

Efficacy of Ascorbic Acid as a Cofactor to Increase Irrigation Water-Use Efficiency (IWUE) and Mung Bean (*Vigna radiata* L.) Yield

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ABSTRACT

Ascorbic Acid (AsA) is a water-soluble antioxidant that makes plants resistant to environmental stresses by neutralizing free radicals. However, it is unknown to what extent this antioxidant may help Improve Irrigation Water Use Efficiency (IWUE) and reduce the adverse effects of water deficit on mung bean growth and yield. In an attempt to clarify whether exogenous application of this antioxidant could alleviate the adverse effects of water deficit on mung bean plants, two seasons (2019 and 2020) of field experiments were conducted using twelve combinations of three AsA levels (distilled water as a control and 10 and 20 mM of AsA) and four irrigation water amounts (25, 50, 75, and 100% of the plant water requirement). Based on the results, the maximum IWUE was obtained with $W_{50}AsA_{20}$ in the two seasons. The beneficial effect of AsA application on IWUE was determined under water stress conditions (W_{50}). High water deficit (W_{50}) plus applying 20 mM ascorbic acid, i.e. $W_{(50)}AsA_{(20)}$ treatment, improved seed yield about 43.7% as in the two seasons compared to high water deficit without ascorbic acid, i.e. $W_{(50)}AsA_{(0)}$. In 2019 and 2020, water saving in $W_{(50)}AsA_{(20)}$ compared to the control, was equal to 50% (2,550 and 2,500 m³ ha⁻¹, respectively). In $W_{(50)}AsA_{(20)}$ treatment, the increase of seed yield ranged between 79-107% in both seasons. Thus, the results reveal the potency of AsA to save water under low water supply and increase yield in mung bean fields.

Keywords: Mung Bean yield, Water deficit, Water saving.

INTRODUCTION

The growing threat of freshwater scarcity and persistent drought in recent years due to climate change has accelerated research on diverse irrigation management strategies and water conservation to produce more "crop per drop" (El-Bially *et al.*, 2018; Li *et al.*, 2022). Therefore, considering the method that leads to less water consumption and meets the full need of the crop for water is considered one of the basic tools to deal with scarce water resources by reducing the amount of irrigation water. Identifying these strategies in all products is very important due to the diverse morpho-physiological characteristics (Wang *et al.*, 2023; Shirzad *et*

al., 2022). Water scarcity is a major agricultural and developmental challenge for the drylands. Many of these regions are faced with growing food insecurity associated with water shortage and erratic rainfall patterns, high population growth, and dwindling land productivity (Bwambale *et al.*, 2022). Iran has different climatic and geographical zones, mostly arid and semi-arid, which are suffering from land degradation. The scarcity of water, as well as the excessive use of water resources, mainly for agriculture creates negative water balances and changes in plant cover and accelerates desertification (Emadodin *et al.*, 2019).

Mung bean (*Vigna radiata* L.), known as a traditional soybean food, has been used as a

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nutritional food and herbal medicine for more than 2000 years (Qin *et al.*, 2022). This plant is an outstanding short-term legume crop, whose cultivation is expanding in most countries of the world due to its antioxidants, high protein, fibers, and nutrient profiles (Alghabari, 2020). Mung bean is one of the most economically important food legumes and provides part of the food requirement that grows in tropical and subtropical regions and is eaten by more than billions of people in the world (Rachaputi *et al.*, 2019). Due to the importance of mungbean as a product to provide a part of human food needs, it is included in the human diet in many countries of the world. Therefore, there is a need to investigate solutions to improve its production, economic value, and reducing the effects of drought (Kang *et al.*, 2014). Drought stress has a profound effect on plant ecological systems (Jaleel *et al.*, 2007). Plant reactions to drought stress at different levels depend on the intensity and duration of the stress as well as on the plant species and its growth stage (Jayakumar *et al.*, 2007). Knowing the response of plants to drought is of great importance and is a fundamental part of finding a solution to increase the tolerance of agricultural plants to water stress (Reddy *et al.*, 2004). As an antioxidant, AsA is dependent on chloroplasts, where the effect of oxidative stress on photosynthesis is reduced. In addition, AsA reduces the change in cell division and acts as a primary substrate in the cyclic pathway of hydrogen peroxide enzymatic detoxification. Also, AsA is one of the important non-enzymatic antioxidants that play an essential role in several key metabolic processes and acts as a powerful antioxidant (Akram *et al.*, 2017). AsA is commonly referred to as vitamin C. In several studies, for example, common beans (Gaafar *et al.*, 2020), chickpeas (Akram *et al.*, 2018), rape (Shafiq, 2014) and corn (Dolatabadian *et al.*, 2010), it is known as a factor for regulating stress tolerance in plants. In addition, AsA acts as a cofactor alongside enzymes that work in various

