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EFFECT OF ENDOMYCORRHIZAL FUNGI INOCULUM ON AGRO MORPHOLOGICAL BEHAVIOR AND PRODUCTIVITY OF SAFFRON (*CROCUS SATIVUS* L.) UNDER WATER AND SALINITY STRESS

Ismail El Aymani[1], Samah Ourras[1], Najoua Mouden[2], Mohamed Chliyeh[1], Karima Selmaoui[1], Soukaina Msairi[3], Rachid Benkirane[1], Cherkaoui El Modafar[4], Amina Ouazzani Touhami[1], Allal Douira[1]

[1] Laboratory of Plant, Animal and Agro-Industry productions, Botany, Biotechnology and Plant Protection Team, Faculty of Sciences, Université ibn tofail-Kénitra-Morocoo

[2] Laboratory of Molecular Chemistry and Environmental Molecules, Multidisciplinary Faculty of Nador-Mohammed I. University Oujda, Morocco

[3] National Agency of Medicinal and Aromatic Plants, Taounate, Morocco

[4] Agrobiotechnology and Molecular Bioengineering Laboratory, Faculty of sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco

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Abstract

The present work tried to evaluate whether arbuscular mycorrhizal fungi (AMF) affected physiological aspects of saffron corms by triggering flowering and dormancy together with improving growth parameter. Endomycorrhizal fungi inoculum was inoculated into potted saffron corms (*Crocus sativus* L.) exposed to stress conditions (water and salinity) and followed for two growing seasons. Results highlighted a variation among saffron responses to endomycorrhizal fungi inoculum under water and salinity stress. The mycorrhizal corms showed a regular flowering period that occurred earlier than that of non-inoculated with AMF. The superior values of morphological traits, such as leaf and root length, leaves number and daughter corm number were between 3 and 12 cm, 11 to 25 cm; 13.4–4.5; 7 and 3 at respective concentrations of 1 g/l and 5 g/l of NaCl. Similarly, in AMF inoculated saffron, no statistical difference was observed in the dry weight average of aerial part in plants facing water level 60% (0.38 g) and 40% (0.27 g) compared respectively to 0.36 g and 0.22 g in control plants. The fresh weight of aerial saffron parts were 2 g (1 g/L), 0.6 g/L and 0.33 g at 5 g/L of NaCl compared to 1.6 g, 0.4 g and 0.2 g in control plants. At water level of 60% and 40%, this weight decreased from 1.46 g to 0.85 g. Almost equal values of dry weight of root parts were noted at 3 g/L (0.33 g) and 5 g/L of NaCl (0.22 g) in saffron plants from bulbs grown in soil incorporated with AMF inoculum compared to 0.25 g (3 g/L) and 0.18 g at 5 g/L of NaCl in control plants.

Keywords: saffron, corms, salinity stress, water stress, flowering period, growth parameters

INTRODUCTION

Saffron, dehydrated or dry stigmas of the flower of *Crocus sativus* L., is considered among the main local product of Morocco. In 2015, saffron plantations covered an area of the order of 1600 ha with an average yield of 3.5 t, which ranks the Kingdom fourth producer in the world.

There are reports of the rusticity of this species and its potential for growing in arid and semi-arid environments, due to where water scarcity and

soil salinity are common. This plant species has an appropriate morphology and physiology traits that promote its resistance to harsh climatic conditions and to successfully grow undervarious temperature and altitude ranges (Alizadeh *et al*., 2009).

Crocus sativus L. is well known to produce annual replacement progeny corms, which ensure its vegetative propagation (Gresta *et al*., 2008; Kumar *et al*., 2009). But earlier studies have revealed some morphological differences of *Crocus sativus* L. in intensity of flower color, pollen size, number of style branches, stamens and viability (Caiola *et al*., 2000). From the point of view of climatic requirements, saffron is characterized by its tolerance to salinity and salt water can be used for the production of saffron (Sepaskhah *et al*., 2009). Arid and semi-arid areas constitute two thirds of the earth's surface (Benbrahim *et al*., 2004). In these areas often marked by severe drought, soil salinization is considered to be one of the main factors limiting agricultural production. In Morocco, the salinization of agricultural soils begins to develop with the extension of irrigated areas, nearly 500,000 hectares of arable land are subject to increasing salinization (MEMECEE, 2015).

