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Research article

Potassium silicate and mycorrhizal fungi effect on morphological traits of *Matthiola incana* under drought stress

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Abstract
The effects of foliar application of potassium silicate and inoculation with mycorrhiza on alleviating the effects of drought stress on *Matthiola incana* plants were explored in a split-split-plot experiment based on a completely randomized design with three replications in Perndis Greenhouse Complex during 2019-2020. The main plot was assigned to drought stress at three levels (25%, 50%, and 70% FC), and the sub-plot was assigned to inoculation with arbuscular mycorrhizal fungi (AMF) at two levels (0 and 200 g of fungi per pot), and the sub-sub-plot was assigned to potassium silicate (PS) at three levels (0, 200, and 400 ppm). The results showed that at moderate drought stress (50% FC), stem dry weight was increased by about 20% compared to the control. The maximum root length (13.9 cm), which was about 53% higher than that of the control, was recorded in AMF-inoculated plants exposed to moderate drought stress and sprayed with 400 ppm SP. The results also showed that the foliar application of 400 ppm PS in the absence of AMF inoculation was related to 46% higher leaf dry weight than the treatments of 0 ppm SP with no AMF inoculation. The highest number of flowers in all drought stress levels was obtained from the application of the higher levels of PS. The maximum root dry weight was observed in AMF-inoculated plants exposed to moderate drought stress and treated with 400 ppm SP. Proline content was reduced by the application of 200 g of AMF and 400 ppm of PS at moderate and severe (25% FC) drought stress levels. In general, at moderate and severe drought stress levels, some vegetative and reproductive traits were improved by the foliar application of 400 ppm PS and AMF inoculation.

Keywords: Flower number, Leaf number, Proline, Stem dry weight.

Abbreviations: Potassium Silicate: PS, Reactive Oxygen Species: ROS, Arbuscular Mycorrhizal Fungi: AMF, Field Capacity: FC.

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Introduction

Matthiola incana is one of the most prominent ornamental species of flowers in Iran, the demand for which has significantly increased in recent years due to color diversity and pleasant aromas (Arab & Khaliqi, 2007). It is one of the important flowering plants that constitute the four main Iranian cut-branch flowers exported to international markets along with tuberose, clove, and rose. Due to its high cold resistance, *Matthiola incana* is one of the best flowers to be cultured in the winter (Elmi, 2009). Also, based on application and use, these flowers are divided into three groups: cut-branch, pot-based, and outdoor landscape. In the latter application, it is planted in margins and flower hills and creates a colorful background for parks in springs (Alvan & Rahmati, 2009).

Due to the recent population growth, global industrialization, and climate change, water scarcity has become a serious global issue that has had a direct impact on the production and quality of agricultural production, an issue that is being further put into the limelight by the ever-changing global climate conditions. Drought is the most important abiotic factor limiting plant growth and yield. In drought-stress conditions, the rate of photosynthesis decreases due to the stomatal closure. With the exacerbation of drought, CO_2 fixation decreases further due to biochemical changes in chloroplasts (Fazeli Kakhki & Moayedi, 2017). In such conditions, many of the plant's vital activities, e.g. photosynthesis, protein metabolism, amino acid synthesis, and enzyme activity, are reduced, resulting in reduced cell division and inflammation, which in turn leads to reduced growth, leaf area, and yield (Munns, 2002). Previous studies have shown that drought stress can be alleviated by using arbuscular mycorrhizal fungi (AMF) and some compounds, such as potassium silicate (Ghazi & Zak, 2003; Liang *et al.*, 2007). Miransari (2010) argues that AMF can ease the effects of drought stress by increasing the plant's ability to absorb water and nutrients, which is itself achieved through expanding the roots further into the soil such that, through the epidermal cells of the roots and the sorbent fibers, the mycorrhiza can significantly increase the amount of phosphorus uptake through which the available nitrogen also increases. Research has shown that arbuscular mycorrhiza provides biochemical access to phosphorus sources, which may lead to the acidification of the rhizosphere, thereby promoting root phosphatase activity in the process (Ruiz-Llozno, 2003). Phosphorus plays a key role in plant growth and accounts for 0.2% of the plant's dry weight. It is involved in the molecular structure of nucleic acids (DNA, RNA), phospholipids, coenzymes, and ATP energy-carrying molecules (Taiz & Zeiger, 2002). Mycorrhiza fungi increase drought tolerance by increasing CO_2 fixation per unit area of leaf due to the increased translocation of assimilates required for growth and tolerance compared to plants not inoculated with mycorrhiza (Azcón-Aguilar & Barea, 2002). It has been revealed that in inoculated plants, mycorrhiza increases water efficiency by increasing photosynthesis and production of more photosynthetic assimilates per unit of water consumed (Fitzsimons & Miller, 2010). In a study on the coexistence of onion with mycorrhiza, an increase in water use efficiency was reported (Bolandnazar *et al.*, 2007).

As the second most abundant element in the earth's crust with a significant share of 28%, silicon is found in most plant tissues and structures, including cell walls, intercellular space, epidermis, roots, leaves, and reproductive organs (Voleti *et al.*, 2008). Plants take up silicon in the form of $Si(OH)^{4-}$ and accumulate it as a deposition of silicic acid. This element

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strengthens the epidermal cell wall, shelters the plant against water loss through cuticle transpiration, and improves the plant's tolerance to salinity and drought stress (Mehregan *et al.*, 2018). Optimal silicon nutrition enhances growth and increases root volume and weight, and eventually, the total adsorbent level of the elements is increased (Sun *et al.*, 2005). Research has shown that the use of silica improves plant growth (Gong *et al.*, 2005). Kamenidou *et al.* (2010) reported that different concentrations of potassium silicate increased the number of flowers per plant and flower diameter. Mehregan *et al.* (2018) demonstrated that the use of 2 mM of potassium silicate in drought stress increased plant height, root length, shoot fresh and dry weight, and root fresh and dry weight of the plants compared to the control. Silicon prevents withering by strengthening xylems and making them resistant to collapse during excessive transpiration. On the other hand, potassium is one of the more vital elements in plant growth, which plays a key role in regulating plant water activities. The accumulation of potassium in xylems reduces the osmotic potential of the vascular fluid and, consequently, increases root pressure and water absorption rate. It also has a beneficial effect on water consumption since inherently lower osmotic potential improves water retention. The reduced rate of transpiration and the regulation of stomatal opening and closing are the result of potassium inflow and outflow in the protective cells of stomata (Taiz & Zeiger, 2002). The increased amount of proline amino acids in plants receiving enough potassium is another mechanism for enhancing the drought resistance of plants. Gunes *et al.* (2008) observed that Si applications provided higher Si and proline concentrations in sunflower plants exposed to drought stress. Probably a more efficient osmotic adjustment as a function of higher proline concentrations is part of the tolerance mechanism to water deficit.

