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تاثیر کلرید پتاسیم بر صفات رویشی سورگوم تلقیح شده با قارچ مایکوریز *Glumus mossea* در تنش کم‌آبی

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چکیده

سابقه و هدف: به منظور بررسی اثر مقادیر مختلف کود پتاسیم بر سورگوم رقم KGS تلقیح شده با قارچ مایکوریز *Glumus mossea* در شرایط تنش کم‌آبی، آزمایشی به‌صورت کرت‌های خردشده در قالب طرح پایه بلوک های کامل تصادفی با چهار تکرار اجرا گردید.

مواد و روش ها: تیمارهای آزمایشی شامل سطوح مختلف تنش در سه سطح شامل؛ آبیاری پس از ۴۰ میلی‌متر تبخیر از تشت تبخیر کلاس A (S1)، آبیاری پس از ۸۰ میلی‌متر تبخیر از تشت تبخیر کلاس A (S2) و آبیاری پس از ۱۲۰ میلی‌متر تبخیر از تشت تبخیر کلاس A (S3) و مقادیر مختلف کود پتاسیم در سه سطح بدون کود پتاسیم (K1)، ۷۵ کیلوگرم در هکتار کلرید پتاسیم (K2) و ۱۵۰ کیلوگرم در هکتار کلرید پتاسیم (K3) بود. صفات مورد بررسی شامل ارتفاع گیاه، تعداد پنجه، طول برگ‌پرچمی، طول پانیکول، عملکرد علوفه تازه و خشک بود.

یافته ها: بیشترین مقدار همه صفات اندازه‌گیری شده از تیمار S1 حاصل شد و با افزایش تنش کم‌آبی تمامی پارامترهای اندازه گیری شده در رشد و عملکرد سورگوم کاهش نشان داد. در بین تیمارهای مقادیر مختلف کود پتاسیم نیز بیشترین طول پانیکول و عملکرد علوفه تازه و خشک سورگوم از تیمار K3 به دست آمد. ارزیابی ضریب همبستگی نشان داد که عملکرد علوفه سورگوم با ارتفاع ساقه و قطر ساقه همبستگی مثبت و معنی‌داری دارد.

نتیجه گیری: در بین تیمارهای اعمال‌شده تیمار مناسب، اعمال ۱۵۰ کیلوگرم کود کلرید پتاسیم در هکتار و آبیاری پس از ۴۰ میلی‌متر تبخیر از تشت تبخیر بود.

واژگان کلیدی: میکروارگانیسم همزیست، قارچ *Glumus mossea*، تنش کم‌آبی، تبخیر، کود.

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The effect of potassium chloride on vegetative parameters of sorghum inoculated with mycorrhizal fungi (*Glumus mossea*) under water stress condition

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Abstract

Background & Objectives: The effect of different levels of potassium fertilizers on sorghum inoculated with mycorrhizal fungi (*Glumus mossea*) was evaluated under water stress condition in a split-plot experiment, based on randomized complete block design in four replicates.

Materials & Methods: Treatments were carried out in three different levels of stress including irrigation after 40, 80 and 120 mm evaporation from pan evaporation class A (S1, S2, and S3, respectively); three different levels of potassium chloride fertilizer treatments including without fertilizers, 75 kg and 150 kg/hec of potassium chloride (K1, K2 and, K3, respectively). The studied parameters were plant height, number of tiller per plant, flag leaf length, panicle length, and fresh and dry forage yield.

Results: Results indicated that the maximum value of all measured parameters obtained from S1. Increasing water stress resulted in a decrease in both yield and growth rate. Furthermore, among K treatments, maximum panicle length and fresh and dry forage yield obtained from K3. Correlation study showed a positive correlation between forage yield of sorghum and height and diameter of the stem.

Conclusion: Among the applied treatments, the optimal amount of potassium chloride fertilizer was 150 kg/hec along with irrigation after 40 mm evaporation from the evaporation pan.

Keywords: Symbiosis microorganisms, *Glumus mossea*, Drought, Evaporation, Fertilizer.

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Introduction

According to different Iran climate classification methods such as Coupons, Domarten, Emberger, Ghosn and others, Sistan area has been categorized as hot and dry climate, with hot and long summers.

Meanwhile, the source of Sistan rainfalls is low -pressure systems of Suran Mediterranean, with the rainfalls most often associated with thunder. This area is counted as one of the driest habitats of Iran, with the mean annual rainfall of 59 mm (1).

