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Research Article

Potassium and Salicylic Acid Fertilization Effects on Productive and Qualitative Traits of *Cyamopsis Tetragonoloba* Under Drought Stress

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Abstract: Drought is one of the main factors of abiotic stress in the agricultural world. The purpose of this study was to assess the impact of drought on Guar (*Cyamopsis tetragonoloba* (L.) Taub.) Plant and finally improve the productivity of the grain yield and the qualitative characteristics in case of high dryness by spraying salicylic acid and potassium. This experiment was performed as a plot divided into strips in a randomized complete block with three replicates over two years in Kerman, Iran. Experimental treatments include drought stress at three levels, salicylic acid (three levels) by foliar application, and potassium (two levels). Guar is resistant to high drought stress and has had a significantly improved yield. Applying 100 kg/ha of potassium in combination with a foliar spray with salicylic acid produced the highest potassium and cereal protein content. The results clearly demonstrated that potassium and salicylic acid application at all levels of drought stress and dry conditions had a positive effect on cereal yield and quality features.

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Footnote: Effect of potassium and salicylic acid on yield and its attributes some agronomic and morpho-physiology traits under drought stress. (PhD), Islamic Azad University, Agricultural Faculty, Jiroft Branch, Jiroft, Iran.

1. Introduction

Drought is one of the most serious challenges in regions where there is a lack of water, such as in Iran. The consequence of drought on vegetation is known to limit plant productivity and growth (Cevik, 2021). Over 80% of Iran is located in arid and semi-arid zones, and deals with extreme dry periods without precipitation and high evapotranspiration (Nouri et al., 2020.a). Drought conditions become more severe, longer, and more frequent, resulting in reduced plant growth and productivity. (Essahibi et al., 2018; Demirhan and Özyazıcı, 2019).

Significant expansion of areas under water stress requires planting crops with adaptability and drought tolerance characteristics (Maqbool et al., 2017). Guar is considered due to its high resistance to drought stress, rocky soils with intense light radiation, and compliance with the climatic conditions of southern Iran, as well as its industrial aspect for the economic growth and prosperity of farmers in the region. This plant is one of the most important economic products belonging to the legume family, which is mainly cultivated in semi-arid regions of the world, such as India, Pakistan, and to a lesser extent, the USA and South Africa (Ghorbani et al., 2019). Guar is used fresh for human consumption, as fodder for animals, and as seeds for gum production. It has a high protein content, around 50% (Chiofalo et al., 2018). Guar seed endosperm is the main source of galactomannans which are used mostly for industrial applications (Mathur, 2012).

Fertilizer plays an important role in supporting plant stress (Azmatet et al., 2020). According to its biochemical properties, any kind of nutrient can influence plant growth and yield (Nouri et al., 2020.b).. Salicylic acid (SA) is a phenol-based phytohormone and regulates vital plants' physiological processes, particularly water uptake and ion transport, transpiration, and photosynthesis (Klessig et al., 2018). SA interacts with other signaling molecules and thus regulates various physiological and morphological responses in plants (Iqbal et al., 2021) and increases protection against abiotic stress (Özyazici and Açikbaş, 2021). SA has been reported to increase calcium, magnesium, and potassium levels in shoots and roots in dry conditions, which can reduce the harmful effects of drought stress on plants (El-Tayeb and Ahmed, 2010). Potassium (K) is a key component of plant growth in terms of physiological and biochemical functions. It is required to activate starch synthesis enzymes. (Fathy et al., 2009). Under stressful conditions, K is capable of reducing the rate of perspiration and increasing the absorption of water, which leads to an increase in yield. Also, this element increases cell turbulence under stress conditions and reduces the adverse effect of reactive oxygen species (Aslam et al., 2021). It was reported that applying K significantly improved the morphological and physiological parameters of plants. (Raza et al., 2018). Studies show that the amount of plant proteins capable of regulating different plant activities under stressful conditions increases as a result of the application of K (Cui et al., 2019).

The objectives of this study were to assess the negative effects of drought on Guar plants and, in the long term, to improve the productivity of cereal yield and qualitative characteristics under high drought by spraying salicylic acid and potassium.