Drought stress has diverse destructive effects on plant morphology and physiology, and it can damage the cell components through enhanced production of reactive oxygen species (ROS) (Ebrahimi *et al.*, 2021; Amiri Forotaghe *et al.*, 2022). The presence of ROS in the cellular environment destroys major cellular macromolecules, such as DNA, RNA, and vital enzymes, which is called oxidative damage (Ashraf & Ali,2008). Also, one of the conspicuous effects of free oxygen radicals on cell health is the destruction of cell membranes (Bhattacharjee & Mukherjee, 2002). Considering the different roles of silicon, potassium, and AMF in plants including the alleviation of the effects of drought stress, the present study aims to elucidate the influence of PS and AMF on water status, and the effects of drought stress in *Matthiola incana*.

Materials and Methods

To investigate the effects of foliar application of potassium silicate and mycorrhizal fungi on alleviating the effect of drought stress on *Matthiola incana*, a split-split-plot experiment was conducted in a completely randomized design with three replications in Parandis Greenhouse Complex located in the northwest of Mashhad County during 2018-2019. In this experiment, the main plot was drought stress at four levels (25, 50, 75, and 100% of field capacity (FC)), and the sub-plot was arbuscular mycorrhiza fungus (AMF) (*Glomus mosseae*) at two levels (0 and 200 g of fungi per pot), and the sub-sub-plot was potassium silicate (PS) at three levels (0, 200, and 400 ppm).

The experiment used 10-kg pots filled with a combined substrate containing soil, sand, and cow manure at a 1:1:1 ratio. First, AMF was added to the beds in each pot.

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AMF was obtained from Turan Biotechnology Company located in Shahrood Science and Technology Park, and the amount of AMF used was 20 grams of AMF for 4 liters of soil as recommended by the company. Drought stress was applied by the field capacity method based on the weighting method using tensiometers. At first, to determine the amount of water needed for each drought stress treatment, the percentage of soil moisture was calculated with the following formula:

$$SMP = \frac{\text{SWW} - \text{SDW}}{\text{SDW}} \times 100$$

in which SMP is soil moisture percentage, SWW is soil wet weight after removing gravity water, and SDW is soil dry weight (dried at 105°C for two days).

Then, based on the pot weight and the weight of the soil used in each pot, the final weight of each pot was calculated separately for each treatment in the field capacity. To apply the treatments, the pots were weighed daily and the water was adjusted for each pot. The effect of plant weight in each treatment was eliminated by additional repetitions of each treatment, and the plant was destroyed at intervals of one week and the weight of the destroyed plant was calculated and applied to the amount of added water (Zekavati *et al.*, 2018). After calculating the field capacity of the desired soil, 75%, 50%, and 25% of this water were applied as a treatment for drought stress. After the growth stages of the plant in the physiological stage, the irrigation was cut short and measurements were performed. Potassium silicate (SILICOCARB) liquid fertilizer manufactured by HYDROCORP, Mexico containing 27% silicon and 17.55% potassium was prepared at pre-determined concentrations, and the plants were foliar sprayed weekly until the end of the experimental period with the prepared solutions for two weeks after application in the pots.

At the end of the experiment, traits such as stem dry weight, leaf dry weight, leaf length, and number, flower fresh and dry weight, number of florets, root fresh and dry weight, root length, and leaf proline content were measured. Proline concentration was measured using an extract prepared with sulfosalicylic acid (3%) (Bates *et al.*, 1973). The proline concentration was read at 520 nm and its value was calculated using the standard proline curve and reported in μM proline per g fresh weight (FW).

Data were analyzed using Minitab-16 and MSTAT-C, and the means were compared using Duncan's test at a probability level of 5%. The graphs were drawn by MS Excel software.

Results and Discussion

Leaf proline content

The results of the analysis of variance (ANOVA) showed that the simple effect of drought stress, AMF, and potassium silicate was statistically significant ($P < 0.01$) on proline content (Table 1). The highest amount of proline (9.58 μM/g FW) was obtained from the treatment of severe stress (25% FC) and no fungi, whereas the lowest (1.35 μM/g FW) was related to full irrigation conditions (Table 2). Proline content increased at higher levels of drought stress. However, the application of potassium silicate to the plants exposed to drought stress increased their proline content (Table 3).

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Table 1. The results of ANOVA (mean squares) for some morphological and physiological traits of *Matthiola incana* plant treated with arbuscular mycorrhizal fungi and potassium silicate in drought stress conditions.

Sources of variations	Degrees of freedom	Stem dry weight	Leaf dry weight	Root dry weight	Flower dry weight	Fresh root weight	Fresh leaf and stem weight	Fresh flower weight	Stem length	Leaf length	Root length	Leaf number	Floret number	Stem diameter	Proline content
Block	2	0.077**	0.031**	0.017**	0.070**	0.153*	8.64**	9.58**	2.972**	0.668**	1079.9**	14.43**	105**	0.001*	1.62**
S	3	3.949**	5.656**	2.229**	11.22**	21.24**	585.38**	725.03**	218.76**	47.99**	47.81**	2257.93**	11420.8**	0.21**	197.01**
E1	6	0.005	0.002	0.002	0.002	0.036	0.99	0.93	0.155	0.037	27.79	1.25	11.9	0.0003	0.155
M	1	0.103**	0.068**	1.926**	0.166**	27.50**	52.57**	241.63**	13.082**	0.390**	39.11**	234.72**	2090.9**	0.035**	10.351**
S × M	3	1.218**	2.112**	0.581**	4.348**	9.449**	535.85**	784.54**	67.945**	20.76**	1.44^{ns}	609.24**	7890.8**	0.069**	0.173**
E2	2	0.036	0.001	0.004	0.008	0.059	0.20	1.32	0.534	0.033	0.198	2.43	17.2	0.0001	0.194
K	2	2.445**	3.687**	0.523**	8.120**	4.556**	1067.14**	1677.97**	130.82**	38.10**	6.713**	1082.39**	17462.8**	0.95**	47.77**
S × K	6	0.180**	0.470**	0.082**	0.768**	0.961**	137.05**	221.75**	6.986**	2.632**	0.311^{ns}	74.15**	2539.6**	0.012**	4.69**
M × K	2	0.343**	0.407**	0.226**	0.626**	2.906**	40.84**	337.05**	9.39**	2.238**	0.736^{ns}	23.72**	3630.4**	0.006**	1.93**
S × M×K	6	0.243**	0.390**	0.137**	1.049**	0.936**	196.82**	467.75**	9.894**	5.083**	0.167^{ns}	74.41**	3263.1**	0.008**	0.73**
E3	38	0.012	0.002	0.001	0.001	0.041	1.67	1.26	0.252	0.043	0.764	1.00	13.0	0.008	0.09