Water resource limitation in arid and semi-arid areas such as Sistan along with nearly two decades (1997-2014) of continuous drought in this region has imposed serious restrictions on crops, destruction of natural pastures, and threatening and reduction of livestock and related industries. As a result, the use of biological resources and application of fertilizers by planting resistant varieties may have a vital role. Microorganisms have a significant role in supplying plant nutrient needs and their protection (2).

Likewise, it is important to attend to forage plants due to their growth ability in regions with specific limitations. Accordingly plants such as sorghum, due to the ability of adaptation to harsh conditions of Sistan region, can be considered as a good pattern for new cultivation in this region (3).

Mycorrhizal fungi increase the uptake of soil salinity and toxicity and play an important role in increasing crop yield (4, 5).

Buttar *et al.*, (6) reported that lack of irrigation significantly reduces canola seed yield 45- 58 %. Kazi *et al.*, (7) reported a positive correlation between the level of irrigation and seed yield, so that changes in water level increased seed yield by 54%. Water stress reduced trunk weight and corn grain yield 23% and 55%, respectively. While in symbiosis with mycorrhizal fungi the reduction rate was reported as 12% and 31%, respectively (8).

Simultaneous root colonization with mycorrhizal fungal including *Glomus mosseae* had a significant effect on wheat growth and element absorption under water stress conditions. The same has been proved in alfalfa (9), onions and peppers, as well (10).

One of the main factors in improving drought resistance is maintaining adequate nutrition in plants under various conditions such as drought. Potassium as one of the most important inorganic soluble elements is necessary for different conditions especially water stress. Potassium helps to reduce the vascular osmotic pressure required to maintain turgor (11).

In a study in India, potassium fertilizer was shown to increase wheat tolerance to drought (12). Nowadays plant potash requirement is supplied by potassium sulfate (K_2SO_4) and potassium chloride (KCl). A 100 percent pure potassium fertilizer contains 52% K2O, and 18% sulfur. So the more impure the fertilizer, the more amount of K2O will drop. Based on the type of element impurity, it sometimes causes the less potassium absorption by the plant. In addition, more impurity in fertilizer not only decreases its solubility in water, but also decreases the dissolution rate.

So those farmers who use the drip irrigation systems are required to consider the dissolution rate. Depending on the purity of potassium sulfate (96% to 99%), the world price increases by about 3%. The average amount of potassium in element form in potassium sulfate is 42%, and in potassium chloride is 50% (13).

Mycorrhizal fungi play an important role in increasing plant yield as they absorb elements that cause soil salinity and poisoning. (4, 5). On the other hand, potassium chloride is about 60% cheaper than potassium sulfate.

The aim of this study was the evaluation of different levels of potassium fertilizer on sorghum inoculated with mycorrhizal fungi (*Glumus mossea*) under water stress condition to find the most adequate fertilizer to obtain the highest sorghum performance in Sistan climate condition.

Materials and methods

Test site and farm soil texture

The experiment was conducted in 2015 in Sistan Agricultural and Natural Resources Research Station, in Zehak, located 24 km southeast of Zabol.

Based on Emberger climate classification, this region, with an average annual rainfall of about 53 mm, is a part of the hot and dry climate zone. The geographical coordinate is 30° 54′ N 61° 41′ E. It is located 483 meters above the sea level, and the soil texture is sandy loam. The field had been plowed the last fall.

Ground preparation and design implementation operations

Irrigation was carried out before cultivation in the first half of March, followed by tillage. Land preparation included autumn plowing, discing, leveling the ground, and finally plotting. In each plot, six stacks of 4 meters long were created, with 30 cm distance from each other.

To prevent water from entering different plot replicates, two streams were digged between each replicate. The interval between replicates was 3 meters, and between plots in each replicate was 1 meter. Based on soil analysis results 300 Kg/Hec urea fertilizer as nitrogen source was applied as follows: 50 % at planting time, 25 % at 6-8 leaves stage, and 25% at flowering stage. Potassium fertilizer was added to the plots before planting, according to the experimental treatments. The experiment was carried out in a split plot, based on randomized complete block design, with four replicates. The experimental treatments were as follow:

M0: without Mycorrhiza

M1: inoculated with Mycorrhiza

S1: irrigation after 40 mm evaporation from evaporation pan A

S2: irrigation after 80 mm evaporation from evaporation pan A

S3: irrigation after 120 mm evaporation from evaporation pan A, and three different levels of potassium fertilizer application

K1: without potassium fertilizer

K2: 75 Kg/Hec potassium chloride

K3: 150 kg/Hec potassium chloride

Preparation and inoculation of seeds with Mycorrhizal fungi

Before planting, the seeds were equally weighed for each treatment, and placed in separate containers. The seeds were subsequently inoculated with Mycorrhizal fungi (*Glumus mossea*), prepared by the National Research Center for Genetics & Life

Sciences.

