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TOLERANCE INDICES AND BIOCHEMICAL VARIATIONS OF SOME FABA BEAN CULTIVARS UNDER WATER DEFICIT

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ABSTRACT

The field experiment was carried out at agriculture research station, Al-Arish, North Sinai, Egypt during two growing seasons(2020/2021 and 2021/ 2022).Three *Vicia faba* L. cultivars (Sakha2, Nubarya1 and Maryot2) were evaluated under water stress levels (severe stress (50%), moderate stress (75%) and control treatment (normal irrigation) (100%) from evapotranspiration to study tolerance indices and biochemical traits. Results indicated that seed yield increased by increasing the water level. The higher level of irrigation the more efficient of crop yield. The reduction in yield/feddan was in linear relation with the increase of water deficit stress. Maryot2 cultivar exceeded the other cultivars in number of pods and seed yield. In contrast, Sakha2 achieved the lowest values for each of these traits in the same conditions while it recorded the highest values in 100 seed weight trait. The interaction effect of water deficit stress and cultivar was significant on seed yield of the faba bean. Water deficit stress significantly reduced seed yield for the three cultivars. Stress tolerance indices classified Maryot2 as the most relatively tolerant cultivar based on drought tolerance index (DTI) in terms of seed yield/feddan valued (0.87 and 0.88) in the 1st and 2nd seasons, respectively, while Sakha2 cultivar recorded the lowest relative tolerance values (0.75 and 0.75) during the growing seasons. Based on yield injury (%), Maryot2 cultivar recorded the highest decrease in seed yield (21.51) in the first season while Nubarya1 recorded the highest value of yield injury in the second season (21.10). In contrast, Sakha2 was the least affected. The protein profile under water deficit stress demonstrated that there were differences among cultivars in response to water deficit stress. Few numbers of new bands were observed only in water deficit stress treated plants for each cultivar and few numbers of bands were disappeared in treated plants compared with control treatment for each cultivar.

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the oldest crops and ranks sixth in production among the different legumes grown worldwide, after soybeans, peanuts, beans, peas, and chickpeas. Faba beans are grown as a rotational crop in the Mediterranean region and fix more than 80% of the plant's nitrogen requirements. However, when compared to other field crops, it is extremely sensitive to water deficit **(Parvin *et al.*, 2019).**

Faba bean (*Vicia faba* L.) is one of the main legumes grown in Egypt (**Anil *et al.*, 2013**). It is an important protein source for human and animal consumption as the seeds are widely used as food and feed all over the world (**Mansour*et al.*, 2021**).

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Water deficit stress is one of the major abiotic stresses, which limit crop production worldwide. It decreases the plants growth and yield **(Siddiqui *et al.*, 2015).** Water stress affects the development, growth and yield components of faba bean, which results in a significant decrease in productivity. **Badran *et al.* (2013)** evaluated a range of genotypes under water deficit stress conditions and the use of biological treatments in fertilization. The study focused the light on the traits of genetic stability and the biochemical genetic background of the genotypes in those different environments to predict the importance of the strains used and focused on the importance of entering tested faba bean breeding programs.

Plant strategies for water stress tolerance include a variety of physiological and biochemical processes such as water-use efficiency maintenance **(Farooq *et al.*, 2009)**. It is noticeable that 65% decrease in water availability resulted in a 40% decrease in faba bean yield, with the yield loss varying by cultivar and other environmental factors **(Daryanto *et al.*, 2015).** Drought reduces crop productivity of most crops including faba bean. Consequently, understanding its genetic architecture has received a lot of attention. Multiple genes control drought, a quantitative trait, and these genes are influenced by the environment **(Blair *et al.*, 2012; Asfaw *et al.*, 2012)**.

Drought tolerance indices are an important criterion that can be used in evaluating a range of genotypes under environmental stress conditions. These indicators can be involved in determining yield reliability of the tested genotypes in the appropriate environments **(Badran, 2022).**

Water scarcity alters the biochemical and physiological processes of plants and as a result reduces the growth and productivity of plants **(Mansour *et al.*, 2021).** Drought stress conditions caused the disappearance of the sixth protein. As well, exposing plants to various stress conditions may result in a lack of natural protein synthesis as well as changes in translation and transcription, which results a production of new proteins through gene expression **(Al-Shewailly and Alpresem 2019)**.The suppression of normal protein synthesis is one of the many signs of drought stress, while the production of stress-related proteins is one of the elements that contribute to drought tolerance (**Karam *et al.*, 2016).**

Therefore, this study was planned to study the water deficit tolerant indices of faba bean cultivars and to examine effect of water deficit stress on yield and protein banding pattern of tested cultivars.