^{ns}, * & **: not significant, 1% significant level and 5% significant level, respectively

S: Drought stress, M: Mycorrhiza fungus, K: Potassium silicate; E1: main plot error, E2: secondary plot error, E3: second secondary plot error

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The results showed that proline content was increased in plants inoculated with the fungi and applied with higher concentrations of silicate. The lowest proline content (3.19 μM/g FW) was obtained from the AMF-inoculated plants treated with 400 ppm PS (Table 4). The application of potassium neutralized the adverse effects of salinity on corn growth by increasing the photosynthetic capacity of corn plants against oxidative stress and maintaining ionic homeostasis (Abbasi *et al.*, 2014). Comparing the interactive effects of drought, AMF, and potassium silicate, the results showed that as the stress level increased, so did the amount of proline. The lowest amount of proline (0.76 μM/g FW) was seen in the control. At moderate and severe stress levels (50% and 25% FC, respectively), inoculation with 400 mg of fungi and the application of 400 ppm PS had a reducing effect on proline levels (Table 6). Proline plays an important role in protecting plants from stress (Zarghami *et al.*, 2014; Zangene & Salehi, 2020). AMF-inoculated plants showed a lower proline content at all salinity levels than non-inoculated control treatments in experiments on wheat leaves (Al-Jum'ah *et al.*, 2019). The results of correlation coefficients showed that proline content had a significant negative correlation with shoot traits (Table 2). This indicates that with increasing drought stress, the shoot dimensions of the plants were decreased and the amount of proline was enhanced for established osmotic adjustment.

Stem and leaf fresh weight

The results of ANOVA for the fresh weight of the stems and leaves of *Matthiola incana* showed that all treatments had a significant effect ($P < 0.01$) on these traits (Table 1). The highest fresh weight of leaf and stem was related to the control treatment, while the lowest was obtained from the plants exposed to severe drought and not inoculated with the fungi (Table 2). It was found that irrespective of drought stress conditions, potassium silicate increased stem and leaf fresh weight significantly so that at a PS rate of 400 ppm and drought stress level of 25%, the stem and leaf fresh weight of *Matthiola incana* was 27.19 g, which was slightly higher than that of the control (8.36 g) (Table 3). The interactive effects of the factors showed that the highest weight (42.41 g) was related to the stress-free, fungus-free, 400 ppm PS-treated plants, while the two lowest ones (3.30 and 3.03 g, respectively) were obtained from the treatment of severe stress (25% FC), no fungus, and 200 ppm PS and 0 ppm PS, respectively (Table **5**). Enjili *et al.* (2018) showed that increasing drought stress reduced the number of shoot branches in sweet pepper plants. Baher *et al.* (2001) reported decreases in the dry weight of roots, stems, and leaves and plant height of bean, basil, and sage plants in drought-stress conditions. It has been suggested that reduced growth is a coping mechanism for plants to survive stressful conditions, as the plants direct nutrients and energy to stress-resisting molecules instead of using them to grow shoots (Khalid, 2006). Inoculation with AMF was reported to be effective in increasing stem and leaf weight in drought conditions. The results of this study are consistent with the findings on trifoliate orange (Xia& Wu, 2006).

Stem and leaf dry weight

The results of ANOVA demonstrated that experimental treatments and their interaction had a significant ($P \leq 0.01$) effect on the stem and leaf dry weight (Table 1). The results indicated that the highest dry weight of stems and leaves (2.24 and 2.47 g, respectively) were related to

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the treatments of full irrigation with no fungi inoculation, while the lowest was attained from the uninoculated plants exposed to severe stress (25% FC) (Table 2).

With increasing drought stress, although fungus inoculation reduced stem and leaf dry weight, various desired traits were improved. The results of the interaction of drought stress with potassium silicate exhibited that the fully irrigated plants or those exposed to mild drought stress (75% FC) produced the highest stem and leaf dry weight. At each level of drought stress, stem and leaf dry weight decreased with decreasing concentration of potassium silicate (Table 3). Moreover, the results showed that the treatment of 400 ppm PS without AMF had 45% and 46% higher stem and leaf dry weight than the treatment of 0 ppm potassium without fungi, respectively. The fungus-free treatments resulted in higher stem dry weight in the presence of potassium silicate when compared to the treatments with fungi and similar amounts of potassium silicate (Table 4). Furthermore, the results showed that when the drought stress was applied at severe drought stress, the fungus-free treatment had the lowest stem and leaf dry weight, regardless of the amount of potassium silicate applied. The highest stem and leaf dry weight was obtained from the treatment of 400 ppm PS without fungus inoculation and drought stress (S1-M2-K1). However, under mild drought stress, the application of 400 ppm PS to non-inoculated plants, and at moderate stress levels, the application of 400 ppm PS to AMF-inoculated plants increased their stem and leaf dry weight (Table 5). It was further shown that silicon has multiple functions under stress and can improve plant growth under drought stress (Ma, 2004). Silicone deposition on the walls of xylem cells prevents them from disintegrating during extreme transpiration that occurs in drought-stress conditions (Meena *et al.*, 2014). The results of the present study also showed that in different treatments, silicon increases stem and leaf dry weight, which is in agreement with previous literature. Research has shown that the application of fungus can significantly improve the shoot of tomato plants (Araghi *et al.*, 2011). It seems that in drought stress, more root growth is the main reason for improved plant growth, while inoculation with AMF and the spread of their hyphae in the root zone is useful in providing the required moisture for plant roots (Araghi *et al.*, 2011). Therefore, it is observed that the use of potassium silicate along with fungus improved stem and leaf dry weight.