metabolic pathways (Rigano *et al.*, 2017). According to research conducted by Naz *et al.* (2017), AsA is very effective in protecting proteins and lipids in plants exposed to water deficit and higher salinity regimes. Gaafar *et al.* (2020) concluded that enhanced water stress tolerance through adequate AsA application is a promising strategy to increase the tolerance and productivity of common beans under water stress. Previous research showed that AsA application under water stress increased chlorophyll a, chlorophyll b, and/or total chlorophyll contents (Madany and Khalil, 2017). Hussein and Khursheed (2014) showed that AsA protected photosynthesis and enhanced leaf photosynthetic pigments under drought conditions, controlling dry matter accumulation. In stressed plants, AsA performs a crucial function in maintaining several metabolic processes. In addition, exogenous application of AsA improved plant performance under water stress and increased crop yield in common bean (Gaafar *et al.*, 2020), maize (*Zea mays*) (Dolatabadian *et al.*, 2010), and wheat (*Triticum aestivum*) (Hafez and Gharib, 2016). As mentioned, Iran is located in a dry and semi-arid region. In recent years, drought has affected the agricultural sector and the yield of products. According to the results of the aforementioned research, AsA has played an effective role in increasing the tolerance of plants to drought stress. Considering this importance, the present research in the Safi Abad region of Dezful, which is also facing drought, aimed to evaluate the effect of AsA foliar application on the Irrigation Water Use Efficiency (IWUE) and reduce the adverse effects of water deficit on mung bean growth and yield

MATERIALS AND METHODS

Site Description

A field experiment was conducted in 2019 and 2020 in the research farm of Safi Abad Natural Resources, Education, and Research

Center, Dezful, Khuzestan Province, Iran (longitude 48 degrees E and latitude 32 degrees N, and 82 meters above sea level). The soil was clay loam with pH 7.1, and electrical conductivity 0.99 ds m^{-1} . The physical properties and water status of the experimental soil are presented in Table 1. Table 2 illustrates monthly mean weather factors, i.e. maximum and minimum air temperature, relative humidity, wind speed and sun shine hours for 2019 and 2020 seasons in the Research Center of Safiabad, Iran.

Experimental Design and Procedures

This research aimed to evaluate the interactive effect of AsA and irrigation water levels on Irrigation Water Use Efficiency (IWUE) and mung bean yield and the environmental conditions of the study area in Safiabad Dezful District, Khuzestan

Province, Iran. The experiment was conducted in split plots in the form of a randomized complete block design, with three replications, where irrigation levels were assigned in the main plots and AsA treatments in the subplots. The experiment consisted of twelve treatments, each showing a combination of the amount of irrigation water and AsA as follows:

1) Four irrigation Water amounts (W) (25, 50, 75, 100% plant water requirement) as the main factor.

2) Three levels of AsA (spraying solution with distilled water as a control and 10 and 20 mM in the vegetative stage before the emergence of flowers, twice with an interval of ten days), as the secondary factors.

The experiment was carried out for two consecutive years and, finally, the data analysis was done. Each plot consisted of six rows (75 cm) with a length of 10 meters, the distance between the plants on the stack was 5 cm and a planting row on the stack and the distance

Table 1. Physical properties and water status of the soil at Safiabad Region.^a

Depth (cm)	Particle size distribution (%)			Texture class	θ_s			BD (kg m ⁻³)
	Sand	Silt	Clay		FC(mm m ⁻¹)	PWP(mm m ⁻¹)	HC (mm h ⁻¹)	
0-15	31.1	35.2	33.7	Clay loam	340	210	17.7	1430
15.1-30	31.8	34.9	33.3	Clay loam	340	210	17.7	1430
30.1-45	32.5	34.1	33.4	Clay loam	340	210	17.7	1430
45.1-60	33.2	33.1	33.7	Clay loam	340	210	17.7	1430

^a FC: Field Capacity, PWP: Permanent Wilting Point, HC: Hydraulic Conductivity, BD: Bulk Density.

Table 2. Means monthly minimum and maximum temperature, relative humidity, wind speed and sunny hours of the Safiabad region.