Salinity is a limiting factor of agricultural productions worldwild especially in arid and semiarid regions (Munns and Gilliham, 2015). The role of plant-microorganism interactions on plant stress responses has been given attention in recent years. Fungal symbionts such as mycorrhizal fungi may influence plant species behaviors under adverse environmental factors like salinity stress (Al-Karaki *et al*., 2001; Porcel *et al*., 2012; Begum *et al*., 2019; Evelin *et al*., 2019).

They establish a mutualistic relationship, the fungi supplying mineral nutrients from the soil while acquiring carbon compounds from the photosynthetic host (Lanfranco and Young, 2012). The AMF form a mycelial network extending under the roots of the plant which significantly enhances the access of roots to a large soil surface area, causing improvement in plant growth (Bowles *et al*., 2016). They also promote nutrient uptake by increasing the availability as well as translocation of various nutrients (Rouphael *et al*., 2015).

Previous studies have demonstrated that AMF increased by twoshold plant productivity in grassland (Van der Heijden *et al*., 1998; Vogelsang *et al*., 2006). Better growth of mycorrhizal plants was observed under both drought (Auge, 2012) and salinity conditions (Porcel *et al*., 2012). The tolerance of mycorrhizal plants to such stresses would be attributed to mineral and water nutrition improvement leading to a better development of the plant plant (Auge, 2012; Ruiz-Lozano *et al*., 1995). Recent studies have proposed different mechanisms that AMF use to alleviate these abiotic stresses. Indeed, arbuscular mycorrhizal fungi play a pivotal role through which several changes in the morpho-physiological traits of the host plant plant (Alqarawi *et al*., 2014; Hashem *et al*., 2015).

To date, little studies are focused on the effect of AMF on growth and development of saffron bulbs subjected to both salt and drought stress conditions. Thus, the aim of the present paper was to investigate both the agro-morphological and bloom traits together with yield of saffron bulbs growing under natural stress of salinity and water in response to AMF inoculation.

MATERIALS AND METHODS

Experimental Site

Trials were carried out in an experimental field station in Kenitra Faculty of Science (13 m above mean sea level, latitude 34°15′39″ North N, longitude 6° 34′ 48″ Ouest (GPS Back Track Bushnell).

Plant Material

Experiments were performed by growing saffron corms into experimental pots at 15/09/2018. These corms come from Talouine the main region of saffron cultivation in Morocco.

Preparation of Inoculum

Composite endomycorrhizal inocula, originating from the rhizospheres of saffron plants developing in saffron fields in the Taliouine-Taznakht region, Ouarzazate province, aged 2, 4, 6 and 10 years (saffron cultivation plots exploited for 2, 4, 6 and 10 years) (El Aymani *et al*., 2019). Barley was used as a host plant for the multiplication of these inocula. Barley grains were disinfected with 5% sodium hypochlorite for 2 minutes and sprouted in plastic jars filled with a mixture of sterile sand and the endomycorrhizal inoculum, stored in the laboratory as mycorrhizal roots. After four weeks of cultivation, the barley roots are collected, rinsed 3 times with distilled water and cut into fragments 1 to 2 mm in length. These roots are used as an endomycorrhizal inoculum.

Three grams of mycorrhizal barley root fragments were incorporated, before planting, in the upper part of each pot filled with sterile sand and intended to receive the saffron bulbs. The substrate in the control pots did not receive mycorrhizal roots. After transplanting the saffron bulbs, the pots were transported to the greenhouse

Treatments

To assess the effect of AMF inoculation on saffron plants exposed to abiotic stress, 2 essays were carried out.In the first one, saffron plants were cultivated in pots filled with soil amended with NaCl at concentration of (0; 1; 3 et 5 g.L-1) and the second one testing three water soil regimes (three levels of water 100%; 60% et 40% of reference evapotranspiration) on mycorrhizal corms and non- inoculated saffron corms (non-AMF), taking into account the rainfall contributions of the city of Kenitra. The water used for irrigation has an electrical conductivity EC of 0.7 mS/cm. The experiments lasted for 2 years.