MATERIALS AND METHODS

Experimental Design and Experimental Conditions

The field experiment was carried out at agriculture research station of Al-Arish, North Sinai, Egypt during successful growing seasons 2020/2021 and 2021/2022. The experiment was laid out in a split plot design with four replications as water deficit levels in main plots and the tested three cultivars in subplots. The experimental treatments consisted of three levels of water deficit stress [*i.e.*, 50% from evapotranspiration (D1) as a severe water deficit stress, 75% from evapotranspiration (D2) as moderate water deficit stress and without water deficit stress (100% from evapotranspiration) as control (D3). In the growing season of 2020-2021, the average temperature was 15.42˚C and the relative humidity (%) was 68.06. In the second year (2021-2022), average temperature was 16.70˚C and the relative humidity (%) was 68.54. Total precipitation for the first and second years was 124.30 and 173.50 mm respectively.

Seeds of three bean cultivars belong to *Vicia faba* L. (Sakha2, Nubarya1 and Maryot2) were used to evaluate them under environmental stress conditions compared to normal conditions.

The distances among the planted hills were 30.00 cm, while the distances between the rows were 60.00 cm. A distance of 2 m was left between each two irrigation treatments as a limit among treatments to prevent overlap among irrigation treatments. Seeds were placed at a depth of 3 to 4 cm in each row. Then the tested cultivars were evaluated under three irrigation water stresses (50%, 75% and 100% from evapotranspiration).

Water Treatments

For every experimental plot, irrigation control was estimated using manual valves. Using the Penman method (**Penman, 1984**), the total amount of irrigation water was determined. Water Requirement under different water levels was conducted weekly as shown in Table 1.

Yield and its components

- The number and weight of pods (g) for each plant were determined in the middle of each experimental unit.
- 100 seeds (g) were counted and weighed randomly.
- Yield per feddan was determined (kg).

Drought tolerance indices

Drought tolerance indices were calculated as follow:

Drought tolerance index (DTI):DTI= (Yp) × (Yd)/(Ýp)^2 (**Fernandez, 1992)**.

Yield injury % (YI): YI = (Yp-Yd)/Yp × 100 (**Blum *et al.*, 1983).**

Superiority measure (SM): SM = Yd/Yp (**Lin and Binns, 1988)**.

Relative performance (RP): RP = (Yd/ Yp)/ R (**Abo-Elwafa and Bakheit, 1999)**.

Where, Yp = yield of cultivar under normal condition; Yd = yield of cultivar under drought stress condition; Ýp = Mean yield of all cultivars under normal condition; Ýd = Mean yield of all cultivars under drought stress condition; R = (Ýd/Ýp).

Electrophoresis of Protein

Three plants were sampled for each cultivar for the three levels of water deficit. SDS-poly-acrylamide gel electrophoresis (SDS- PAGE) technique was conducted in the Agriculture Research Center, Cairo, Egypt.

The SDS-PAGE procedure was followed by **Laemmli (1970).** Ten plants were selected for young leaf collection, and 1 gram of the sample was treated with liquid nitrogen and ground with 2 ml of Lan's buffer (2X) in a mortar and pestle. Using a gel photography and documentation system (BIO RAD Model Gel Doc2000), protein fractions were examined.

Statistical Analysis

Statistical analyses were performed to ascertain the independent and combined effects of water deficit stress and cultivar using statistics program and put through the appropriate statistical analysis of split plot design, testing for significance at the 5% level using the differences among means for all traits according to **Waller and Duncan (1969)**.

RESULTS AND DISCUSSION

Yield and its Components

Number of pods per plant

Number of pod per plant is one of the most important yield components. The results of Table 2 showed that, the highest values of number of pods was obtained under normal irrigation level (D3) in the 1st and 2nd growing seasons.