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Table 2. The comparison of means for the interaction of the drought stress and arbuscular mycorrhizal fungi on some morphological and physiological traits of *Matthiola incana.*

Drought	Fungus	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Flower dry weight (g)	Root fresh weight (g)	Fresh leaf and stem weight (g)	Flower fresh weight (g)	Stem length (cm)	Leaf length (cm)	Root length (cm)	Leaf number	Floret number	Stem diameter (mm)	Proline content (µM/g FW)
S1	M1	1.681^{b}	1.793^{c}	0.277^{f}	2.613^{d}	0.677^{f}	9.818^{d}	7.497^{d}	18.20^{c}	8.644^{c}	6.888^{e}	31.22^{c}	46.44^{d}	0.63^{c}	1.35^{f}
	M2	2.247^{a}	2.471^{a}	0.451^{e}	3.693^{a}	1.110^{e}	25.479^{a}	26.50^{a}	21.96^{a}	10.967^{a}	8.842^{d}	40.55^{a}	105.44^{a}	0.73^{a}	2.42^{e}
S2	M1	1.688^{b}	1.848^{c}	0.797^{c}	2.584^{d}	1.638^{cd}	12.849^{c}	7.88^{d}	18.42^{c}	8.689^{c}	10.21^{bcd}	31.66^{c}	47.77^{d}	0.63^{c}	1.31^{f}
	M2	1.748^{b}	2.054^{b}	0.482^{e}	2.744^{c}	1.115^{e}	16.414^{b}	16.89^{b}	19.23^{b}	9.378^{b}	8.902^{d}	32.33^{c}	77.22^{b}	0.64^{bc}	1.95^{e}
S3	M1	1.797^{b}	1.986^{b}	1.486^{a}	2.859^{b}	4.667^{a}	16.649^{b}	14.93^{c}	19.37^{b}	9.533^{b}	12.734^{a}	34.33^{b}	61.667^{c}	0.67^{b}	3.70^{d}
	M2	1.133^{c}	1.046^{d}	0.857^{c}	1.586^{e}	1.950^{c}	6.320^{e}	3.578^{e}	14.52^{d}	6.844^{d}	10.298^{bc}	16.11^{d}	25.77^{e}	0.50^{d}	6.67^{c}
S4	M1	1.006^{c}	0.967^{e}	1.210^{b}	1.471^{f}	3.533^{b}	5.384^{e}	2.827^{e}	13.71^{e}	6.478^{e}	11.004^{b}	13.55^{e}	22.55^{e}	0.48^{d}	7.76^{b}
	M2	0.739^{d}	0.776^{f}	0.670^{d}	1.120^{g}	1.396^{de}	3.322^{f}	0.922^{f}	10.57^{f}	5.567^{f}	9.516^{cd}	7.333^{f}	13.11^{f}	0.37^{e}	9.58^{a}

Drought: S1, S2, S3, and S4 represent 100%, 75%, 50%, and 25% of FC, respectively. Mycorrhizal fungus: M1 and M2 indicate with and without the fungus, respectively. In each column, means with a similar letter are not different significantly at a level of 0.05 based on the LSD test.

Table 3. The comparison of means for the interaction of drought stress and Potassium silicate on some morphological and physiological traits of *Matthiola incana.*

Drought	Potassium silicate	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Flower dry weight (g)	Root fresh weight (g)	Fresh leaf and stem weight (g)	Flower fresh weight (g)	Stem length (cm)	Leaf length (cm)	Root length (cm)	Leaf number	Floret number	Stem diameter (mm)	Proline content (µM/g FW)
S1	K1	2.514^{a}	2.712^{a}	0.432^{h}	4.146^{a}	1.028^{ghi}	26.807^{a}	33.643^{a}	23.05^{a}	11.483^{a}	8.50^{def}	44.0^{a}	122.6^{a}	0.80^{a}	1.66^{gh}
	K2	1.868^{c}	2.098^{b}	0.356^{hi}	3.067^{c}	0.887^{hi}	17.773^{b}	11.432^{d}	20.083^{b}	9.750^{c}	7.767^{ef}	36.1^{b}	69.66^{c}	0.65^{c}	1.50^{hi}
	K3	1.510^{de}	1.585^{d}	0.303^{i}	2.245^{f}	0.764^{i}	8.365^{cd}	5.932^{ef}	17.118^{d}	8.183^{d}	7.410^{f}	27.5^{d}	35.5^{de}	0.6^{de}	2.49^{f}
S2	K1	2.134^{a}	2.685^{a}	0.698^{ef}	3.432^{b}	1.449^{f}	27.197^{a}	25.158^{b}	22.503^{a}	11.033^{b}	9.52^{cde}	42.1^{a}	112.5^{b}	0.75^{b}	0.93^{i}

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	K2	1.645^{cd}	1.768^{c}	0.655^{f}	2.607^{e}	1.392^{fg}	9.248^{c}	7.082^{e}	17.950^{cd}	8.433^{d}	9.35^{cde}	31.0^{c}	42.5^{d}	0.6^{de}	1.67^{gh}
	K3	1.376^{ef}	1.399^{e}	0.565^{g}	1.954^{g}	1.238^{fg}	7.650^{cde}	4.938^{ef}	16.033^{e}	7.633^{e}	9.19^{def}	22.8^{e}	32.5^{ef}	0.56^{ef}	2.30^{fg}
	K1	1.677^{cd}	1.769^{c}	1.406^{a}	2.699^{d}	4.398^{a}	18.684^{b}	17.383^{c}	18.785^{c}	9.500^{c}	12.70^{a}	31.3^{c}	62.66^{c}	0.61^{cd}	4.56^{e}
S3	K2	1.542^{de}	1.590^{d}	1.180^{b}	2.286^{f}	2.895^{bc}	9.573^{c}	6.748^{e}	17.267^{d}	8.117^{d}	11.1^{abc}	27.0^{d}	42.66^{d}	0.6^{de}	5.20^{de}
	K3	1.176^{fg}	1.188^{f}	0.928^{c}	1.681^{h}	2.632^{cd}	6.197^{def}	3.725^{fg}	14.803^{f}	6.950^{f}	10.1^{bcd}	17.3^{f}	25.83^{fg}	0.55^{f}	5.79^{d}
	K1	0.985^{g}	0.937^{g}	1.228^{b}	1.404^{i}	3.083^{b}	4.920^{ef}	2.423^{gh}	13.100^{g}	6.367^{g}	11.7^{ab}	12.1^{g}	21.0^{gh}	0.45^{g}	7.89^{c}
S4	K2	0.938^{g}	0.873^{gh}	0.779^{de}	1.332^{i}	2.255^{de}	4.473^{f}	2.123^{gh}	12.517^{g}	6.100^{g}	10.1^{bcd}	10.8^{g}	18.16^{h}	0.45^{g}	8.59^{b}
	K3	0.694^{h}	0.805^{h}	0.814^{d}	1.149^{j}	2.055^{e}	3.667^{f}	1.145^{h}	10.808^{h}	5.600^{h}	9.91^{cd}	8.33^{h}	14.33^{h}	0.40^{h}	9.53^{a}

Drought: S1, S2, S3,and S4 represent 100%, 75%, 50%, and 25% of FC, respectively. Potassium silicate: K1, K2, and K3 denote 400 200, and 0 ppm, respectively. In each column, means with a similar letter are not different significantly at a level of 0.05 based on the LSD test.