2. Material and Methods

2.1. Site description and planting

This experiment was performed as a strip split-plot in a randomized complete block design with three replications for two years (2019 and 2020) in the Agricultural Research Center of southern Kerman, Iran (28.54 degrees north and 57.85 degrees east).

Experimental treatments include drought stress at three levels (no drought stress: 100% irrigation, moderate drought stress: 80% full irrigation, and high drought stress: 60% full irrigation), salicylic acid solution according to the doses (0, 0.1 mM: 138.12 mg l^{-1}, and 0.5 mM: 690.6 mg l^{-1}) were applied by foliar application and potassium (non-application and application of 100 kg/ha). Drought stress was determined by determining the irrigation cycle and duration based on KC coefficient, plant evapotranspiration, and 10-year meteorological statistics. The exact duration of discharge was calculated based on the formula of water requirement = evapotranspiration/time.

The planting date in both years was 20 July and the growth period was approximately between 100 to 120 days, and irrigation was applied mechanized and drip. The project consisted of 18 plots (treatments) in three replications (54 treatments in total on land 60 meters long and 15 meters wide (900 square meters)). The dimensions of each plot were 2 × 2 square meters (4 square meters), and the distance of each plot was 1.5 meters, and the distance between replicates was 2 meters. Each plot consisted of 6 rows, and the row spacing was 30 cm, and the seed spacing on the row was 10 cm.

2.2. Laboratory analyses

Guar galactomannan gum (Gum) content flour was prepared from guar seeds by milling endosperm splits to a fine powder after the removal of the seed (testa) and germ (Das et al., 1977). Grain yield (GY), grain endosperm content (Ando), harvest index (HI), and biological yield (BY) were measured by Das method (Das et al., 1977). The fresh leaves were dried at 70 ° C for 48 hours then it was milled. Protein (Pro) content by Kjeldahl apparatus and leaf potassium (K leaf) content by Swift and Sparks method (1996) were measured.

2.3. Statistical analysis

All parameters were tested using variance analysis (ANOVA). Bidirectional ANOVA was used to determine the effect of two levels of potassium and salicylic acid on Guar under different levels of irrigation (three levels). Furthermore, parameter correlation analyses were performed using a linear regression model and the PCR. Some of the datasets have been modified in terms of logarithm to satisfy the ANOVA requirement in terms of normality and homogeneity of variance. Multiple comparisons were made across partial datasets using the Duncan test. All statistical analyses have been done in software R (4.3.19).

3. Results

The analysis of variance of related-yield traits indicated that drought stress significantly affected all parameters (Table1). K fertilization, as well as a foliar spray with SA, caused significant effects on all parameters. The interactions between the stress, year, K, and SA were statistically significant for most parameters (Table1).

Table 1. Two-way ANOVA results of variables of at different years of C. tetragonoloba under different irrigation and fertilization levels

Variables	df	Grain yield (Ton/ha)	Biological yield (Ton/ha)	Harvest index	Grain endosperm (%)	Grain gum (%)	Grain protein (%)	Leaf potassium (mg/g)
Year (A)	1	0.95 **	22.6**	29 ns	27.5**	20.4**	**21.4****	**0.42****
Replication (Year)	4	0.003 ns	0.36**	21.7 ns	0.007 ns	0.04**	**0.24 ns**	**0.02 ns**
Drought stress (B)	2	4.05 **	481.8**	1332.6**	730**	309**	**710.3****	**30.5****
A×B	2	0.002 ns	0.58**	16.3 ns	0.01 ns	0.29**	**0.68***	**0.05***
Error a	8	0.04	0.18	38	0.01	0.002	**0.2**	**0.01**
Potassium (C)	1	15.2**	33**	923.6**	80.3**	53.6**	**65****	**0.78****
A×C	1	0.00001ns	0.02ns	10.8ns	0.008ns	0.39**	**0.04ns**	**0.03ns**
B×C	2	0.05ns	9.5**	53.8*	60**	0.36**	**0.06ns**	**3****
Salicylic acid (D)	2	10.7**	2.2**	1227**	16.3**	10.6**	**69.2****	**0.55****
A×D	2	0.0008ns	0.03ns	21.2ns	0.01ns	0.09**	**0.07ns**	**0.06***
B×D	4	0.08*	0.34**	63**	1.4**	0.06**	**0.09ns**	**0.08****
C×D	2	1.6**	0.51**	212.6**	1**	0.26**	**0.79****	**0.22****
B×C×D	4	0.07*	0.3*	19.7ns	1**	0.06**	**0.72****	**0.02ns**
A×B×C×D	12	0.002ns	0.11ns	11ns	0.01ns	0.12**	**0.71****	**0.05****
Error b	60	0.02	0.08	16	0.01	0.007	**0.17**	**0.01**
CV (%)	-	7	3.2	16	0.27	0.22	**1.3**	**5.6**