Experimental Design

Complete randomized block design with a total of 75 plants displayed in two experimental units was conducted.The first potted unit consisted of 45 saffron plants for salinity stress assay and the second one for water stress composed of 30 saffron plants (*5 bulbs per treatment, 8 treatments in the salt stress assay and 6 treatments in water stress assay) with three replicates were established for each concentration of salt and /or water regime (Fig. 1 and 2).

Observations regarding the time of the first and last flowering dates, the total harvest period (days) together with agro-morphological traits, viz, plant height (cm), number of leaves per mother corm, leaf length (cm), fresh weight of aerial saffron plant parts (g), dry saffron weight (g) and produced daughter bulbs were recorded.At the end of the experimental trial, saffron plant samples were placed in an oven with 80 °C until constant weightand then dry weight of aerial biomass was measured while the fresh weight of aerial biomasswas previously quantified.

5 g/L + M 5 g/L 3 g/L + M 3 g/L 1 g/L+ M 1 g/L 0 g/L + M 0 g/L

1: *Effect of salt concentrations on the growth of Crocussativus seedlings after two growing seasons of corms transplanting (M: C. sativus plants from substrates inoculated with endomycorrhizalfungi inoculum)*

100% 100% + M 60% 60% + M 40% 40% + M

2: *Effect of water stress on the growth of C. sativus seedlings after two growing seasons of stress (M: saffron plants from substrates inoculated with endomycorrhizal inoculum)*

Statistical Analysis

Response variables were subjected to both statistical descriptive and variance analysis (ANOVA) with SPSS software for Windows version 20". A comparison of means test was performed using the Tukey test ($P \leq 0.05$).

RESULTS

Effect on the Harvest Period

The following up of the experiment showed an obvious effect of endomycorrhizal fungi on flowering parameters under abiotic stresses. The onset of the flowering stage was at the second week of October and was widding up at the end of November.

Influenced with water stress, the first flowers were observed in plants derived from AMF-inoculated bulbs under water regime of 100% followed by those of 60% then non inoculated bulbs and finally on inoculated bulbs irrigated with 40% of water level.

Under 1 g/l of NaCl, flowers appears firstly on plants from inoculated bulbs then appear those of plants from AMF-inoculated bulbs in soil amended with 3 g/L of NaCl. However, a delayed appearance of flowers was noted in soil amended with 5 g/L of NaCl, although flower production occurred in advance in inoculated saffron plants than non-inoculated plants (Tab. I).

Effect on Vegetative Cycle

Results from Tab. II showed different dates at which saffron plants entered dormancy which varied versus treatments and stress conditions excerced. Leaves beginning to discolor and yellowing signs began long before the end of March and dormancy was accelerated under strenght stress conditions and water deficit of 40% and in

I: *Effect of different stress conditions on harvest period of flowers*

Treatement		Flowering period	
		October	November
		9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24-25-26-27-28-29-30-1-2-3-4-5-6-7-8-9-10-11-12	
Salt stress	0g/l T	Harvest period	
	0g/l M		
	1g/l T		
	1g/l M		
	3g/l T		
	3g/l M		
	5g/l T		
	5g/l M		
Water stress	100 T		
	100% M		
	60% T		
	60% M		
	40% T		
	40% M		

II: *Effect of AMF inoculation on dormancy dates of saffron plants exposed to water an salt stress*