Mycorrhizal fungal spores were reproduced according to the method described by Mukerji *et al* (14). The spores were propagated in culture over a period of four months, in the vicinity of sorghum roots, in an environment containing three parts sand to one part loam soil. The greenhouse condition of natural light, a temperature of 16 to 28° C, 14 hours of light and 10 hours of darkness was supplemented.

Hence Mycorrhiza fungi were prepared with 120 spores per each gram, spore separation was performed in 10 mM sodium citrate buffer medium. As described by Declerck *et al.* (15) following the full opening of sodium citrate buffer gel and releasing spores in the gel, the spores were passed through a 400 mesh sieve and were rinsed with plenty of water until sodium citrate buffer was completely removed. After washing, spores were transferred to a beaker containing distilled water. The spore was counted using a stereomicroscope.

Studying different cultivars including Sistan local cultivar and KGS29 and KGS25 cultivars from Karaj Seed and Plant Improvement Research Institute, Mehrban *et al.*, identified KGS29 as the most suitable sorghum cultivar in Sistan region due to several advantageous features including plant height, dried leaf and stem weight and suitable stem diameter.

Therefore, KGS29 cultivar has been selected for the current study. Cultivation was performed according to local planting schedule in 10th April 2015 by planting the seeds at 2.5 cm soil depth by hand. Irrigation plan of 7 days period was repeated until 8 leaves stage.

Thereafter, it was continued based on the evaporation from evaporation pan (5 times irrigation under stress condition S, 3 times irrigation under stress condition S2, and 2 times irrigation under stress condition S3) till the appearance of the panicle.

Weeding in the early stages of growth was performed mechanically and with the labor force. To prevent the adverse effects of pesticides on the activity and survival of microorganisms (Mycorrhiza), no herbicide was applied in this study. Using manpower the harvesting was carried out at seeding stage on 10th May 2015. In order to specify the measured traits during sampling, 4 meters was added up in length after cutting edge-effect from middle two lines of each plot.

Data analysis

The measured traits included plant height, stem diameter, tiller number, leaf length, panicle length, as well as fresh and dry forage yield. Before variance analysis, the normal distribution of the data was assessed using Minitab software. Variance analysis was performed in SAS 9.1 software. Mean comparison was performed with Duncan's multiple range tests at 1% and 5% probability levels.

Results

Soil physical and chemical properties

In order to study the physical and chemical properties of the soil, samples were taken from 0-30 cm depths from different parts of the field before planting. The result of the analysis of the soil property is shown in Table 1.

Plant height

The results of variance analysis showed that

Table 1. Physical and chemical characteristics of the soil in the studied area (depth of 0-30cm).

Sand %	Silt %	Clay %	Available K (p.p.m)	Available P (p.p.m)	Total nitrogen%	Organic carbon%	pH	The electrical conductivity (ds/m)
55	31	14	110	3.5	0.03	0.2	8.2	2.8

the effect of water stress on plant height is significant (p <0.01).

No significant association was found between plant height and potassium fertilizer treatment in normal condition. However, in water stress condition, a significant association was found between sorghum height and potassium fertilizer treatment (Table 2).

Comparing the means, the highest plant height obtained from S2K2 treatment. No significant difference was observed between S2K2 treatment and S1K1 and S1K3 treatments. The lowest plant height was obtained from S2K3 treatment (Table 5).

Stem Diameter

A significant association was found between water stress and stem diameter at the level of 1%. No association was found between stem diameter and application of potassium fertilizer either in normal or stress condition (Table 2). According to the results, maximum stem diameter was obtained from S1 treatment.

No significant difference was observed between S1 and S2 treatments. S3 treatment significantly reduced stem diameter in water stress condition (Tables 2 and 3).

Tiller number

Variance analysis showed a significant correlation between tiller number and water stress. No significant correlation was found between tiller number and potassium fertilizer treatment (Table 2).

Variance analysis showed a significant correlation (P <0.05) between tiller number and potassium fertilizer treatment in water stress condition (Table 2).