**,*, ns: respectively, significant at the level of 1, 5%, and no-significant.

The highest grain protein content and leaf potassium were found in the high drought stress under high application of potassium and salicylic acid in two years (Figure 1). Moreover, the lowest leaf potassium content was observed in the no drought stress and salicylic acid.

At all drought stress levels, their maximum grain yield was found in the high application of potassium and salicylic acid (Figure 2). The lowest biological yield was recorded in high drought stress under no application of potassium and salicylic acid, whereas the highest content of it exists in no drought at all levels of salicylic acid and high potassium.

The percentage of grain and gum endosperm followed similar trends under various drought stress conditions (Figure 3). There was a general decline in grain and gum endosperm with increasing drought. The highest harvest index was found in the high drought stress under high application of potassium and salicylic acid in two years (Figure 4).

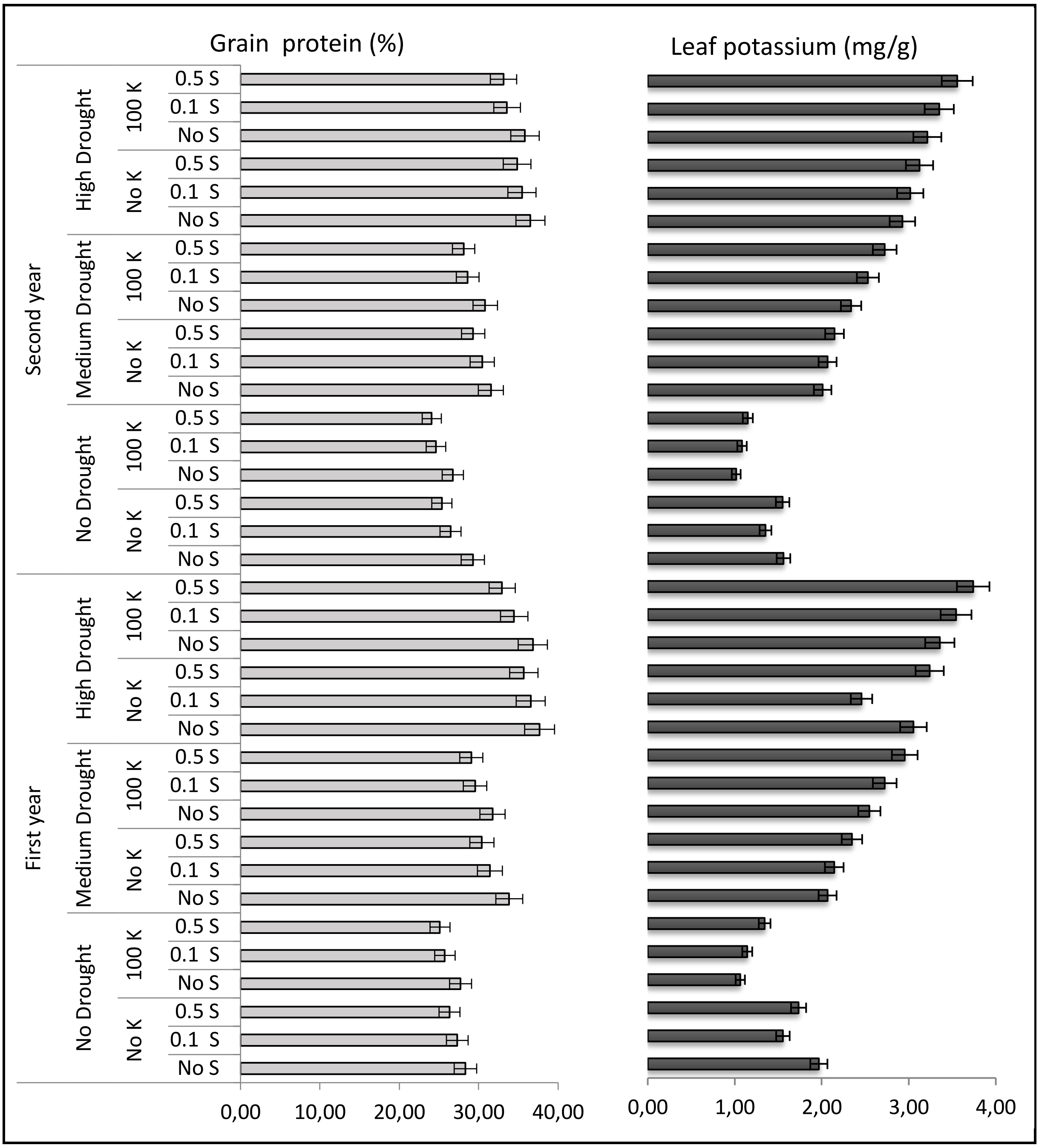

Figure 1. Average comparison of the three effects of drought stress, salicylic acid and potassium treatment on guar in two years on Nutrient factors.