Traitements		Date of dormancy	
		March	April
		25-26-27-28-29-30-31-1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-19-20	
Stress Salin	0g/l T		
	0g/l M		
	1g/l T		
	1g/l M		
	3g/l T	Active period	Dormancy period
	3g/l M		
	5g/l T		
	5g/l M		
Stress Hydrique	100 T		
	100% M		
	60% T		
	60% M		
	40% T		
	40% M		

absence of AMF inoculation. The dormant state of saffron bulbs treated with AMF and exposed to 3 g/L of NaCl was attained early in April, at the second fortnight of April for inoculated bulbs, grown in soil amended with 1 g/L of NaCl, or forward in the end of March in AMF inoculated corms grown at 5 g/L of NaCl. Without salt treatment, saffron bulbs showed lengthened vegetative period and dormancy occurred at the third week of April. With AMF inoculation, saffron plants remained vegetatively active until the first and the second week of April in the case of water deficit of 60% and 40% respectively. In absence of both water and salt stress, symptoms of dormancy's saffron plants were detected only after the mid-April.

Effect on Growth Parameters

During two growing seasons, subjected to three irrigation regimes and four NaCl concentrations in soil, the planted saffron bulbs had shown different growth abilities (Fig. 1 and 2). The whole growth parameters of saffron plants, viz, leaves number, leaves length, bulbs number and fresh and dry biomass of aerial and root parts inversely varied to stress intensity (Tab. II).

Length of Leaves

Under salinity stress, bulbs which were cultivated in soil incorporated with endomycorrhizal fungi showed an increase of leaf length varying from 3 cm and 12 cm compared to un-inoculated plants, but a significant decrease in leaf length was recorded when the salt concentrations tested augment. On the other side, the combination of water stress and AMF application leads to an increase of leaf length to 4 cm for 100% water level and 13 cm for 40% water level (Tab. III).

Root Length

A positive effect of endomycorrhizal fungi on growth roots was noted. Hence, in plants from inoculated bulbs, the root length average reached 25 cm; 21 cm and 11 cm at 1 g/l; 3 g/l; 5 g/l of salt concentrations respectively against 19 cm; 16 cm; 10 cm in control plants (Tab. IV).

The root length of mycorrhizal plants was superior than that of non- inoculated plants with an increases in the order of 5 cm, 7 cm and 6 cm were respectively obtained with 100%, 60% and 40% of water level used in irrigation (Tab. IV).

Fresh and Dry Weight of Aerial Parts

In saffron plants, AMF seems to act positively on aerial part development. The fresh weight was superior in inoculated plants than control plants and significant difference marked fresh weight values under the three water regimes 100% (1.7 g), 60% (1.4 g) and 40% (0.9 g) compared to 1.25 g at 100% of water, 1.3 g (60%) and 0.7 g (40%) for control plants.

Though salt stress strongly affected the fresh weight of aerial saffron parts, AMF seems enhance the growth of above ground parts of saffron showing weight values of 2 g; 0.6 g et 0.33 g respectively at 1 g/L; 3 g/L; 5 g/L of NaCl compared to 1.6 g, 0.4 g and 0.2 g in control plants.

The dry weight of plant showed slight significant increase in AMF inoculated plants than in control ones under salt or water stress. AMF effect varied according to challenged abiotic stress. In AMF presence, no statistic difference was observed in dry weight values of aerial part in plants facing water level 60% (0.38 g) and 40% (0.27 g) compared respectively to 0.36 g and 0.22 g in control plants. Likewise, statistically equal dry weight values were noted at 3 g/L (0.33 g) and 5 g/L of NaCl (0.22 g) in saffron plants from bulbs grown in soil incorporated with AMF inoculum compared to 0.25 g (3 g/L) g and 0.18 g at 5 g/L of NaCl in control plants (Tab. V).

III: *Mean length of aerial part (M.L.A) in AMF-inoculated plants (Plants M) and non inoculated plants (Controls) of Crocus sativus L. under water and salt stress. Data (Means ± SD) followed by different letters above bars showed significant differences at p < 0.05 between treatments.*

Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5 g/l
Control (M.L.A. cm)	27 ^{ab}	17 ^{bc}	14 ^{c}	27 ^{ab}	20 ^{ab}	17 ^{c}	10 ^{d}
Micorrhized plants (M.L.A. cm)	31 ^{a}	29 ^{a}	20 ^{b}	31 ^{a}	32 ^{a}	25 ^{b}	13 ^{d}