There were insignificant differences between the two seasons of study between the tested cultivars. The severe irrigation level recorded the lowest values in pods number of faba bean in 1st and 2nd seasons. As for cultivars effect, the highest number of pod per plant was belonged to Maryot2

Table 1. Water requirements for faba bean plant weekly

Week	ETo-Penman	Kc	ETc	With Leaching req. Factor	Gross water req.	Irrigation req.
	mm/day		mm/day	(20%)	m^3/Fad. / day	liter/plant/ day
1	3.15	0.51	1.59	1.91	0.72	0.90
2	2.88	0.53	1.54	1.84	0.69	0.86
3	2.60	0.56	1.47	1.76	0.66	0.82
4	2.45	0.68	1.67	2.00	0.75	0.94
5	2.30	0.80	1.83	2.20	0.83	1.03
6	2.15	0.91	1.97	2.36	0.88	1.11
7	2.00	1.03	2.06	2.48	0.93	1.16
8	1.85	1.15	2.12	2.55	0.96	1.19
9	1.98	1.20	2.38	2.85	1.07	1.34
10	2.30	1.14	2.62	3.15	1.18	1.48
11	2.49	1.02	2.54	3.04	1.14	1.43
12	2.93	0.95	2.79	3.34	1.25	1.57
13	3.37	0.85	2.87	3.44	1.29	1.61
14	3.81	0.75	2.86	3.43	1.29	1.61
15	4.03	0.70	2.82	3.38	1.27	1.58
16	4.24	0.65	2.75	3.31	1.24	1.55
17	4.45	0.60	2.67	3.20	1.20	1.50
18	4.66	0.55	2.56	3.08	1.15	1.44
19	4.87	0.50	2.44	2.92	1.10	1.37
20	4.60	0.45	2.35	2.81	1.01	1.31

Table 2. Means of tested cultivars under three water deficit levels for pods number and 100-seed weight (g) traits in growing seasons 2020/2021 and 2021/2022

Factor	Pod number		100 seed weight (g)	
Water irrigation level	**2020**	**2021**	**2020**	**2021**
Water deficit50%	16.98[c]	20.94c	66.50c	78.53c
Water deficit 75%	18.61[b]	24.13b	73.77b	86.33b
Normal irrigation	20.22a	25.22a	78.00a	104.03a
Cultivar				
Sakha 2	17.01[b]	22.00b	75.47a	93.86a
Nubarya1	19.13[a]	25.85a	72.66b	88.02b
Maryot 2	19.41[a]	22.52b	70.13c	87.00c

and Nubarya1 cultivars whereas, Sakha2 had the lowest estimates in the 1st and 2nd seasons. Similar results were reported by **Arya and Khushw (2000)**, **Khurgami *et al.* (2009), Mansur *et al.* (2010) and Badran *et al.* (2013).** Furthermore, **Mansour *et al.* (2021)** stated that the number of pods per plant under the non-stress condition increased by 71% when compared to the severe water deficit stress condition.

Weight of 100 seed (g)

Table 2 shows the effect of water deficit stress levels on 100-seed weight of three cultivars of faba bean. Under the level of severe water deficit (D1), the results gave the lowest values in the 1st and 2nd seasons, while under the level of normal irrigation (D3); the results gave the highest values in the 1st and 2nd seasons. The decrease in 100-seed weight under stress conditions may be related to a reduction in the photosynthetic translocation to growing seed. **Mansur *et al.* (2010) and Arya and Khushwa (2000)** came to similar findings. Sakha2 cultivar recorded the highest values of 100-seeds weight in the 1st and 2nd seasons followed by Nubarya1 while Maryot2 ranked third. Perhaps the reason for the increase in the weight of the seeds of the cultivar Sakha2 is due to the fact that this trait is genetically related to the cultivars rather than the influence of the external and environmental factors that are affected by them, and these findings are in harmony with those obtained by **Kubure *et al.* (2015).**

Seed Yield/ Faddan

The results in Table 3 indicates that there is a clear increase in the seed yield with increasing irrigation level. The severe water deficit level (D1) recorded the lowest values for the seed yield (694 and 754 kg/ fed.) during the first and second seasons respectively. The decrease in seed yield/ plant was linear with increasing water deficit stress. Normal irrigation produced the highest values of seed yield (857 and 922 kg/fed.) during the 1st and 2nd growing seasons respectively. In this respect, **Mahalakshmi and Bidinger (1985)** reported that water deficit stress at seed filling stage reduced seed yield up to 50%. Three factors determine the final seed yield: the number of pods per plant, the number of seeds per pod, and the degree of seed fill. All yield components dramatically decreased in tandem with a decline in grain yield under drought stress. These results are in harmony with that represented by **Ludlow and Mushow, (1990) and Gwathmey *et al.* (1992), Badran*et al.* (2013) and Migdadi *et al.* (2016)** who attributed the decrease in seed yield under drought stress to a decrease in pods per plant, seeds per pod, and seed weight.