Month	Minimum air temperature (°c)	Maximum air temperature (°c)	Relative humidity (%)	Wind speed (m s ⁻¹)	Sunny hours (h)
First year					
July	29.2	47.6	48	0.85	338
August	25.4	35.5	62	0.95	303
September	18.7	37.5	62	0.98	283
December	14.8	29.9	60	0.83	192
November	8	21.8	61	0.87	202
Second year					
July	25.9	47.1	50	0.89	332
August	25.4	44.7	56	0.95	305
September	21.1	38.2	66	1.09	250
December	15.1	25.7	56	0.79	172
November	10.9	20.6	55	0.89	127



between each other was 2 meters. Planting operation was carried out on July 20 at the rate of 25 kg per hectare by manual rowing. After the planting operation, irrigation was carried out normally and the same until the plant had four leaves, then, the treatments were applied. To apply drip treatments on each row, a drip strip with a diameter of 175 microns and a distance of 20 cm between the holes was used. The twelve "irrigation-AsA" treatments involved were denoted as follows:

W(100)AsA(0),	W(100)AsA(10),
W(100)AsA(20),	W(75)AsA(0),
W(75)AsA(10),	W(75)AsA(20),
W(50)AsA(0),	W(50)AsA(10),
W(50)AsA(20),	W(25)AsA(0),
W(25)AsA(10),	W(25)AsA(20).

Irrigation water requirement for mung bean was calculated by determining daily reference Evapotranspiration (ET_0) of FAO Penman-Monteith equation (Allen *et al.*, 1998) for each growing season of mung bean. From ET_0 , crop Evapotranspiration (ET_c) was computed using the following equation according to Doorenbos *et al.* (1977):

$$ET_c = ET_0 \times K_c \quad (1)$$

Where: ET_c = Crop Evapotranspiration (mm d^{-1}); ET_0 = Reference Evapotranspiration (mm d^{-1}), and K_c = Crop coefficient (1.15).

Sampling and Assessments

Irrigation Water Use Efficiency (IWUE)

To calculate IWUE, the maximum yield produced per unit of water used by the mung bean plant was determined (El-Bially *et al.*, 2018). When calculating the seed moisture content, it was about 17%. IWUE was calculated as mung bean yield (kg) per water used (m^3) during the growing season.

Chlorophyll and Carotenoid Content

Arnon's method (1949) was used to measure the content of chlorophyll and carotenoids. Half a gram of each fresh leaf

sample was homogenized in five mm of 80% acetone, then, a centrifuge was used at 13,000 rpm at 4°C for 15 minutes, and its volume was reduced to 10 mm with acetone. Next, the amount of light absorption was measured using a spectrophotometer at wavelengths of 470, 645 and 663 nm, and the concentration of chlorophyll a, b and their sum and carotenoids were obtained using the following formula.

$$\text{Chlorophyll a} = (19.3 \times A_{663} - 0.86 \times A_{645}) V / 100W$$

$$\text{Chlorophyll b} = (19.3 \times A_{645} - 3.6 \times A_{663}) V / 100W$$

$$\text{Carotenoids} = 100 (A_{470}) + 3.27 (\text{chlorophyll a mg}) - 104 (\text{chlorophyll b mg}) / 227$$

Plant Parameters

To measure the leaf area index, PAR/LAI Ceptometer was used to measure all the plots at a time interval of 15 days. It is the ratio of the leaf area to the area of cultivated land:

$$LA = LA / CLA$$

Where, LA = Leaf Area, and CLA = Cultivated Land Area.

Seed yield with 17% humidity was determined by weighing the seeds from 3 m^2 from the middle of each plot.

Statistical Analysis

SAS software was used for the statistical analysis of the data. Means were compared using Duncan's multiple range test at 0.05 probability level. EXCEL software was used to draw the graphs.