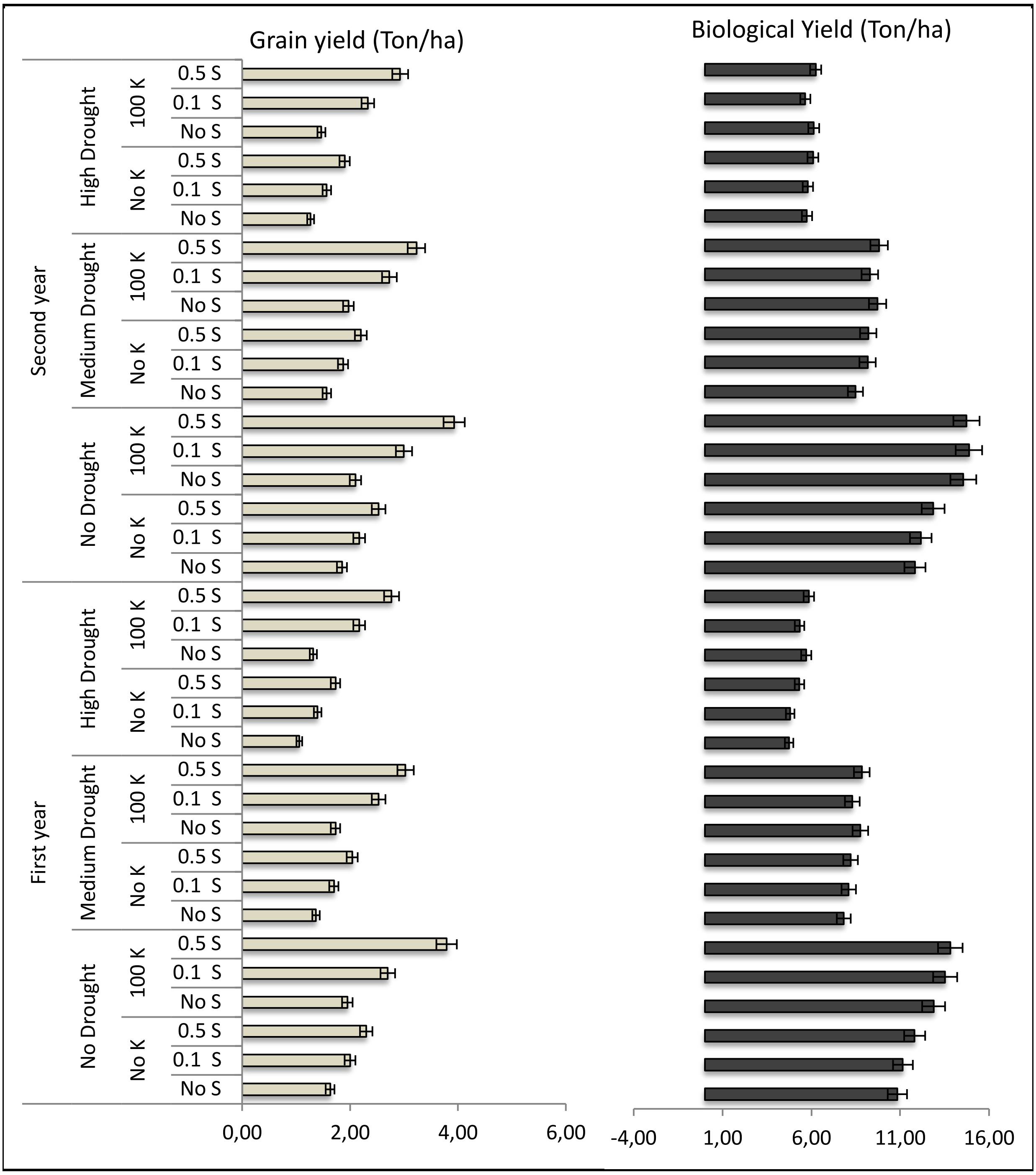

Figure 2. Average comparison of the three effects of drought stress, salicylic acid and potassium treatment on guar in two years on yeild factors.