Table 3 also shows a significantly effect of cultivars of seed yield, Maryot2 cultivar gave the highest mean for this feature during the first and second seasons (847and 867 kg /fed.), respectively while Nubarya1 ranked second and obtained (775 and 844 kg/fed.) in first and second seasons, respectively outperforming Sakha2 which gave the lowest average (742 and 810 kg/fed.) for the 1st and 2nd seasons, in the same respective order. About the interaction between water deficit treatment and cultivar, the highest seed yield in first and second experimental season was obtained by Maryot2 cultivar under normal irrigation level (control) (902 and 966 Kg/ fed.) in the 1st and 2nd seasons, respectively followed by Nubarya1 under normal irrigation level (D3) in 1st and 2nd seasons (868 and 944 Kg/fed.). In first studied season, the lowest seed yield was recorded under the severe irrigation with Sakha2 cultivar (685 kg/fed.) while Nubarya1 under the severe irrigation ranked the last in the second season (Table 3). Reduction of seed yield under water deficit stress was previously reported in different faba bean genotypes (**Darkwa *et al.*, 2016; Rasti *et al.*, 2018; Sanchez-Reinoso *et al.*, 2018)**.

Table 3. Interaction between water deficit stress and cultivars during the two growing seasons (2020/2021 and 2021/2022) for yield per feddan

Cultivar	100% (Control)	75%	50%	Mean	100% (Control)	75%	50%	Mean
	2020/2021				2021/2022			
Sakha2	802^{bcd}	743^{def}	685^{i}	**742^{C}**	857^{b}	826^{bc}	747^{d}	**810^{B}**
Nubarya1	868^{b}	773^{cde}	690^{h}	**775^{B}**	944^{a}	871^{b}	739^{e}	**844^{A}**
Maryot2	902^{a}	845^{bc}	708^{ef}	**847^{A}**	966^{a}	865^{b}	771^{cd}	**867^{A}**
Mean	**857^{A}**	**787^{B}**	**694^{C}**		**922^{A}**	**854^{B}**	**754^{C}**	

Tolerance Indices of Tested Cultivars

Stress tolerance indices were investigated in order to identify the tolerant or sensitive cultivars based on seed yield per feddan. Seed yield weight per feddan of the three cultivars was evaluated under non-stress (100% from evapotranspiration) and severe stress conditions (50% from evapotranspiration) in order to calculate various sensitivity and/or tolerance indices (Table 4). The drought tolerance index (DTI) determined that the cultivar that was most relatively tolerant in the 1st and 2nd seasons was Maryot2 in 1st and 2nd seasons, with a seed yield/feddan of 0.87 and 0.88, respectively. In spite of this, Sakha2 cultivar throughout the growing seasons recorded the lowest relative tolerance values (0.75 and 0.75) according to yield injury (%). In the first season, Maryot2 cultivar had the greatest deficit in seed yield (21.51), whereas in the second season, Nubarya1 had the highest yield injury value (21.10). Sakha2, on the other hand, was least affected. Sakha2 cultivar had higher values (0.86 and 0.87 for superiority measure and attained (1.06 and 1.07) for relative performance during the two growing seasons, respectively as shown in Table 4. Additionally, the results showed that the cultivars could be categorized into two groups based on how well they fed and produced seeds overall in both stressful and non-stressful conditions of water deficit: (Group a) is made up of Maryot2 cultivar, which consistently outperforms in both stress and non-stress conditions (902 and 966 kg/fed.) and (708 and 771) under stress conditions in the 1st and 2nd seasons, respectively. On the another hand, Sakha2cultivar performs poorly under non-stress conditions for seed yield (802 and 857 kg/fed.) during both seasons, respectively while Nubarya1 cultivar performs poorly under stress conditions in second season (739 Kg/fed.) according to performance indices (Group b).

This study separated the tested cultivars into tolerant and sensitive groups under low and high water deficit levels based on the seed yield of faba bean yield/fed. According to **Badran and Moustafa (2014)**, the evaluation based on the drought tolerance index (STI) is a reliable predictor to choose high-yielding cultivar under high stress compared to the normal condition. On the other hand, **Guterre *et al.* (2001**) reported that crop tolerance to salinity or water deficit stresses can be increased by selecting high yield cultivars based on the stress sensitivity index (SSI). Therefore, it is preferable to rely on factors other than environmental stress tolerance when classifying tested cultivars under water deficit stress as opposed to optimal conditions or low stress. These previous finding are consistent with **Fernandez (1992**) and **Badran (2022**) who stated that, in comparison to non-stress conditions, cultivars are divided into four groups based on how well they perform on average under stress.