RESULTS AND DISCUSSION

Irrigation Water Use Efficiency (IWUE)

The value of IWUE in the interaction of irrigation and AsA was calculated by dividing kg seed yield per hectare (kg ha^{-1}) by applied water ($\text{m}^3 \text{ ha}^{-1}$) (Figure 1). The

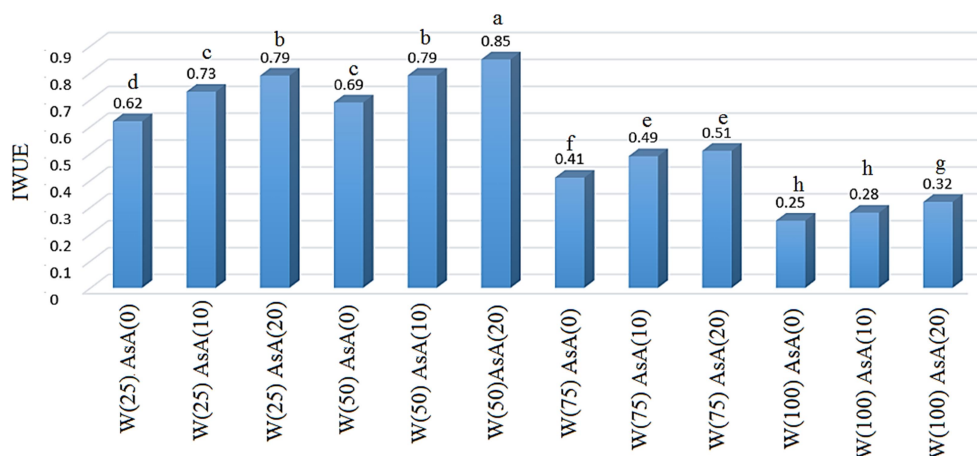


Figure 1. Effects of different irrigation–Ascorbic Acid (AsA) treatments on Irrigation Water Use Efficiency (IWUE) for mung bean mean of 2019 and 2020 seasons. (Small letters indicate statistic comparison). Duncan's multiple range test at 0.05 significant level.

maximum IWUE was obtained in W(50)AsA(20) and there was no significant difference in the two seasons. The beneficial effect of AsA application on IWUE was determined under water stress conditions (W50) compared to well-irrigated (W100), and there was a significant difference between them. Therefore, with the use of AsA and the decrease in the amount of irrigation, IWUE increased, such that the highest IWUE was in W(50)AsA(20) treatment. AsA application was more beneficial on IWUE under water-stressed (W50). The obtained result is in line with the research result of Canavar *et al.* (2014). Our findings indicated that the potency of AsA-treated mung bean plants can relatively convert applied water into the production of seeds under moderate water deficit conditions. Shahrkhnia *et al.* (2016) in their research on tomatoes reported that the highest water efficiency index was observed in the treatment of 60% water requirement, at higher water treatments, IWUE decreased. El-Bially *et al.* (2018) concluded that the use of AsA as a safe and cheap foliar spray during the intermittent dry spells, especially in vegetative stage, is regarded necessary. This confirms the result of our research. This result can be interpreted as the application of AsA is very necessary for the

management of agricultural water resources and it plays an effective role in the critical conditions of water shortage.

Water Saving and Yield Changes

By evaluating the interaction of irrigation and AsA on mung bean yield (kg ha^{-1}), it was found that the most beneficial treatment was W(50)AsA(20). The yield in this treatment in 2020 was equal to $2,491 \text{ kg ha}^{-1}$ and in 2019 was $2,350 \text{ kg ha}^{-1}$, which is the highest among all treatments in the two seasons, and the amount of water consumption was 50%. By using the mentioned treatment, in addition to increasing the yield, the amount of saving in water consumption was very impressive. There was a significant difference between W(75)AsA(10), W(75)AsA(20), W(50)AsA(0), W(50)AsA(10) and W(50)AsA(20) with the W(100)AsA(0) treatment, which indicates significant water saving despite the increase in yield due to the use of AsA (Figure 2). Under water-stressed condition (W50), application of AsA had positive and significant effects on seed yield ha^{-1} (in both seasons). In both seasons, W(50)AsA(20) treatment improved seed yield by about 43.7% compared with