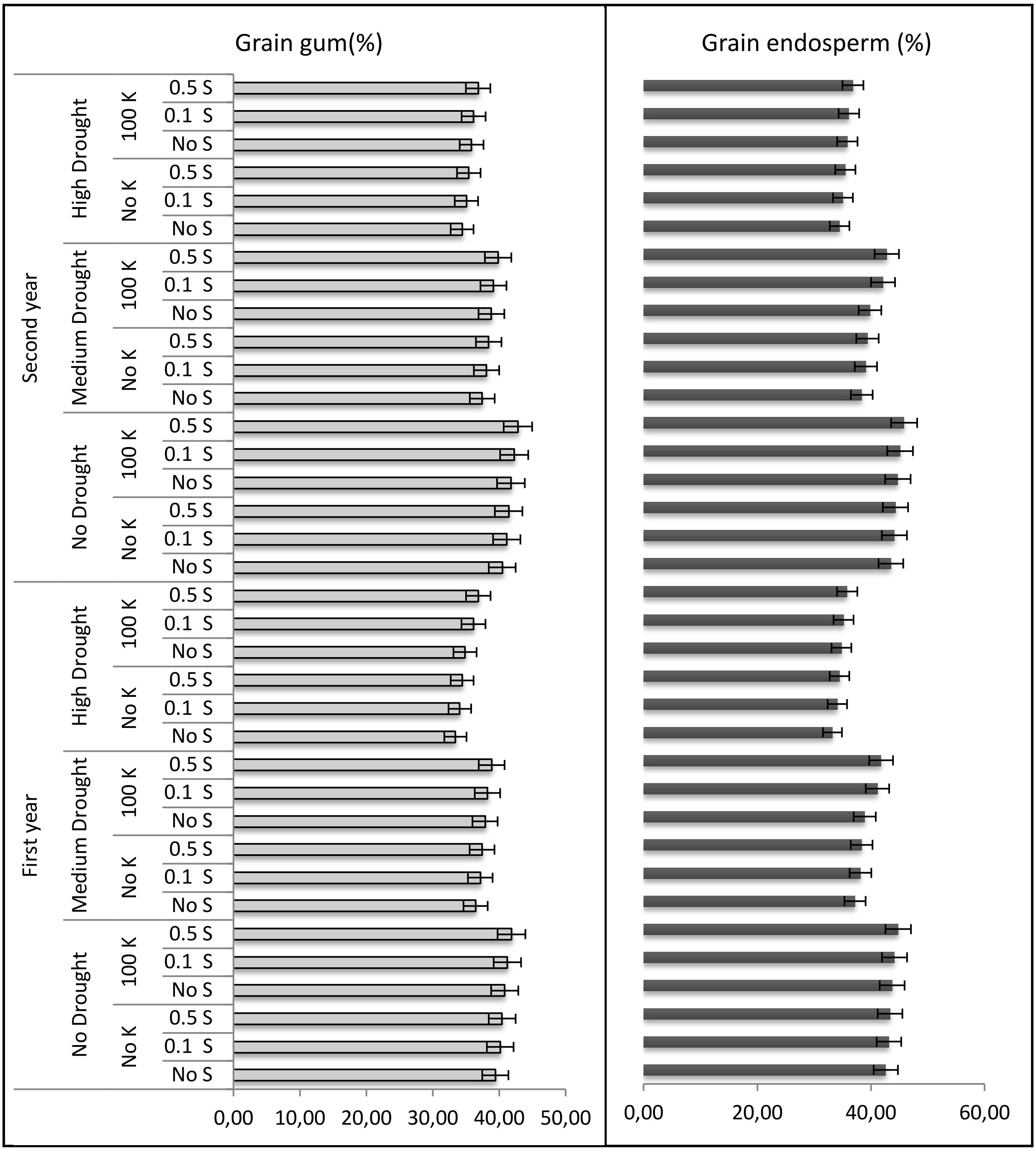

Figure 3. Average comparison of the three effects of drought stress, salicylic acid and potassium treatment on guar in two years on grain factors.