Table 4. Tolerance indices of tested faba bean cultivars under stress and non-stress condition for seed yield during the growing seasons (2020/2021 and 2021/2022)

Cultivar	Yp	Yd	Yp	Yd	DTI		YI (%)		SM		RP	
	2020/ 2021	2020/ 2021	2021/ 2022	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022
Sakha2	802	685	857	747	0.75	0.75	13.95	12.84	0.86	0.87	1.06	1.07
Nubarya1	868	690	944	739	0.81	0.83	21.05	21.10	0.79	0.79	0.98	0.99
Maryot2	902	708	966	771	0.87	0.88	21.51	20.23	0.78	0.80	0.97	0.98
Mean	**857**	**694**	**922**	**754**	**0.81**	**0.82**	**18.84**	**18.05**	**0.81**	**0.82**	**1.01**	**1.00**

Note. Yp= seed yield /fed. under 100% from evapotranspiration (D1); Yd =seed yield /feddan under 50%from evapotranspiration (D3); DTI= drought tolerance index; YI= yield injury; SM= superiority measure; RP= relative performance.

Protein Structure

Sodium dodecyl-sulfate polyacrylamide gel electrophoresis (SDS-PAGE) technique

The protein profile was generated using SDS PAGE analysis, as quantitatively detected protein expressions in plants occurred under different environmental stress conditions (Fig. 1). The protein profile under water deficit stress ranged from 25 to 300 kDa (Table 5).

Sakha2 was displayed five bands under normal irrigation (D3) and three bands for each treatment of irrigation (D1 and D2). Nubarya1 was recorded six bands for control treatment (D3), four bands for severe irrigation treatment (D1) and seven bands for moderate irrigation treatment (D2). Moreover, Maryot2 was recorded five bands for controlled plants and two bands under severe irrigation treatment while it recorded five bands under moderate irrigation treatment. Changes in protein sites, amino acid sequences, frame shift mutations, or variations in DNA's nitrogenous bases could cause variations in the number of bands seen between the treated and control plants. Because of this, there are many more distinct polypeptide bands produced by protein synthesis (alternative splicing and post-transcription modification) than genes in a genome. These polypeptide bands can be utilized as markers for individual genes **(Mondini *et al.*, 2009).** Furthermore, in the controlled plants, Sakha2 displayed two bands out of five bands, which were not observed in the two plants treated with water deficit. These bands that vanished at 75 and 90 kDa could have been denatured or not expressed in plants that were treated with water deficit. However, Nubarya1 only detected one band (90 kDa) out of six bands in the controlled plants, and both of the water deficit treated plants had no more bands. Additionally, Maryot2 showed two of the five bands that were thought to be distinct bands for the controlled plants in comparison to treatments under stress from a water deficit. The disappearance of proteins can be explained theoretically as either the "turning off" of the synthetic genetic machinery (genes) that make up proteins in response to salt treatment or as the result of a small number of peptide bonds breaking and the creation of shorter polypeptide chains than the original protein due to the lack of related genes or DNA sequences. Another possibility is that individual polypeptide chains gather together or cross-link to cause protein denaturation (**Elavumoottil *et al.*, 2003; Shikazono *et al.*, 2005).** Another study found that stress accelerated plant degradation and suppressed protein synthesis **(Maleki *et al.*, 2014; Wu *et al.*, 2018).**