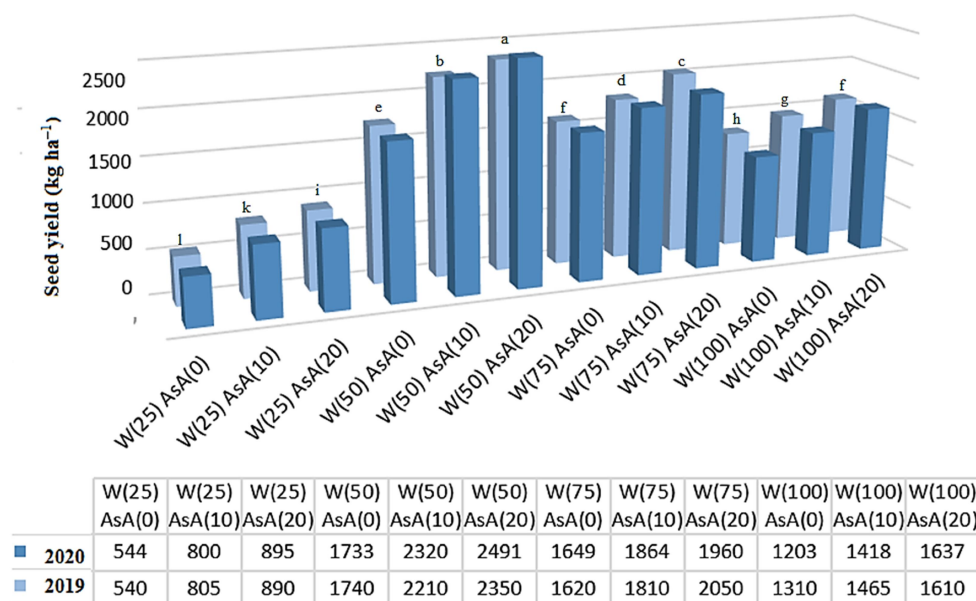


Figure 2. Effects of different irrigation–Ascorbic Acid (AsA) treatments on seed yield (kg ha^{-1}) for mung bean. Duncan's multiple range test at 0.05 significant level; (W) Water amounts.

high water deficit without AsA, i.e. W(50)AsA(0).

It was found that the use of AsA significantly saved water and increased yield. In the W(50)AsA(20) treatment compared to the reference treatment, the water saving in the 2019 and 2020 crop seasons was equal to 50% ($2,550$ and $2,500 \text{ m}^3 \text{ ha}^{-1}$, respectively). The crop yield in 2019 increased by 79.4% ($1,040 \text{ kg ha}^{-1}$) and in 2020 by 107.1% ($1,288 \text{ kg ha}^{-1}$) (Table 3).

Based on the results, AsA had a beneficial effect on mung bean seed yield under water-stressed conditions. Moreover, in the case when saving water by 50.0% (amounted to $2,550 \text{ m}^3 \text{ ha}^{-1}$ in the 2019 season and $2,500 \text{ m}^3 \text{ ha}^{-1}$ in 2020), for W(50)AsA(20) treatment, the increased seed yield ranged between 79-107% in both seasons. In general, such results reveal the potency of AsA to save water under low water supply in mung bean. El-Bially *et al.* (2018) stated that AsA, in a situation where the plant is under stress, can increase activity and provide performance components by modulating the negative effect of stress. Naz *et al.* (2016) concluded that the improvement of plant growth under water

stress treatments can be achieved by the application of AsA. This result confirms the result of our research. According to the research results of Hafez and Gharib (2016), ascorbic acid can reduce the negative effects of water stress by acting as a growth factor to accelerate the growth of shoots and roots in water stress conditions and reduce the loss of flag leaf darkness in low stress conditions.

This result can be interpreted as the application of AsA is very necessary to increase production and improve the economic situation of farmers and agricultural water saving, and it plays an effective role in critical water shortage conditions.

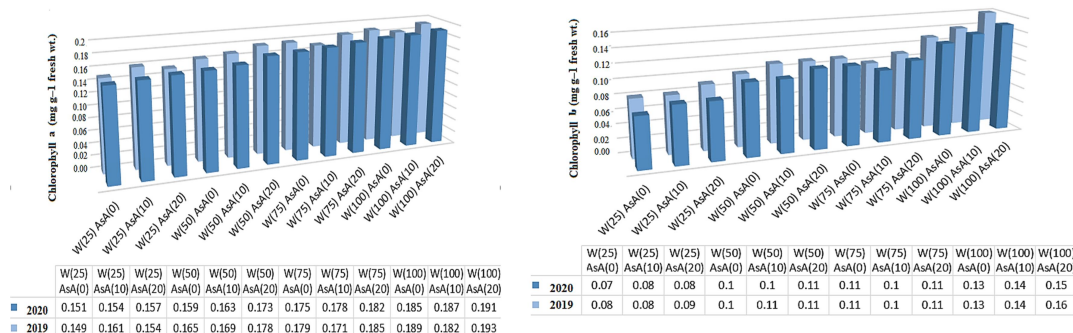
Chlorophyll and Carotenoid Contents

Chlorophyll a, b Content

The results in Figure 3 show the degradation of chlorophyll a, b content in mung bean leaves under water stress. In this regard, a significant difference between

Table 3. Saved water and the change in seed yield of mung bean under different irrigation–AsA treatments in 2019 and 2020 seasons.