Table 4. The comparison of means for the interaction of arbuscular mycorrhizal fungi and potassium silicate on some morphological and physiological traits of *Matthiola incana*.

Fungus	Potassium silicate	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Flower dry weight (g)	Root fresh weight (g)	Fresh leaf and stem weight (g)	Flower fresh weight (g)	Stem length (cm)	Leaf length (cm)	Root length (cm)	Leaf number	Floret number	Stem diameter (mm)	Proline content (μM/g FW)
	K1	1.731^{b}	1.907^{b}	1.211^{a}	2.783^{b}	3.517^{a}	17.246^{b}	13.494^{b}	19.075^{a}	9.342^{b}	11.30^{a}	33.08^{a}	60.16^{b}	0.65^{a}	3.19^{d}
M1	K2	1.578^{c}	1.701^{c}	0.883^{b}	2.480^{c}	2.334^{b}	9.407^{d}	7.087^{c}	17.623^{b}	8.225^{c}	10.30^{ab}	28.75^{c}	43.91^{c}	0.60^{b}	3.45^{d}
	K3	1.320^{d}	1.337^{e}	0.732^{c}	1.882^{e}	2.035^{c}	6.873^{e}	4.357^{d}	15.585^{d}	7.442^{d}	9.99^{bc}	21.25^{e}	29.75^{d}	0.56^{c}	3.93^{c}
	K1	1.925^{a}	2.145^{a}	0.671^{d}	3.058^{a}	1.488^{d}	21.558^{a}	25.810^{a}	19.644^{a}	9.850^{a}	9.43^{bcd}	31.75^{b}	99.25^{a}	0.65^{a}	4.24^{c}
M2	K2	1.418^{d}	1.464^{d}	0.602^{e}	2.167^{d}	1.380^{d}	11.128^{c}	6.606^{c}	16.285^{c}	7.975^{c}	9.09^{cd}	23.75^{d}	42.58^{c}	0.55^{c}	5.11^{b}
	K3	1.058^{e}	1.152^{f}	0.572^{e}	1.632^{f}	1.310^{d}	5.967^{e}	3.513^{d}	13.797^{e}	6.742^{e}	8.66^{d}	16.75^{f}	24.33^{e}	0.49^{d}	6.12^{a}

Mycorrhizal fungus: M1 and M2 indicate with and without the fungus, respectively; Potassium silicate: K1, K2, and K3 denote 400 200, and 0 ppm, respectively. In each column, means with a similar letter are not different significantly at a level of 0.05 based on the LSD test.

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Stem length and diameter

Based on the results of ANOVA, stem length and diameter were significantly ($p \leq 0.01$) affected by all experimental treatments (Table 1). Among the interaction of fungi and different levels of drought, the maximum stem length and diameter (21.96 and 0.73 cm, respectively) were obtained from the uninoculated plants that were fully irrigated. However, as the drought stress intensified, the positive effect of fungi was further pronounced, an effect that was more evident at mild and moderate drought stress levels (Table 2). The use of potassium silicate also had a positive effect on longitudinal growth and stem diameter in drought stress conditions. Regarding the interaction of fungi and potassium silicate, the results showed that the use of 400 ppm PS increased the length and diameter of the stems of both inoculated and uninoculated plants (Table 4). Comparing the three-way effect of drought stress, mycorrhizal fungus, and potassium silicate showed a positive effect of fungus and potassium silicate at the irrigation level of 100% FC. The maximum stem length and diameter were related to full irrigation without fungi and 400 ppm PS (27 and 0.9 cm, respectively). This 53% increase compared to the control implies that potassium silicate can be effective in maintaining plant and water absorption in drought stress. The lowest values were observed at severe drought stress without the application of either fungi or potassium silicate (8.81 and 0.33 cm, respectively) (Table 6). Research has reported contradictory results on the effect of potassium silicate on plant height of many other plant species under drought stress conditions (Kim *et al.*, 2002; Gong *et al.*, 2003; Mattson & Leatherwoo, 2010). However, the use of potassium silicate has increased stem diameter in some ornamental plants such as sunflowers (Kamenidou *et al.*, 2008) and cloves and Kalanchoe (Bae *et al.*, 2010). The growth of the branches and shoots is strongly influenced by the growth environment and the vital activities of the plants. Hence, the plant must have enough water available to it, and if the water supply is not provided due to the decrease in the turgor pressure of the growing cells (effect on cell length), plant growth will be decelerated or even stopped (Ahmadi & Baker, 2000; Ghaemi *et al.* 2020).

Root fresh and dry weight

The results of ANOVA (Table 1) showed that the effect of drought stress levels on root fresh and dry weight was significant ($P \leq 0.01$). The results of the interactive effect of drought stress and mycorrhizal fungus inoculation showed that the highest amount of root fresh and dry weight was obtained from the inoculated plants exposed to moderate drought (50% FC) (4.66 and 1.48 g, respectively), while the lowest amount was observed in the inoculated plants that were fully irrigated (0.67 and 0.27 g, respectively) (Table 2). In this experiment, the highest root fresh weight (4.39 g) and the highest root dry weight (1.40 g) were observed in the plants exposed to moderate stress and treated with 400 ppm PS, while the lowest ones were observed in the control treatment with the values of 0.76 g and 0.30 g, respectively (Table 3). By increasing the concentration of potassium silicate, both in inoculated and uninoculated plants, increases were observed in root dry weight. The results of the treatment interactions (Table 5) showed that the highest root dry weight was obtained from the interaction of ‘50% FC × fungi inoculation × 400 ppm PS’, while the lowest one was obtained from ‘100% FC × fungi inoculation × 0 ppm PS’.

