhizal inoculation on the concentration of various elements in different plant species. The concentration of manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), cadmium (Cd), and lead (Pb) was measured in soils which were cultivated with *Petunia hybrida, Antirrhinm majus*, and *Dianthus chinensis* plants that were either inoculated with mycorrhiza or used as a control.

The results showed that mycorrhizal inoculation had a significant effect on the concentration of some elements in the soil. In *Petunia hybrida* soil, the concentration of Mn 266.85ppm, Cu31.08 ppm, and Zn 91.26 was significantly lower in the mycorrhizal-inoculated plants compared to the control plants on the other hand *Antirrhinum majus*, mycorrhizal inoculation significantly decreased the concentration of as 2.69ppm. Whereas *Dianthus chinensis*, mycorrhizal inoculation significantly increased the concentration of Co13.68 ppm and as 6.69 ppm, but significantly decreased the concentration of Pb 1.46 ppm.

Table 5: Effect on mycorrhiza inoculation on heavy metals at three different soils which cultivated with three of winter ornamental plants

Plant	Treatment	Mn (ppm)	Fe(%)	Co (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Pb (ppm)
Petunia hybrida	Inoculation with Mycorrhiza	266.85 ± 0.58^{c}	3.58 ± 0.58^{a}	12.67 ± 0.58^{ab}	267.78 ± 0.58^{c}	31.08 ± 0.58^{b}	91.26 ± 0.58b^{c}	1.19 ± 0.58^{c}	0.42 ± 0.34^{a}	0.42 ± 0.34^{a}	1.41 ± 0.58^{a}
Petunia hybrida	Control	337.97 ± 0.58^{a}	3.65 ± 0.58^{a}	12.61 ± 0.58^{ab}	289.84 ± 0.58^{a}	34.33 ± 0.58^{a}	92.28 ± 0.58^{b}	3.78 ± 0.58^{b}	0.66 ± 0.33^{a}	0.46 ± 0.33^{a}	1.46 ± 0.58^{a}
Antirrhinum majus	Inoculation with Mycorrhiza	295.43 ± 0.58^{b}	3.68 ± 0.58^{a}	11.68 ± 0.58^{b}	283.6 ± 0.58^{b}	32.87 ± 0.58^{ab}	90.27 ± 0.58^{c}	2.69 ± 0.58^{bc}	0.42 ± 0.34^{a}	0.44 ± 0.33^{a}	1.05 ± 0.58^{a}
Antirrhinum majus	Control	337.97 ± 0.58^{a}	3.65 ± 0.58^{a}	12.61 ± 0.58^{ab}	289.84 ± 0.58^{a}	34.33 ± 0.58^{a}	92.28 ± 0.58^{b}	3.78 ± 0.58^{b}	0.77 ± 0.29^{a}	0.47 ± 0.33^{a}	1.46 ± 0.58^{a}
Dianthus chinensis	Inoculation with Mycorrhiza	295.43 ± 0.58^{b}	3.68 ± 0.58^{a}	13.68 ± 0.58 ^{a}	283.6 ± 0.58^{b}	32.87 ± 0.58^{ab}	94.27 ± 0.58^{a}	6.69 ± 0.58^{a}	0.42 ± 0.33^{a}	0.44 ± 0.33^{a}	1.05 ± 0.58^{a}
Dianthus chinensis	Control	337.97 ± 0.58^{a}	3.65 ± 0.58^{a}	12.61 ± 0.58^{ab}	289.84 ± 0.58^{a}	34.33 ± 0.58^{a}	92.28 ± 0.58^{b}	3.78 ± 0.58^{b}	0.77 ± 0.29^{a}	0.47 ± 0.33^{a}	1.46 ± 0.58^{a}

* For each parameter and the mean of three replicates ± SD, means not followed by the same letter are significantly different by Duncan's Multiple range test (P>0.05

Inoculation with three different commercial AM inocula resulted in root colonization rates of up to 36%, which increased the number of buds, flowers a, and shoot P and K concentrations. But it did not significantly affect shoot dry matter or shoot N concentration. And the results showed that a combination of compost addition with mycorrhizal inoculation can improve the nutrient status and flower development of plants grown on peat-based substrates in organic cultivation (Perner *et al.*, 2007) The use of AMF for pot-grown ornamental plants experiencing drought, can enhance growth and visual qualities. However, caution should be exercised when using hydrogel until its effects and potential drawbacks are thoroughly understood (Rydlova & Püschel, 2020). Najafi *et al.* (2012) studied the interaction between mycorrhiza and PGPR and found that this interaction has an effective effect on the concentration of iron and zinc in barley plants. In greenhouse experiments, maize, barley, alfalfa, and zinc violets were grown until flower and seed formation in two different heavy metal soils when incubated with Glomus Br1 and supplemented with nutrient solutions. However, controls consisting of sterilized heavy metal soils not inoculated with Glomus Br1 or yellow lupins as nonmycorrhizal plants did not grow. The Glomus Br1 isolate from the zinc violet was found to be more effective in supporting the growth of maize or alfalfa in heavy metal soils than a commonly used *Glomus intraradices* Schenck and Smith isolate.(Hildebrandt *et al.*, 1999). Nowak (2007) investigated the impact of Cd and Pb on the growth and flowering of scarlet sage. Although these heavy metals did not have a significant effect on the plant's growth and flowering, they did reduce its decorative value due to leaf chlorosis and necrosis. The amount of Cd and Pb accumulated in the plant's shoots was found to be dependent on the metals' content in the growing medium. Furthermore, mycorrhization increased the accumulation of Cd and Pb in the plant's shoots when grown in high concentrations of these metals in the growing medium. Based on these findings, it can be concluded that heavy metal pollution can impact the aesthetic value of scarlet sage plants, and mycorrhization may exacerbate the accumulation of Cd and Pb in their shoots when grown in contaminated soils. An investigation highlights the benefits of mycorrhizal fungi in phytoremediation. Mycorrhizal fungi release organic acids that increase the solubilisation of insoluble phosphate compounds in soil, making them available to plants. They also release glomalins and metallothionine, which help to immobilize and reduce the toxicity of heavy metals in soil. Additionally, mycorrhizal fungi can induce resistance in plants against various stress factors, including pathogens, drought, and salinity stress. The review suggests that identifying heavy metal stress-resistant genes in mycorrhizal plants could aid in phytoremediation efforts(Bano & Ashfaq, 2013).