Treatments	Saved water % and (m ³ ha ⁻¹)		Change in seed yield % and (kg ha ⁻¹)	
	2019	2020	2019	2020
W(100) AsA(0)	0.0% (0.0)	0.0% (0.0)	0.0% (0.0)	0.0% (0.0)
W(100) AsA(10)	0.0%(0.0)	0.0% (0.0)	11.8% (155)	17.9% (215)
W(100) AsA(20)	0.0%(0.0)	0.0% (0.0)	22.9% (300)	36.1% (434)
W(75) AsA(0)	25% (1275)	25% (1250)	23.7% (310)	37.1% (446)
W(75) AsA(10)	25% (1275)	25% (1250)	38.2% (500)	53.4% (643)
W(75) AsA(20)	25% (1275)	25% (1250)	56.5% (740)	62.5% (757)
W(50) AsA(0)	50% (2550)	50% (2500)	32.8% (430)	44.1% (530)
W(50) AsA(10)	50% (2550)	50% (2500)	68.7% (900)	92.9% (1117)
W(50) AsA(20)	50% (2550)	50% (2500)	79.4% (1040)	107.1%(1288)
W(25) AsA(0)	75% (3825)	75% (3750)	-58.8% (-770)	-54.8% (-659)
W(25) AsA(10)	75% (3825)	75% (3750)	-38.5% (-505)	-33.5%(-403)
W(25) AsA(20)	75% (3825)	75% (3750)	-32.1% (-420)	-25.6%(-308)

**Figure 3.** Leaf chlorophyll a, b content of mung bean obtained from different irrigation–Ascorbic Acid (AsA) treatments in 2019 and 2020 seasons. Duncan's multiple range test at 0.05 significant level; Water amounts (W).

irrigation-AsA treatments in chlorophyll a, b content was observed during both seasons, when reduction in water supply reduced chlorophyll a and b. In contrast, these effects were significantly minimized and less evident when plants were treated with AsA. In 2020, the amount of chlorophyll a and b in the W(50)AsA(20) increased by about 9 and 10%, respectively, compared to W(50) AsA(0). Such findings are in accordance with those found by El-Bially *et al.* (2018) and Manivannan *et al.* (2007). Dolatabadian *et al.* (2009) reported that drought stress reduces the amount of chlorophyll in corn while AsA prevents the destruction of chlorophyll and indirectly increases it due to its antioxidant properties.

Carotenoid Content

Carotenoids are a group of pigments that, in addition to their role in the formation of pigments, have also antioxidant properties. According to the research results, AsA can prevent the reduction of carotenoids both in favorable conditions and in drought-stress conditions. For example, in 2020, the carotenoid content in the W(100)AsA(20) treatment increased about 7% compared to the reference treatment, i.e. W(100)AsA(0). Also, in W(50)AsA(20) compared to W(50)AsA(0) there was an increase of about 13%. Khalid and Qader Khursheed (2014) also reported that AsA application can



prevent the reduction of carotenoids in both favorable and drought-stress conditions. The results of the findings of Sherin *et al.* (2022) also showed that the number of carotenoids showed a significant difference under the influence of AsA (Figure 4).

Plant Parameters

Leaf Area Index (LAI) and 1,000 Seed Weight (TSW) of mung bean were significantly different among irrigation-AsA treatments. The highest TSW value was assigned to W(50)AsA(20), which surpassed all other treatments with 56.9 and 53.9 g, respectively, in the two seasons. The highest LAI value was in W(100)AsA(20). Obviously, those well-watered plants treated with AsA produced LAI significantly higher than all other treatments. Under W50 water-stressed conditions, application of AsA had positive and significant effects on TSW (in both seasons), and under favorable irrigation conditions (W100), application of 20 mM AsA had positive and significant effects on LAI (in both seasons). W(50)AsA(20) improved TSW by about 52% in both seasons compared to W(50)AsA(0). W(100)AsA(20) improved LAI by about 17.3% in both seasons compared to W(100)AsA(0) (Figure 5). Such findings are

in accordance with those found by Dolatabadian and Jouneghani (2009). Also, Sajedi and Ardakani (2010) stated that drought stress reduced the LAI in saffron, which was partially resolved by using AsA, which is consistent with the findings of the present research. Regarding the TSW, our findings are in accordance with those found by Moradi Tochaei *et al.* (2016).