IV: *Mean length of root (M.L.R) part in AMF-inoculated plants (Plants M) and non inoculated plants (Controls) of Crocus sativus L. under water and salt stress. Data (Means ± SD) followed by different letters above bars showed significant differences at p < 0.05 between treatments.*

Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5 g/l
Control (M.L.R. cm)	22 ^{b}	18 ^{c}	13 ^{d}	22 ^{ab}	19 ^{b}	16 ^{c}	10 ^{d}
Micorrhized plants (M.L.R. cm)	27 ^{a}	25 ^{ab}	19 ^{bc}	27 ^{a}	25 ^{a}	21 ^{ab}	11 ^{d}

V: *Fresh and dry weight of aerial parts in AMF-inoculated plants (Plants M) and non inoculated plants (Controls) of Crocus sativus L. under water and salinity stress. Data (Means ± SD) followed by different letters above bars showed significant differences at p < 0.05 between treatments.*

Fresh weight of aerial parts							
Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5 g/l
Control (F.W.A. mg)	1,2^{b}	1,3^{b}	0,8^{c}	1,2^{b}	1,6^{ab}	0,4^{cd}	0,2^{d}
Micorrhized plants (F.W.A. mg)	1,9^{a}	1,45^{b}	0,85^{c}	1,9^{a}	2^{a}	0,6^{c}	0,33^{cd}
Dry weight of aerial parts							
Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5 g/l
Control (D.W.A. mg)	0,35^{b}	0,36^{ab}	0,22^{d}	0,35^{b}	0,37^{b}	0,25^{c}	0,18^{d}
Micorrhized plants (D.W.A. mg)	0,45^{a}	0,38^{ab}	0,27^{d}	0,45^{a}	0,46^{a}	0,33^{cd}	0,22^{c}

VI: *Fresh and dry weight of root parts in AMF-inoculated plants (Plants M) and non-inoculated plants (Controls) of Crocus sativus L. under water and salinity stress. Data (Means ± SD) followed by different letters above bars showed significant differences at p < 0.05 between treatments.*

Fresh weight of root part (F.W.R)							
Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5 g/l
Control (F.W.R. in mg)	1^{b}	0,9^{b}	0,3^{d}	1^{b}	1,3^{ab}	0,5^{d}	0,2^{e}
Micorrhized plants (F.W.R. in mg)	1,2^{a}	1^{b}	0,55^{c}	1,2^{b}	1,5^{a}	0,7^{c}	0,3^{ed}
Dry weight of root part (D.W.R)							
Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5g/l
Control (D.W.R. in mg)	0,4^{c}	0,38^{c}	0,15^{d}	0,4^{c}	0,5^{bc}	0,28^{e}	0,08^{f}
Micorrhized plants (D.W.R. in mg)	0,65^{a}	0,55^{b}	0,26^{cd}	0,65^{a}	0,55^{b}	0,33^{d}	0,12^{f}

Fresh and Dry Weight of Root Part

The results from the Tab. IV indicated that AMF incorporation in substrate culture induced root development representing a fresh weight of 1.5 g, 0.7 g and 0.3 g in plants exposed to the respective concentrations 1 g/L; 3 g/L; 5 g/L of NaCl compared to 1.3 g, 0.5 g and 0.2 g in control plants. Suffering from water deficit, inoculated saffron plants also recorded an increased root fresh weight in the order of 1 g and 0.5 g for respective water stress 60% and 40%. At the same time, mycorrhizal plants showed a higher dry weight of root parts of 0.55 g (60% of water level) and 0.26 g (40%) than control plants reaching 0.38 g (60% of water level) and 0.15 g (40%) (Tab. VI).

Mean Number of Leaves

Under the three water levels, there were no significant differences in the mean number of leaves between plants from AMF inoculated bulbs and those without mycorrhizal treatment. However, at 60% of water, AMF inoculum had resulted in similar increase of that recorded in plants with no irrigation deficiency. In regard to salt stress conditions, the treatment with AMF induced a largest number of leaves attaining 13.4, 7 and 4.5 on average compared with 13, 5 and 3.5 on average in non- inoculated bulbs grown in substrate culture added with 1 g/L, 3 g/L and 5 g/L of NaCl respectively. The promising effect of AMF treatment was significant in corms cultivated in growing substrate added with 3 g/L and 5 g/L of NaCl rather than those without AMF inoculation (Tab. VII).