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The general coping mechanism that plants employ in drought conditions is to reduce their fresh and dry weight (Farooq *et al.*, 2009). With increasing drought stress levels from 90% to 45% of field capacity in common chicory, root fresh and dry weights decreased significantly (Jazizadeh & Mortezaeinejad, 2017).

Root length

The results of ANOVA showed that root length was significantly ($P \leq 0.01$) affected by all experimental treatments (Table 1). Among the interactions of fungi and different levels of drought, the maximum root length (12.73 cm) was observed in the fungus-inoculated treatment exposed to moderate drought stress (50% FC) (Table 2). This result shows that despite the plant's exposure to drought stress, the mycorrhizal fungus was still able to increase root length. Regarding the effect of drought stress on safflower plants, it was observed that with increasing drought stress levels, the amount of root length was increased compared to that of the control (Sodaeizadeh *et al.*, 2016). The highest root length was obtained from the treatment of 400 ppm potassium silicate at 50% drought stress with 12.7 cm, while the lowest (7.41 cm) was attained in the control (Table 3). Examining the interaction of fungi and potassium silicate, the results indicated a positive effect of both treatments on the root length of *Matthiola incana*. Inoculation with fungi and the application of 400 ppm PS increased root size by 26% compared to the control treatment (Table 4). Comparing the interactive effect of drought stress, AMF, and potassium silicate, the positive effect of both treatments was evident at moderate drought stress. The maximum root length was observed in the inoculated plants treated with 400 pm PS under moderate drought stress (13.90 cm), while the lowest yield was observed in the inoculated plants treated with potassium silicate under full irrigation conditions (6.45 cm). This 53% increase compared to the control treatment means that AMF and potassium silicate both have been effective in maintaining the plant and water uptake in drought stress conditions (Table 6).

In a similar study on the application of silicone on cucumbers, plant photosynthesis and growth rate of the roots were enhanced (Samoels *et al.*, 1993), which is consistent with our results. AMF are among free-living fungi that are commonly found in most soils and plant root ecosystems. Some species colonize roots and trigger root growth and development as they increase resistance to environmental stress (Caporal *et al.*, 2014).

Average leaf length and number

The results of ANOVA indicated that the effect of all treatments was significant ($P < 0.01$) on average leaf length and number (Table 1). The results of fungal interaction with drought stress showed that the maximum length and number of leaves were obtained under control conditions and non-application of fungi. This effect was observed even when the irrigation rate reached 75% of FC. But, in more severe drought stress (50% and 25% FC), the use of AMF increased the length and number of leaves (Table 2). The application of potassium silicate in drought stress treatments showed that the concentration of potassium silicate affected the alleviation of drought stress. At each level of drought stress, 400 ppm PS had a better effect on the length and number of leaves compared to the other treatment levels (Table 3). The highest leaf length (9.85 cm) was obtained from the application of 400 ppm potassium silicate to the fungus-inoculated plants,

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while the highest number of leaves was obtained from the fungus-applied treatment exposed to 400 ppm potassium silicate. Moreover, the lowest value for both traits was obtained from the treatment of 0 ppm PS without mycorrhiza fungi (Table 4). The results of the interaction of the three factors showed that at severe drought stress, the minimum values of leaf length and number were unaffected by adding higher amounts of potassium silicate and adding mycorrhiza fungus, as they could not improve the length and number of leaves. The lowest leaf length and number (5.0 cm and 5.33, respectively) were obtained from the fungus-free treatment without potassium silicate and the stress level of 25% FC. The highest values were obtained from full irrigation, 400 ppm PS, and the absence of AMF (Table 5). Water deficit reduces the number, size, and length of leaves. Moreover, a decrease in leaf area leads to a decrease in plant yield through a decrease in photosynthesis, a process that is of paramount importance. The expansion of the leaf area depends on leaf turgor pressure, temperature, and the amount of assimilates for growth, all of which are affected by drought stress (Reddy *et al.*, 2004). Omid Beigi and Sarvestani (2010) argue that in Mexican flowers, as the drought stress intensifies, the number and average length of leaves decreases, which is consistent with our findings.

Flower fresh and dry weight

The results of ANOVA showed a significant effect of experimental treatments on flower fresh and dry weight (Table 1). The interaction between drought stress and fungus showed that the highest amount of flower fresh and dry weight was obtained from the control treatment and non-use of fungi in the culture medium, while the lowest value was obtained from the severe drought stress (25% FC) and non-use of fungi (Table 2). When potassium silicate was used in drought treatments, the data showed the concentration of potassium silicate and the extent to which the effects of drought stress were alleviated. At all drought levels, 400 ppm of potassium silicate resulted in the best performance regarding the flower fresh weight (Table 3). Findings also demonstrated that in all drought stress treatments, the dry weight of the flowers decreased by reducing the amount of potassium silicate concentration. The highest flower dry weight (0.80 g) was observed in the severe drought stress and 0 ppm PS. As the concentration of potassium silicate was increased, in both fungus-applied and fungus-free treatments, the flower's fresh and dry weight increased. The results also showed that the highest flower fresh and dry weights were obtained from the non-stress, fungus-free treatment applied with 400 ppm PS, while the lowest ones were obtained from potassium-free fungus-free treatment at the severe stress level (Table 5).

Number of florets

The number of florets was significantly affected by all experimental treatments (Table 1). The results of the interaction between drought stress and fungus application showed that in two stress levels of 100% and 75% FC, inoculation with mycorrhiza fungus reduced the number of flower buds in the plant, while in moderate and severe stress levels, the application of fungus increased the number of florets by 58% and 42% compared to the fungus-free treatments at the same stress levels (Table 2). The highest number of florets (122 florets) was obtained from the fully irrigated plants treated with 400 ppm PS, while the minimum was observed in the treatment of 0 ppm