The means comparison showed the highest tiller number in S1K1 treatment (irrigation

Table 2. Variance analysis of plant yield, yield components and morphological factors.

S.O.V	d.f	Mean of squares							
		Dried fodder yield	Fresh fodder yield feed (t/ha)	Panicle weight	Panicle Length	Flag leaf length	Tiller number	Stem Diameter (cm)	Plant Height
Drought tension	2	13341.26**	213.231**	0.025^{ns}	27.364*	144.124*	0.259*	0.345**	204.787**
Mycorrhiza	1	15.990*	47.7^{ns}	21788.2**	2.5**	17.4*	0.12^{ns}	0.04**	1478.3**
Mycorrhiza * Drought	2	256.6^{ns}	45.6^{ns}	0.22*	3.6^{ns}	36.5^{ns}	0.33^{ns}	.07^{ns}	120.6*
The main mistake	4	641.92	8.715	0.103	2.581	9.956	0.370	0.016	11.07
Level of potassium fertilizer	2	19356.92*	58.116**	0.446^{ns}	28.594**	1.823^{ns}	0.259^{ns}	0.197^{ns}	13.48^{ns}
Drought * level of potassium fertilizer	4	3847.97*	44.141**	0.090^{ns}	9.017^{ns}	68.334*	0.481*	0.081^{ns}	179.25*
Sub Error	12	3250.45	6.886	0.232	3.144	17.987	0.130	0.084	39.22
Replication	2	765.17	1.449	0.049	3.837	56.831	0.148	0.274	108.59
C.V	-	10.98	9.58	14.13	8.73	12.68	13.9	12.57	6.92

*, **, ^{ns} : Respectively significant at 1%, significant at 5%, and non-significant.

Table 3. Mean comparison of the effect of different stress levels on sorghum panicle length.

Trait	120 mm Evaporation pan	80 mm Evaporation pan	40 mm Evaporation pan
Panicle Length (cm)	19.06 b	19.54 b	22.36 a

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

Table 4. Mean comparison of the effect of potassium levels on sorghum panicle length.

Trait	150 kg/Hec	75 kg/Hec	Lack of fertilizer
Panicle Length (cm)	22.36a	19.54a	19.06b

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

after 40 mm evaporation from evaporation pan A, without applying fertilizer). There was no significant difference between S1K1 and S1K2 treatments.

The least tiller number obtained from S3K1 treatment (Table 5).

Such results indicate that under extreme tensions, raising the amount of potassium fertilizer increases the tiller number. The effect of mycorrhizal fungi in stress condition was not significant on tiller number (Table 2).

Flag leaf length

While a significant correlation (p <0.05) was found between flag leaf length and water stress condition, potassium fertilizer treatment did not show any significant effect on flag leaf length (Table 2). Our results showed a significant correlation (p <0.05) between flag leaf length and potassium fertilizer treatment under water stress condition (Table 2). Comparing the means showed the most flag leaf lengthobtained from S1K1 treatment and the least from S1K3 (Table 5).

Panicle length

Table 5. Interaction effect of stress drought different levels × potassium fertilizer.

Treatment	Dried forage yield (kg/ha)	Fresh forage yield (Ton/Hec)	During flag leaf (cm)	Tillers (cm)	Height (cm)	Stem Diameter (cm)
S1M0	6232.5ab	22.33bc	30.56bc	1.00b	94.99a	1.2d
S1M1	6312.4ab	23.6bc	29.68bc	1.02b	95.03a	1.49ab
S2M0	4892.3bc	18.58c	33.25c	0.99b	93.12ab	1.11d
S2M1	4982.6bc	17.92c	24.12c	0.98b	93.45ab	1.5ab
S3M0	4033.5d	20.25c	23.85c	0.80c	81.23bc	1.22cd
S3M1	4125.8d	19.98c	22.7c	0.82c	81.56bc	1.61a
S1K1	6334.5ab	30.90ab	33.00ab	2.02a	95.80a	1.21d
S1K2	6451.35a	31.47ab	30.02bc	2.00a	82.47bc	1.21d
S1K3	7324.35a	35.73a	39.00a	1.79ab	96.33a	1.29cd
S2K1	5063.5abc	24.70bc	32.00ab	1.67ab	93.90ab	1.28cd
S2K2	6135.65abc	29.93ab	33.05ab	1.33ab	99.73a	1.25cd
S2K3	4981.5bc	24.30bc	37.00ab	1.33ab	80.43c	1.26cd
S3K1	4038.5d	19.70c	33.01ab	1.00b	83.00bc	1.3c
S3K2	41149.35cd	20.07c	38.04ab	1.67ab	92.33abc	1.32c
S3K3	6082.35abc	29.67ab	23.01c	1.67ab	90.70abc	1.31c