Mean Number of Bulbs

The highest concentration of NaCl tested 5 g/L caused a reduction of bulbs production nevertheless the results showed a notable stimulation of bulbs production in presence of AMF inoculums regardless the concentration of NaCl in substrata culture. Furthermore at 3 g/L and 5 g/L, statistically, the number of bulbs produced by AMF inoculated plants seems to be equal. In response to water stress, AMF inoculated plants produced on average 5 and 4 daughter bulbs surpassing control plants from which emerged 4 bulbs (water level of 60%) and 3 bulbs (40% of water level) (Tab. VIII).

VII: *Mean number of leaves in uninoculated plants (control) and AMF-inoculated plants (Plants M) of Crocus sativus L. under water and salinity stress. Data (Means ± SD) followed by different letters above bars showed significant differences at p < 0.05 between treatments.*

Mean number of leaves (M.N.L)							
Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5 g/l
Control (M.N.L)	13 [a]	7 [b]	6 [b]	13 [a]	13 [a]	5 [c]	3,5 [d]
Micorrhized plants (M.N.L)	13,5 [a]	9 [ab]	7 [b]	13,5 [a]	13,4 [a]	7 [b]	4,5 [c]

VIII: *Mean number of daughter bulbs derived from non-mycorrhizal mother bulbs (control) and AMF-inoculated plants (Plants M) of Crocus sativus L. under water and salinity stress. Data (Means ± SD) followed by different letters above bars showed significant differences at p < 0.05 between treatments.*

Mean number of daughter bulbs (M.N.D.B)							
Stress	Water treatment			Salt treatment			
	100%	60%	40%	0 g/l	1 g/l	3 g/l	5 g/l
Control (M.N.D.B)	6 [a]	4 [c]	3 [d]	6 [a]	6 [a]	3 [b]	2 [bc]
Micorrhized plants (M.N.D.B)	6,5 [a]	5 [b]	4 [c]	6,5 [a]	7 [a]	4 [b]	3 [bc]

DISCUSSION

The findings indicate the importance of endomycorrhizal fungi inoculum in improving growth parameters of saffron plants under both water and salt stresses. Irrespective to water regime and salt treatment applied, endomycorrhizal fungal inoculum had also actively affected the flowering period and vegetative cycle time spans.

The effect of the endomycorrhizal fungi on the flowering stage differed according to species used and the cultural practices applied (Nowak, 2004). The flowering of saffron can occur from mid-October to the end of November according to the climatic conditions. Results given above showed that saffron plants flowered longer in the presence of AMF. This agreed with previous studies stating that AMF caused earlier flowering, increased the total duration of flowering and increased flower number (Conversa *et al*., 2013; Derelle *et al*., 2015; Gaur, 2000; Lu and Koide, 1994; Trimble *et al*., 1995; Vaingankar and Rodrigues, 2014). Likewise, inoculated Ajania plants had on average significantly more inflorescences, a greater number of flowers, and had a longer flowering time than uninoculated plants (Vosnjak *et al*., 2021). Indeed, there is conflicting result regarding flowering–AMF interaction. For instance, mycorrhizal Geranium plants present more delayed flowering period than non-mycorrhizal plants (Nowak, 2004). In experiments on *Chrysanthemum Morifolium* Ramat, Sohn *et al.* (2003) demonstrated that AMF inoculation significantly shortened flowering time as shown for *Impatiens balsamina* (Gaur *et al*., 2000); *Callistephus chinensis* (Gaur and Adholeya, 2005). Garmendia and Mangas (2012) found that *Glomus mosseae* reduced by one month the time needed for 80% of the plants to flower. Scagel (2004) demonstrated that AMF alter aspects of corm quality influencing the timing of shoot emergence in the growing cycle following inoculation but did not delay the timing of flower emergence. This likely due to an altered carbohydrate metabolism could contribute to change the flowering timing. In the current study, it started atmid -October to the early November but the time required for flower initiation seems to vary depending upon the stress that is studied and its intensity.