CONCLUSION

The results showed that the effect of mycorrhizal inoculation on the growth and development of three plant species, *Petunia hybrida, Antirrhinum majus, and Dianthus chinensis*, as compared to their respective controls. The results indicated that mycorrhizal inoculation has a positive effect on plant growth and development in all three species, including foliage fresh weight, root fresh weight, flower numbers, root length, plant length, flower diameter, leaves number, petiole length, leaf area, length, width, and aspect ratio. The mycorrhizal treatment resulted in significantly higher values for most parameters compared to the control, demonstrating the importance of mycorrhizal inoculation for enhancing plant growth and development.

In addition, this study investigated the effect of mycorrhizal inoculation on concentration of heavy metals in soil which were cultivated with pervious plants. Results showed that mycorrhizal inoculation had varying effects on the concentration of different heavy metals, with *Petunia hybrida* showing a decrease in Mn, Cu, and Zn, *Antirrhinum majus* showing a decrease in as, and *Dianthus* *chinensis* showing an increase in Co and as and a decrease in Pb. Overall, mycorrhizal inoculation has potential for soil remediation and plant growth.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

REFERENCES

Bano, S. A., & Ashfaq, D. (2013). Role of mycorrhiza to reduce heavy metal stress. *Natural Science*, *2013*.

Besmer, Y. L., & Koide, R. T. (1999). Effect of mycorrhizal colonization and phosphorus on ethylene production by snapdragon (*Antirrhinum majus* L.) flowers. *Mycorrhiza*, *9*, 161-166.

Fortin, S., & Melchert, V. (2015). Effect of mycorrhizae on Artemisia annua. *Worcester Polytechnic Institute*.

Gaur, A., & Adholeya, A. (2005). Diverse response of five ornamental plant species to mixed indigenous and single isolate arbuscular-mycorrhizal inocula in marginal soil amended with organic matter. *Journal of plant Nutrition*, *28*(4), 707-723.

Hildebrandt, U., Kaldorf, M., & Bothe, H. (1999). The zinc violet and its colonization by arbuscular mycorrhizal fungi. *Journal of plant Physiology*, *154*(5-6), 709-717.

Huang, C., He, X., Shi, R., Zi, S., Xi, C., Li, X., & Liu, T. (2022). Mycorrhizal fungi reduce the photosystem damage caused by drought stress on *Paris polyphylla* var. *yunnanensis*.

Najafi, A., Ardakani, M. R., Rejali, F., & Sajedi, N. (2012). Response of winter barley to co-inoculation with *Azotobacter* and Mycorrhiza fungi influenced by plant growth promoting rhizobacteria. *Ann Biol Res, 3*(8), 4002-4006.

Nouri, E., Breuillin-Sessoms, F., Feller, U., & Reinhardt, D. (2014). Phosphorus and nitrogen regulate arbuscular mycorrhizal symbiosis in Petunia hybrida. *Plos one, 9*(3), e90841.

Nowak, J. (2007). Effects of cadmium and lead concentrations and arbuscular mycorrhiza on growth, flowering and heavy metal accumulation in scarlet sage [Salvia splendens Sello'Torreador']. *Acta Agrobotanica*, *60*(1).

Perner, H., Schwarz, D., Bruns, C., Mäder, P., & George, E. (2007). Effect of arbuscular mycorrhizal colonization and two levels of compost supply on nutrient uptake and flowering of pelargonium plants. *Mycorrhiza*, *17*, 469-474.

Reddy DMR, S., Schorderet, M., Feller, U., & Reinhardt, D. (2007). A petunia mutant affected in intracellular accommodation and morphogenesis of arbuscular mycorrhizal fungi. *The Plant Journal*, *51*(5), 739-750.

Rouphael, Y., Franken, P., Schneider, C., Schwarz, D., Giovannetti, M., Agnolucci, M., De Pascale, S., Bonini, P., & Colla, G. (2015). Arbuscular mycorrhizal fungi act as biostimulants in horticultural crops. *Scientia Horticulturae*, *196*, 91-108.

Rydlova, J., & Püschel, D. (2020). Arbuscular mycorrhiza, but not hydrogel, alleviates drought stress of ornamental plants in peat-based substrate. *Applied Soil Ecology*, *146*, 103394.