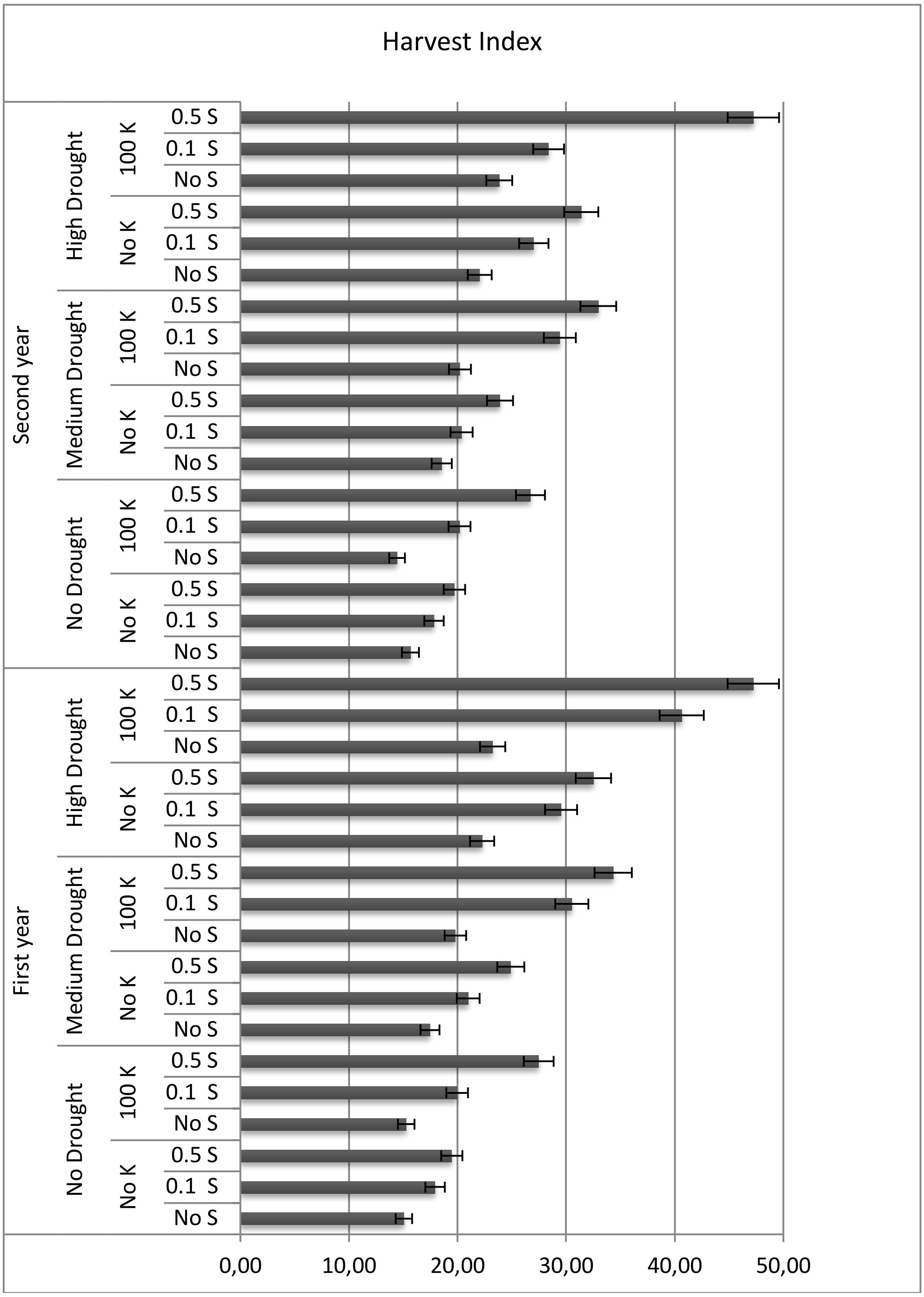

Figure 4. Average comparison of the three effects of drought stress, salicylic acid and potassium treatment on guar in two years on harvest index.

In order to more accurately assess the relationships between the characteristics of drought stress treatments, a major component analysis was conducted (Figure 5). As the graph shows, the first and second components represented about 75% and 22.1%, respectively. Approximately every association between the traits was affected by drought stress and fertilization. Furthermore, GY can be more attributed to the moderate drought stress application of 100 K and 0.5 SA, while Ando, BY, and Gum were associated with no drought, the application of 100 K, and 0.5 SA. Moreover, K leaf, HI, and Pro were integrally occupied with a high correlation with high drought stress, application of 100 K and 0.5 and 0.1 SA.