Similarly, dormant stage was also altered by AMF inoculation, salinity level and water regime. The dormancy period increased with increasing salinity concentration and water level. According to Seghieri *et al.* (1995), decreasing soil water reserves affect the intensity of flowering and the outcome of the reproductive phase, even when flowering has begun normally. However, it must be noted that active period was more prolonged in AMF-plants. Similar alleviation effects of AMF inoculation were reported on the negative effects of water stress on inflorescence number of *Bidens pilosa* (Song, 2007). Jin *et al.* (2015) found that AMF addition improved the flower date delay and the reduction in flowering duration caused by Cu supply. Consistent observations were reported by Steiner *et al.* (1985) and Turner (1986) who also observed that the duration of the “sowing - flowering” cycle shortens with increasing water deficit and advancement of the phenological development of plants. Indeed, drought avoidance is one of drought resistance mechanism. It consists on the ability of a plant to complete its life cycle before the water became deficient in soil and plants. The arbuscular mycorrhizal (AM) symbiosis represents a beneficial interaction between plants and microorganisms which enhance the plant's nutrient uptake by extending the root absorbing area. In return, the

symbiont receives plant carbohydrates for the completion of its life cycle (Strullu *et al*., 1997). Maybe, dormant earliness might be the mechanism avoidance that saffron escaped from high salinity levels and weak rate irrigation which saffron plants are subjected to. Such suggestions allow us to purpose that mycorrhizal saffron plants are able to adapt their reproduction cycle to different regimes of water availability or salt stress.

Concerning plant growth parameters, significant improvement of plant biomass, leaf number and length, root length and daughter corms number was detected in inoculated plants, probably due to the great symbiosis establishment and abiotic stress tolerance acquisition. In line with our results, Püschel *et al*. (2014) noticed that mycorrhizal drought-stressed plants were distinctly more vital than were their well-watered, but non-mycorrhizal plants. Likewise, Shamshiri *et al*. (2012) found that promotive effects of AMF on plant growth parameters are more obvious when the plants are under nutrient deficient condition in general and phosphorous deficiency in specific. Our results are in agreement with those of Turkmen *et al*. (2008) who have demonstrated the beneficial effects of AMF species on salt tolerance based on the plant growth parameters and nutrient contents. Against water stress, Begum *et al*. (2019) found that inoculation with AMF (*Glomus versiforme*) had a noticeable impact on the growth and development of maize under drought stress by strengthening key tolerance mechanisms. Coffee plants inoculated with *Rhizophagus clarus*, *Claroideoglomus etunicatum*, and *Dentiscutata heterogama* were tolerant to water stress and showed increased growth indexes (Moreira *et al*., 2018). According to Bárzana *et al*. (2012), AMF can improve waterstress tolerance by physiological alteration of the above-ground organs and tissues, the accumulation of dry matter and enhances water moisture uptake.

CONCLUSION

The current survey indicated that mycorrhizal inoculum had differently affected agronomical and physiological traits of saffron plants a function of both salinity level and water reserve. Adding AMF inoculum into growing medium imparted a positive effect on plant growth parameters of saffron plants and corm production by improving the length of both aerial and root plant parts, number of leaves and daughter bulbs produced. Furthermore, AMF-plants were able to keep the regular flowering time extending from mid-October to November and slowing metabolism process by entering in dormant period. These beneficial effects allow us to suggest that AMF inoculation had the potential to cope with adverse effect of abiotic stresses by adapting available resources with plant growth stages. The suitable management of these symbionts represents a feasible strategy since it would contribute to improve the growth of saffron plants and enabling easier adaptation to stressful conditions. Thus, mycorrhiza use can consider to be used in saffron cultivation for a sustainable agricultural strategy for growers.

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Contact information
Ourras Samah: samah.ourras@uit.ac.ma (corresponding author)