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability

K1: without potassium fertilizer
K2: 75 kg of potassium chloride
K3: 150 kg of potassium chloride
M0; without Mycorrhiza
M1; inoculated with Mycorrhiza
S1: Irrigation after 40 mm evaporation from class A evaporation pan
S2: Irrigation after 80 mm evaporation from class A evaporation pan
S3: Irrigation after 120 mm evaporation from class A evaporation pan

Table 6. Correlation between different traits in sorghum studied.

Trait	Plant height	The number of tillers	Length of flag leaf	Panicle Length	Fresh forage yield
Stem Diameter	^{ns} 0.519				
The number of tillers	-0.158	1.000			
Length of flag leaf	-0.253	-0.748*	1.000		
Panicle height	-0.107	-0.343	0.731*	1.000	
Fresh forage yield	0.424*	-0.293	-0.053	-0.048	1.000
Dried forage yield	0.467*	-0.011	0.156	-0.055	-0.482

*, **, ^{ns}: Respectively significant at 1%, significant at 5%, and non-significant

Our results showed a significant correlation between panicle length and water stress (p <0.05) as well as potassium fertilizer treatment (p <0.01). But the results were not significant when potassium fertilizer was applied under water stress condition (Table 2).

Based on our results the maximum and minimum panicle length were obtained from S1 and S3 treatments, respectively (Table 3).

Among different potassium fertilizer treatments, the maximum and minimum panicle length were obtained from K3 and K1 treatments, respectively (Table 4).

The effect of mycorrhizal fungi on panicle length in stress condition was not significant (Table 2).

Fresh and dry forage yield

A significant correlation was found between sorghum fresh and dried forage yield and water stress condition, potassium fertilizer treatment, as well as potassium fertilizer treatment under water stress condition (Table 2). The highest fresh and dried forage yield was obtained from S1 treatment, with 32.7 Ton/Hec fresh, and 560.43 Kg/Hec dried forage yield. On the other hand, the least fresh and dried forage yield was obtained by S3 treatment (Table 3).

No significant association was found between fresh and dry forage yield and mycorrhizal fungi under stress condition (Table 2).

Our results showed the maximum and minimum fresh and dry forage yield obtained from S1K1 and S3K1 treatments, respectively (Table 5). As indicated in Table 5, potassium fertilizer treatment has increased fresh and dry forage yield in stress conditions.

Simple correlations between traits

There was a positive correlation (p <0.05) between flag leaf length and panicle length. Fresh and dried forage yield also showed a positive correlation with stem length and diameter. A negative correlation was observed between the number of tillers and flag leaf length. No significant correlation was found between other traits.

Discussion

Plant height

Lack of moisture affects the length of the internodes by preventing the growth of cells, and thus reducing the height of the stem (16).

Due to increased plant height, new leaves are formed in the upper part of the plant, which increases the photosynthesis efficiency by absorbing more sunlight. If the rate of water absorption by the root is less than the transpiration rate, the turgor pressure of the stoma decreases and the aperture tends to be closed. The stomata that are partially closed not only limit the transpiration, but also reduce the carbon dioxide flow, the photosynthesis rate, the phloem sap, and consequently the plant height (16).

The plant height is dependent on the environmental conditions (17). Several studies have reported increased plant height induced by Mycorrhizal fungi (17-19). With enhancing root volume by Mycorrhizal fungi, water absorption from the soil increases, a process which improves the plant's resistance to stressful, hot and dry situations (18, 19).

However, the plant height is partly influenced by environmental conditions (17). It seems that the reason for decreased plant height in the absence of Mycorrhizal fungi in Sistan region is severe and persistent heat condition during the growing season.

Tiller number

Variance analysis showed a significant correlation between tiller number and water stress. No significant correlation was found between tiller number and potassium fertilizer treatment. Sayed (20) showed that water stress reduces the tiller number and wheat dry matter yield linearly due to the adverse effect of the stress on plant growth quality. Furthermore, it has been reported that Mycorrhizal fungi increase photosynthesis rate by enhancing water and nutrient uptake, a process which increases assimilate production and tillering (21).