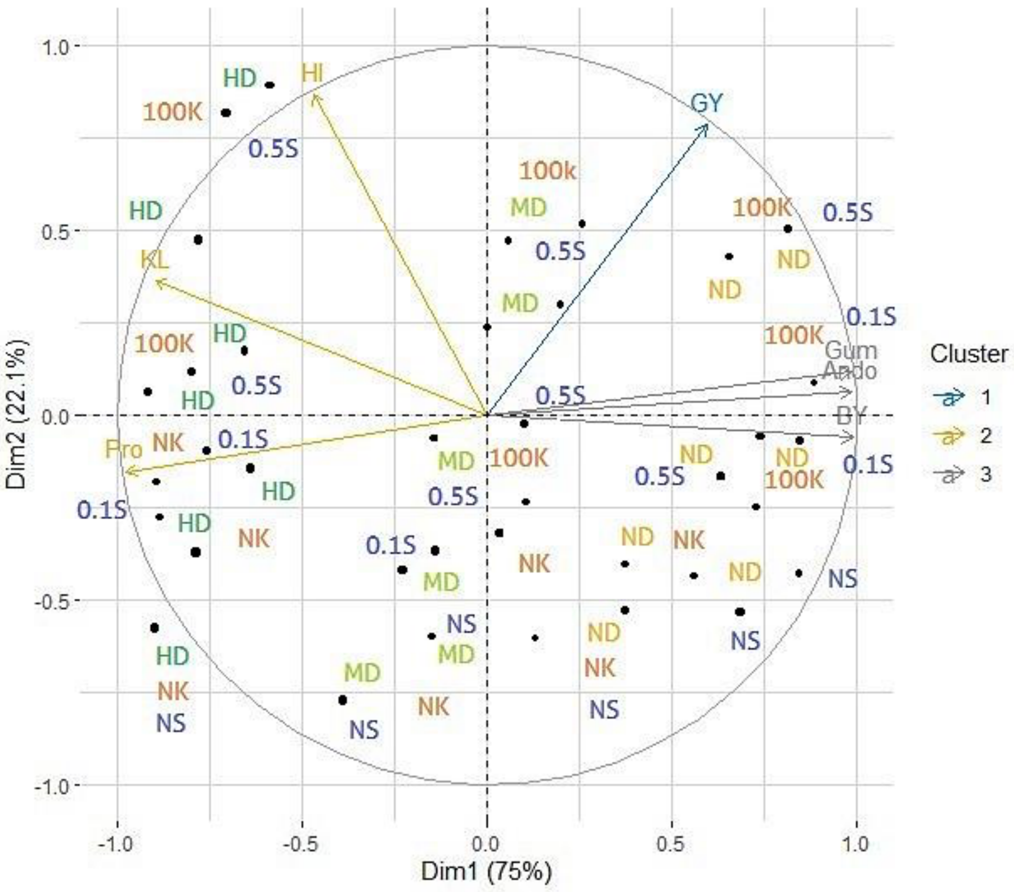

Figure 5. Principal component analysis for showing association among measured traits of C.tetragonoloba. KL: Leaf potassium (mg /g), HI: Harvest index, BY: Biological yield, Gum: Percentage of seed gum, Pro: Percentage of grain protein, Ando: Seed endosperm percentage. ND: without drought stress, MD: moderate drought stress, HD: high drought stress, NS: No salicylic acid, 0.1 S: 0.1 mM salicylic acid, 0.5S: 0.5 mM salicylic acid, NK: non- potassium, 100K: application of 100 (kg/ha) potassium.

4. Discussion

In this study, the combined effect of foliar application of salicylic acid and varying levels of potassium fertilization on Guar productivity and nutrients was assessed. The application of salicylic acid by irrigation or spraying has made it possible to improve the mechanisms of tolerance to abiotic stress in plants subjected to environmental stress (Khan et al.,2015; Gondor et al.,2016). Hoang et al., (2019) reported that drought tolerance is a major challenge in breeding rice in unfavorable environments that stopping irrigation in each growth period reduces the vegetative and reproductive growth of the plant.

Our result showed that a high level of K slightly increased grain protein, leaf potassium, grain and biological yield, harvest index, and grain endosperm and gum under drought stress conditions . About each combination of traits was affected by drought stress and fertilization. The current results were similar to those reported by Neseim et al. (2014) and Abdel-Motagally and Attia (2007). The highest cereal protein and foliar potassium content were found in the high drought stress due to the heavy application of potassium and salicylic acid over the last two years. Salicylic acid is also essential for plant growth, physiological performance, and crop productivity under abiotic stress conditions (War et al., 2011). The highest grain protein and foliar