Protein Yield

Protein yield (kg ha^{-1}) of mung bean were significantly different among irrigation-AsA treatments. The highest protein yield value belonged to W(50)AsA(20). The W(50)AsA(20) treatment surpassed all other treatments with 512 and 515 kg ha^{-1} , respectively, in the two seasons. Under W50 water-stressed conditions, application of AsA had positive and significant effects on protein yield (in both seasons). W(50)AsA(20) improved protein yield by about 103 and 77% in 2019 and 2020, respectively, compared to W(25)AsA(0) (Figure 6). In line with the findings of this research, Salingpa *et al.* (2018) reported that ascorbic acid with a concentration of 300 mM led to an increase in mung bean yield under salt stress conditions. El-Beltagi *et al.* (2020) also reported that foliar application

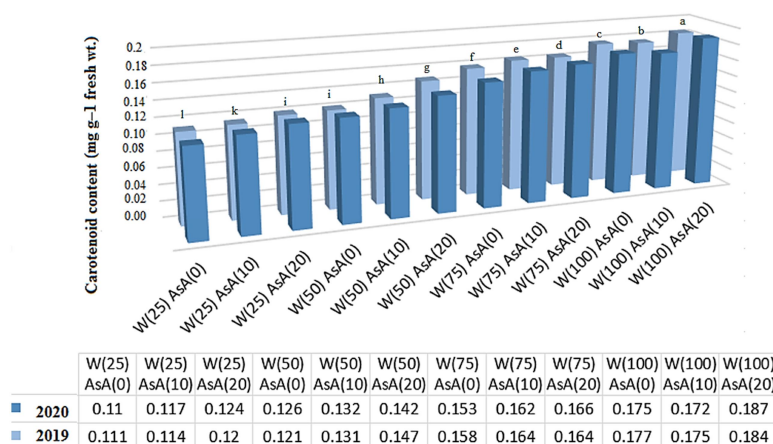


Figure 4. Carotenoid content of mung bean obtained from different irrigation-Ascorbic Acid (AsA) treatments in the 2019 and 2020 seasons. Duncan's multiple range test at 0.05 significant level; Water amounts (W).

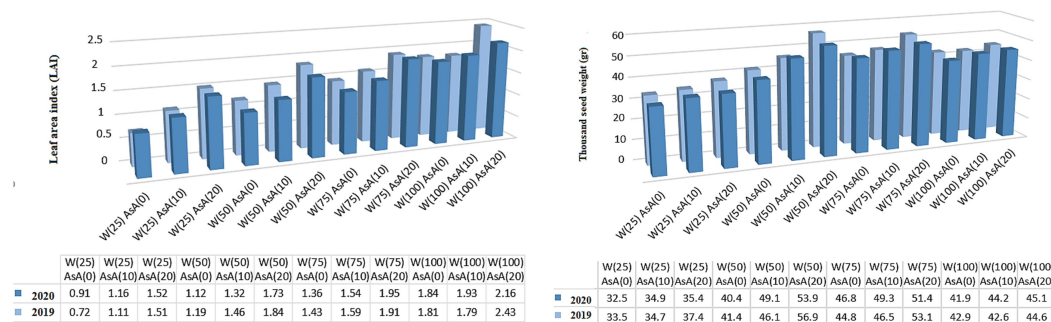


Figure 5. Leaf Area Index (LAI) and 1000 seed weight of mung bean obtained from different irrigation–AsA treatments in 2019 and 2020. Duncan's multiple range test at 0.05 significant level; Water amounts (W).

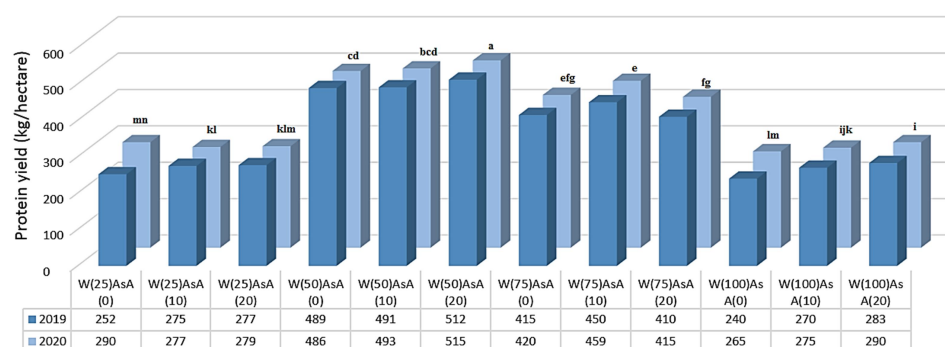


Figure 6. Protein yield (kg ha^{-1}) of mung bean obtained from different irrigation–AsA treatments in the 2019 and 2020 seasons. Duncan's multiple range test at 0.05 significant level; Water amounts (W).

of ascorbic acid improved chickpea yield under different moisture regimes.