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potassium silicate at the most severe drought stress level (25% FC). At all stress levels, higher levels of potassium silicate increased the number of florets compared to their lower-level counterparts, a trend that was observed in all treatments (Table 3). The application of 400 ppm PS to the uninoculated treatment produced the highest number of florets (99.2), which showed an increase of about 39% compared to the treatment with fungi and the same amount of potassium silicate. In both fungus-applied and fungus-free treatments, decreasing the concentration of potassium silicate from 400 ppm to 0 ppm reduced the number of florets in the plant (Table 4). The results showed that in cases where there were no restrictions for irrigation (as in the control treatment) and also the culture medium lacked AMF, the highest number of florets in the plant (n=191) was obtained from the application of 400 ppm PS, while the lowest number (n=10.3) was observed in the inoculated plants treated with 0 ppm PS and exposed to severe drought stress level (Table 3). In a study conducted by Iyyakkannu *et al.* (2010) in Korea, the application of a subsurface irrigation system with a solution containing potassium silicate and calcium silicate in different cultivars of chrysanthemum enhanced flowering performance. Similar results were obtained in other ornamental plants (Fuchsia *et al.*, 2010; Mattson & Leatherwoo, 2010). The results in Table 7 showed that the number of florets had a positive significant effect on stem dry weight (r = 0.91**) and leaf dry weight (r = 0.94**) (Table 7). This indicates that the emergence of floret was enhanced in stems with increasing leaf and stem dry weight. The assimilation and allocation of substance to reproductive organs depended on the growth and development of the leaves and stems, which is one of the main sources of production. These materials, therefore, increased with an increase in leaf and stem dry weight and floret number in the plants (Taiz & Zeiger, 2002).

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Table 5. The comparison of means for the interactions of drought stress, arbuscular mycorrhizal fungi, and potassium silicate on morphological traits of *Matthiola incana*.

Drought	Mycorrhizal fungus	Potassium silicate	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Flower dry weight (g)	Root fresh weight (g)	Fresh leaf and stem weight (g)	Flower fresh weight (g)
S1	M1	K1	1.823^{cdefg}	1.963^{fg}	0.328^{nop}	2.894^{ef}	0.880^{jkl}	11.197^{de}	8.73^{efg}
		K2	1.724^{defgh}	1.892^{g}	0.282^{op}	2.778^{fg}	0.663^{kl}	10.07^{def}	8.147^{efgh}
		K3	1.497^{ghijk}	1.522^{jk}	0.220^{p}	2.166^{j}	0.487^{l}	8.183^{defghi}	5.607^{ghijk}
	M2	K1	3.206^{a}	3.461^{a}	0.537^{kl}	5.398^{a}	1.177^{hijkl}	42.417^{a}	58.55^{a}
		K2	2.012^{bcd}	2.304^{cd}	0.431^{lmn}	3.356^{d}	1.111^{hijkl}	25.47^{c}	14.71^{d}
		K3	1.524^{fghijk}	1.648^{ij}	0.386^{mno}	2.324^{i}	1.042^{ijkl}	8.54^{defghi}	6.257^{fghijk}
S2	M1	K1	1.938^{cde}	2.234^{de}	0.816^{efg}	3.006^{e}	1.743^{fgh}	21.23^{c}	11.127^{de}
		K2	1.679^{defghi}	1.827^{gh}	0.796^{fgh}	2.670^{gh}	1.647^{fghi}	9.56^{defg}	7.33^{efghi}
		K3	1.449^{ghijk}	1.481^{k}	0.777^{fgh}	2.078^{j}	1.523^{fghij}	7.75^{efghij}	5.20^{ghijkl}
	M2	K1	2.330^{b}	3.136^{b}	0.581^{jk}	3.859^{b}	1.255^{ghijk}	33.163^{b}	39.19^{b}
		K2	1.612^{efghij}	1.709^{hi}	0.513^{klm}	2.544^{h}	1.137^{hijkl}	8.93^{defgh}	6.83^{fghij}
		K3	1.303^{ijklm}	1.317^{l}	0.352^{nop}	1.830^{kl}	0.953^{jkl}	7.14^{fghijk}	4.67^{hijklmn}
S3	M1	K1	2.115^{bc}	2.418^{c}	1.928^{a}	3.693^{c}	6.680^{a}	30.35^{b}	30.49^{c}
		K2	1.901^{cdef}	2.102^{ef}	1.504^{c}	2.965^{e}	3.850^{c}	12.34^{d}	9.533^{ef}
		K3	1.375^{hijkl}	1.438^{kl}	1.030^{d}	1.917^{k}	3.470^{c}	7.25^{efghijk}	4.95^{ghijklm}
	M2	K1	1.239^{jklmn}	1.120^{m}	0.888^{ef}	1.705^{lm}	2.117^{ef}	7.01^{efghijk}	4.27^{ijklmno}
		K2	1.183^{klmn}	1.079^{mn}	0.856^{efg}	1.608^{mn}	1.940^{fg}	6.80^{fghijk}	3.96^{ijklmno}
		K3	0.978^{mn}	0.937^{no}	0.827^{efg}	1.445^{op}	1.793^{fgh}	5.143^{hijk}	2.50^{klmno}
S4	M1	K1	1.047^{lmn}	1.012^{mno}	1.773^{b}	1.538^{no}	4.763^{b}	6.20^{fghijk}	3.61^{ijklmno}
		K2	1.009^{lmn}	0.983^{mno}	0949de	1.445^{nop}	3.177^{cd}	5.64^{ghijk}	3.33^{gklmno}
		K3	0.961^{mn}	0.906^{op}	0.902^{def}	1.369^{pq}	2.660^{de}	4.30^{ijk}	1.667^{lmno}
	M2	K1	0.923^{mn}	0.862^{op}	0.677^{hij}	1.271^{qr}	1.450^{ghij}	3.63^{jk}	1.23^{mno}
		K2	0.866^{mn}	0.763^{pq}	0.608^{ijk}	1.158^{r}	1.333^{ghijk}	3.30^{k}	0.91^{no}
		K3	0.428^{n}	0.704^{q}	0.725^{ghi}	0.930^{s}	1.450^{fghij}	3.03^{k}	0.62^{no}

Drought stress: S1, S2, S3,and S4 represent 100%, 75%, 50%, and 25% of FC, respectively; Mycorrhizal fungus: M1 and M2 indicate with and without the fungus, respectively; Potassium silicate: K1, K2, and K3 denote 400 200, and 0 ppm, respectively. In each column, means with a similar letter are not different significantly at a level of 0.05 based on the LSD test.