In this case, less water flow from the roots reduces water potential in the leaves, closes a part of the apertures, decreases carbon dioxide absorption, and ultimately causes the roots to slow down. Such crops do not show wilting symptoms and are simply smaller than normal ones (22).

However, some studies indicated that tiller number is significantly increased following the simultaneous addition of Mycorrhizal fungi and phosphorus fertilizer, as compared to the control (23, 24).

Flag leaf length

Reduction of the flag leaf length under water stress has been previously reported by Mobasser et al. (25). One of the important reasons for reducing plant yield under drought stress is the disruption of physiological activities of the plant, especially decreasing leaf area index along with other vegetative traits (3).

There was no significant association between Mycorrhiza and sorghum inoculation and flag leaf length. It has been reported that the leaf length and width is a plant genetic feature and less influenced by the environmental conditions. Therefore, in the present study, different treatments showed little effect on the flag leaf length (26).

Panicle length

As compared to other measured characteristics at this experiment, panicle length was more affected by the adverse effects of water stress (12). Under moisture stress, the amount of nitrate in sorghum grain increases that should be considered during feeding the livestock. Nevertheless, early cultivation can be a factor to avoid the stress (27).

One of the reasons for the improvement of plant growth characteristics including panicle length, when potassium fertilizer is applied, can be the role of this element in enhancing plant tissues strength, especially under stress conditions (11). Hagin and Tucher (12) indicated that potassium fertilizer treatment increases the wheat spike length.

Fresh and dry forage yield

The highest fresh and dried forage yield was obtained from S1 treatment, with 32.7 Ton/Hec fresh, and 560.43 Kg/Hec dried forage yield. On the other hand, the least fresh and dried forage yield was obtained by S3 treatment.

This indicates adverse effects of water stress on the quantitative performance of the forage. Paygozar et al. (28) reported reduced millet dried forage yield under water stress condition. Results of other studies by Song (29) and Afkari Bajehbaj (30) on different plants including corn, sunflower, and wheat indicates the reduction of dried forage yield and biomass under drought stress condition and confirms the findings of this research. Cox and Julliof (31) also reported reduced dried forage yield in soybean and sunflower under moisture stress condition.

Egli et al. (32) showed that moisture stress during the growing season significantly reduces dried forage yield in soybean shoots. In water stress condition, reduced dried forage yield can be due to the turgor pressure caused by leaf area reduction or decrease in photosynthesis rate due to biochemical limitations such as photosynthetic pigments deficiency, especially chlorophyll (33).

Other side effect caused by decreased leaf area includes the change in water and nitrogen consumption pattern (34). Mirza et al. (35) stated that under stress condition flowering in summer savory plants occurs earlier than in plants under normal condition, and stress causes a reduction in stem height, as well as fresh and dry yield of both stems and roots.

Simple correlations between traits

There was a positive correlation between flag leaf length and panicle length. Fresh and dried forage yield also showed a positive correlation with stem length and diameter.

A negative correlation was observed between the number of tillers and flag leaf length. No significant correlation was found between other traits.

Faker-Baher et al. (36) found a negative correlation between extreme water stress and shoots height and number in summer savory. Colom and Vazzana (37) showed a negative correlation between drought stress and the number of sub-branches and dry forage yield of African lover grass (*Eragrostis curvula* L).

Thus, applying symbiotic bacteria accelerates essential element absorption and prevent rinsing the element by water and soil poisoning that is in fact sustainability in the agronomic system to supply the plant requirements by soil microorganisms (21).

Conclusion

Based on our results increasing the water stress declined all the studied characteristics including plant height, tiller, flag leaf length, panicle length, and fresh and dry forage yield. Therefore, in Sistan climate conditions, proper management to supply plant water requirement, especially at the end of growth stage, and selection of drought-tolerant genotypes are essential. Moreover, with comprehensive management, it is possible to handle the stress toward increasing sorghum yield. Because of salinity and drought condition in Iran, potassium chloride is known as a plant poison and is not usually recommended.

Our results showed that applying 150 Kg/Hec potassium fertilizer is the best treatment in Sistan area conditions. Provided that the amount of chloride in potassium chloride fertilizer should not exceed more than 2 %.

While the effect of mycorrhizal fungi in stress condition was significant on plant height and stem diameter, it had no significant effect on stem diameter, tiller number, flag leaf length, panicle length and fresh and dry forage yield, and under extreme stress conditions (more than 40 mm evaporation) was significant only on plant height.

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