CONCLUSIONS

Due to frequent droughts in different provinces of the country as well as in the research area, the necessity of identifying water-use-management solutions and saving water consumption has been given more attention. Based on the results obtained from this research, with the use of AsA and the decrease in the amount of irrigation, the amount of IWUE increased, such that the highest amount of IWUE was in W(50)AsA(20) treatment. These results could be explained in the viewpoint of seed yields produced under such conditions more than the other ones, resulting in higher IWUE values. Also, under W50water-

stressed conditions, application of AsA had positive and significant effects on seed yield ha^{-1} (in both seasons). High water deficit (W50) plus applying 20 mM AsA, i.e. W(50)AsA(20) treatment, improved seed yield about 43.7% in both seasons compared to high water deficit without AsA, i.e. W(50)AsA(0). It was found that the use of AsA significantly saved water and increased yield. In the W(50)AsA(20) compared to the reference treatment, the water saving in 2019 and 2020 was equal to 50% (2,550 and 2,500 $\text{m}^3 \text{ha}^{-1}$, respectively). Based on the results, AsA has a beneficial effect on mung bean seed yield under water-stressed conditions. In general, such results reveal the potency of AsA to save water under low water supply in mung bean fields. Under water-stressed condition (W50), application of AsA had positive and significant effects



on seed yield and TSW (in both seasons), while under favorable irrigation conditions, W100 and application of 20 mM AsA had positive and significant effects on LAI (in both seasons). Thus, our study suggests the use of AsA in irrigation for optimal management of water resources and saving water consumption by relatively mitigating the detrimental impact associated with low water supply.

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اثر بخشی اسید اسکوربیک به عنوان یک کوفاکتور در افزایش راندمان آبیاری (IWUE) و عملکرد گیاه ماش (*Vigna radiata* L.)

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چکیده

اسید اسکوربیک (AsA) یک آنتی اکسیدان محلول در آب است که با خنثی کردن رادیکال های آزاد، گیاهان را در برابر تنش های محیطی مقاوم می کند. با این حال، مشخص نیست که این آنتی اکسیدان تا چه حد ممکن است به بهبود کارایی مصرف آب آبیاری (IWUE) و کاهش اثرات نامطلوب کمبود آب بر رشد و عملکرد ماش کمک کند. در تلاش برای روشن شدن اینکه آیا کاربرد این آنتی اکسیدان می تواند اثرات نامطلوب کمبود آب بر روی گیاهان ماش را کاهش دهد، در دو فصل زراعی سال های (۲۰۱۹ و ۲۰۲۰) آزمایش مزرعه ای با استفاده از دوازده ترکیب از سه سطح AsA و چهار مقدار آب آبیاری انجام شد (۲۵، ۵۰، ۷۵ و ۱۰۰ درصد آب مورد نیاز گیاه). بر اساس نتایج، حداکثر IWUE با W(50)AsA(20) در دو فصل به دست آمد. اثر سودمند کاربرد AsA بر IWUE در شرایط تنش آبی (W50) تعیین شد. کمبود آب زیاد (W50) به علاوه استفاده از ۲۰ میلی مولار اسید اسکوربیک، یعنی تیمار W(50)AsA(20)، عملکرد دانه را در حدود ۴۳.۷٪ در دو فصل نسبت به کمبود آب بالا بدون اسید اسکوربیک، یعنی W(50)AsA(0) بهبود



بخشید. در تیمار W(50)AsA(20) نسبت به تیمار مرجع، صرفه جویی در مصرف آب در فصل زراعی ۲۰۱۹ و ۲۰۲۰ معادل ۵۰ درصد (به ترتیب ۲۵۵۰ و ۲۵۰۰ مترمکعب در هکتار) بود. در تیمار W(50)AsA(20)، افزایش عملکرد دانه در هر دو فصل بین ۷۹٪-۱۰۷٪ بود. بنابراین، چنین نتایجی نشان دهنده قدرت AsA برای صرفه جویی در آب در شرایط کم آبی در مزارع ماش و افزایش عملکرد در حد مطلوبی است.