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Table 6 (continued). The comparison of means for the interactions of drought stress, arbuscular mycorrhizal fungi, and potassium silicate on morphological and physiological traits of *Matthiola incana*

Drought	Mycorrhizal fungus	Potassium silicate	Stem length (cm)	Leaf length (cm)	Root length (cm)	Leaf number	Floret number	Stem diameter (mm)	Proline content (µM/g FW)
S1	M1	K1	19.10^{def}	9.06^{def}	7.397^{fgh}	35^{ef}	54.33^{def}	0.7^{c}	1.17^{klm}
		K2	18.56^{efg}	8.76^{efg}	6.81^{gh}	32^{fg}	50^{efg}	0.6^{d}	1.31^{jklm}
		K3	16.93^{ghi}	8.1^{ghij}	6.45^{h}	26.66^{i}	35^{hijk}	0.6^{d}	1.57^{ijklm}
	M2	K1	27^{a}	13.9^{a}	9.06^{cdefgh}	53^{a}	191^{a}	0.9^{a}	1.10^{klm}
		K2	21.6^{c}	10.73^{c}	8.71^{defgh}	40.33^{cd}	89.33^{c}	0.7^{c}	1.04^{lm}
		K3	17.73^{gh}	8.26^{ghi}	8.66^{defgh}	28.33^{hi}	36^{hij}	0.6^{d}	0.76^{m}
S2	M1	K1	20.64^{cd}	9.70^{d}	10.007^{bcdef}	38.66^{d}	64.66^{d}	0.7^{c}	1.83^{ijkl}
		K2	18.16^{efg}	8.5^{efgh}	9.90^{bcdef}	31.33^{gh}	44.66^{fgh}	0.6^{d}	2.00^{ijkl}
		K3	16.46^{hij}	7.86^{hijk}	9.78^{bcdef}	25^{ij}	34^{hijk}	0.6^{d}	3.41^{fg}
	M2	K1	24.36^{b}	12.36^{b}	9.11^{cdefgh}	45.66^{b}	160.33^{b}	0.8^{b}	2.13^{hijk}
		K2	17.73^{fgh}	8.36^{fgh}	8.79^{defgh}	30.66^{gh}	40.33^{ghi}	0.6^{d}	2.300^{hij}
		K3	15.60^{ijk}	7.4^{jklm}	8.37^{efgh}	20.66^{k}	31^{ijkl}	0.53^{de}	2.47^{ghi}
S3	M1	K1	22.22^{c}	11.83^{b}	13.90^{a}	43.66^{bc}	95.66^{c}	0.73^{bc}	3.19^{fgh}
		K2	19.76^{de}	9.16^{de}	11.87^{abc}	37.33^{de}	57.66^{de}	0.7^{c}	3.77^{f}
		K3	16.14^{hij}	7.6^{ijkl}	11.49^{abcd}	22^{jk}	31.66^{ijkl}	0.6^{d}	4.13^{f}
	M2	K1	15.34^{ijk}	7.16^{klmn}	10.45^{bcde}	19^{kl}	29.66^{ijklmn}	0.5^{e}	5.93^{e}
		K2	14.77^{jkl}	7.06lmn	10.41^{bcde}	16.66^{lm}	27.66^{jklmn}	0.5^{e}	6.64^{de}
		K3	13.46^{lmn}	6.3^{opq}	10.18^{bcdef}	12.66^{nop}	20^{lmnop}	0.5^{e}	7.45^{cd}
S4	M1	K1	14.33^{klm}	6.767^{mno}	12.42^{ab}	15^{mn}	26^{jklmn}	0.5^{e}	7.66^{cd}
		K2	14^{klm}	6.46^{nop}	11.25^{abcde}	14.33^{mno}	23.33^{klmno}	0.5^{e}	7.70^{c}
		K3	12.8^{mn}	6.2^{opq}	11.10^{abcde}	11.33^{op}	18.33^{mnop}	0.46^{ef}	7.91^{c}
	M2	K1	11.86^{no}	5.967^{pq}	9.64^{bcdefg}	9.33^{pq}	16^{nop}	0.4^{fg}	8.12^{c}
		K2	11.03^{o}	5.733^{q}	9.62^{bcdefg}	7.33^{qr}	13^{op}	0.4^{fg}	9.49^{b}
		K3	8.81^{p}	5.0^{r}	9.73bcdefg	5.33^{r}	10.33^{p}	0.33^{g}	11.15^{a}

Drought stress: S1, S2, S3, and S4 represent 100%, 75%, 50%, and 25% of FC, respectively; Mycorrhizal fungus: M1 and M2 indicate with and without the fungus, respectively; Potassium silicate: K1, K2, and K3 denote 400, 200, and 0 ppm, respectively. In each column, means with a similar letter are not different significantly at a level of 0.05 based on the LSD test.

Table 7. Results of correlation coefficients between morphological traits of *Matthiola incana* under the influence of arbuscular mycorrhizal fungi, potassium silicate, and drought stress conditions.

	Proline content of the leaf	Stem diameter	Number of florets	Average leaf count	Root length	Length of leaf	Stem length	Fresh weight of flowers	Fresh root weight	the dry weight of flowers	dry root weight	Dry weight of leaves	Dry weight of stems
Dry weight of stems	-.784**	.974**	.916**	.970**	-0.106	.977**	.984**	.874**	-0.025	.989**	-0.074	.976**	1
Dry weight of leaves	-.768**	.965**	.944**	.975**	-0.106	.985**	.979**	.887**	-0.029	.984**	-0.074	1	
dry root weight	0.3	-0.017	-0.043	-0.042	.966**	-0.005	-0.028	0.03	.959**	-0.049	1		
the dry weight of flowers	-.739**	.960**	.936**	.969**	-0.085	.985**	.975**	.902**	0.003	1			
Fresh root weight	0.236	0.043	-0.009	0.014	.946**	0.059	0.029	0.074	1				
Fresh weight of flowers	-0.460*	.821**	.977**	.794**	0.017	.907**	.843**	1					
Stem length	-.816**	.985**	.903**	.986**	-0.059	.984**	1						
Length of leaf	-.741**	.962**	.946**	.970**	-0.037	1							
Root length	.349	-0.047	-0.057	-0.086	1								
average leaf count	-.845**	.975**	.860**	1									
Number of florets	-.561**	.878**	1										
Stem diameter	-.815**	1											
Proline content of the leaf	1												

** and * are correlation is significant at the 0.01 and 0.05 probability levels

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Conclusion

The findings of the present study showed that the use of high levels of potassium silicate (400 ppm) alleviated the effect of 50 and 25% FC drought stress on *Matthiola incana*. At these stress levels, the stem dry weight was 2.13 and 1.67 g/plant, respectively, which was higher than no silicate application. The same trend was also observed for leaf dry weight and root fresh and dry weight. The application of potassium silicate and fungi was also able to reduce proline concentrations at different levels of drought. Based on these results, the use of 400 ppm potassium silicate with fungi can reduce drought stresses in *Matthiola incana*.

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