potassium content were observed in the high drought stress due to a high application of potassium and salicylic acid in two years. Potassium is an influential macronutrient that plays a key role in improving plants' water conditions, stomatal movements, enzyme activity, osmoregulation, and membrane stability which may help the plants to tolerate the adverse effect of drought stress (Ahmad et al., 2014; Erel et al., 2015). Raza et al. (2013) found that the application of K improved the absorption of K, N, P, and Ca into wheat during drought conditions.

Consumption of potassium and salicylic acid at all levels of stress caused by dryness and even under non-critical conditions had a positive effect on guar yield and yield components. As drought stress increased, the effect of potassium and salicylic acid on increased guar gum resistance to drought stress was very apparent. The reason for this can be attributed to the effect of salicylic acid in reducing sodium uptake and increasing potassium uptake, as well as increasing the activity of antioxidant enzymes and increasing drought tolerance in guar gum.

Conclusion

In conclusion, Guar is resistant to high drought stress and had a significant increment in yield under the application of potassium and salicylic acid. However, with increasing drought stress up to 80%, a significant decrease in biological yield was observed. In general, the application of potassium and salicylic acid at all levels of drought stress and even non-stress conditions had a positive effect on yield and plant nutrients. The reason for this can be attributed to the effect of salicylic acid in reducing sodium uptake and increasing potassium uptake, as well as increasing the activity of antioxidant enzymes and increasing drought tolerance in guar gum.

Conflict of interest

The authors declare that they have no conflict of interest.

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