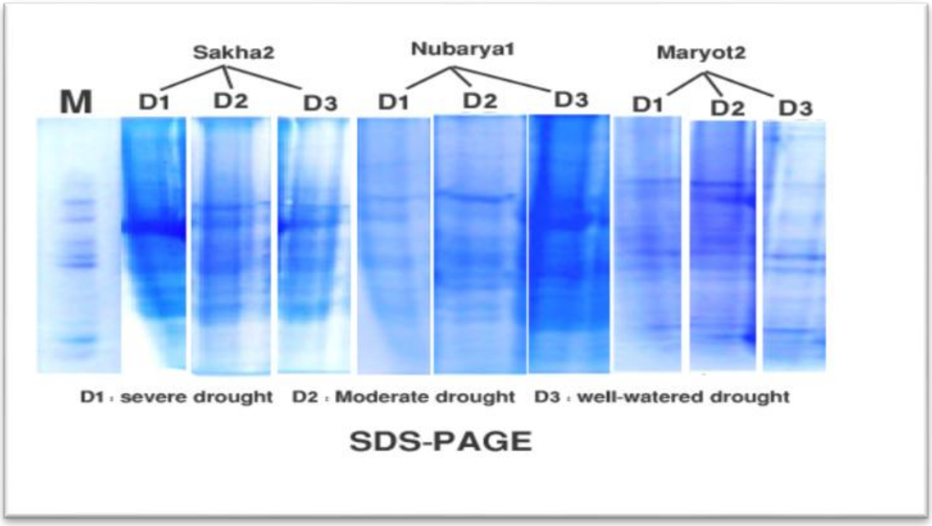

Fig. 1. Profile of molecular weights (KDa) of tested three cultivars under the three irrigation levels

Table 5. The presence (+) and absence (-) of leaves protein of cultivars under the irrigation levels

Band No.	M.W (KDa)	Sakha 2			Nubarya1			Maryot2		
		D1	D2	D3	D1	D2	D3	D1	D2	D3
1	300	-	-	-	-	+	+	-	-	+
2	200	+	-	-	+	+	+	-	-	-
3	150	-	+	+	+	+	+	+	+	+
4	100	+	+	+	+	-	-	-	+	-
5	90	-	-	+	-	-	+	-	+	+
6	75	-	-	+	+	+	+	+	+	+
7	50	-	-	-	-	+	+	-	-	-
8	35	+	+	+	-	+	-	-	-	+
9	25	-	-	-	-	+	-	-	+	-
Total		**3**	**3**	**5**	**4**	**7**	**6**	**2**	**5**	**5**

D1= Severe water deficit level, **D2**= Moderate water deficit level, **D3**= well-watered level

Other two bands were maintained in both water deficit treated plants of Sakha2 presenting similar molecular weights to controlled plants (35 and 100 kDa). They may be genetically related to plant germination and growth processes **(Rani *et al.*, 2007).** Interestingly, Nubarya1 showed up in control and water deficit treated plants with the same three bands at 75, 150, and 200 kDa. Additionally, Maryot2 showed that the stressed and controlled plants had molecular weights that were comparable (75 and 150 kD). At this point, the genetic foundation of a tolerant genotype and the genotype's capacity for stress adaptation may be the cause of water deficit stress protein expression **(Husaini and Rafiqi, 2012).**

It is interest to note that, Sakha2, Nubarya1 and Maryot2, recorded two, four and two new bands, respectively with molecular weight (150 and 200 kD) for Sakha2, (25, 35, 50 and 100 kD) for Nubarya1 as well as (25 and 100 kDa) for Maryot2 were detected only in water deficit treated plants and absent in controlled plants **(Table 5).** It makes sense that suppression of normal protein synthesis is one of the many signs of water deficit stress, while the production of stress-related proteins is one of the elements that leads to drought tolerance (**Folgado *et al.*, 2013; Karam *et al.*, 2016).**Thus, new bands of Sakha2, Nubarya1, and Maryot2 may affect the avoidance of osmotic adjustment damage from dehydration in opposition to water shortage stress **(Trivedi and Patel, 2016).**This means that two additional bands may be taken into consideration as biochemical indicators of the cultivar's sensitivity to water deficit stress for the species in question. Water deficit stress is thought to cause changes in plant gene expression, causing some genes to produce more transcripts and, in turn, more proteins that correspond to the emergence of new bands and the denatured or non-expression of other constant bands at this stress threshold (**Khalili *et al.*, 2018).**

Noticeably, the protein profile under water deficit stress showed that there were differences among the cultivars in response to water deficit stress. Table 5 showed that few numbers of newly bands were observed only in water deficit stress treated plants for each cultivar and few numbers of bands were disappeared in water deficit treated plants compared with control treatment for each cultivar. Drought tolerance may be regulated differently by different genes. For instance, a number of genes in the dehydrin (DHN) gene family were exclusively expressed in plants under stress, indicating their involvement in the molecular pathways that plants use to respond to water deficit stress **(Huseynova *et al.*, 2015)**.

This result was in line with what **Al-Shewailly and Alpresem (2019)** discovered which was that the sixth protein disappeared as a result of water deficit stress. According to these results, plants exposed to different stress conditions may experience altered translation and transcription, a lack of natural protein synthesis, and the production of new proteins through gene expression in response to the stress conditions that the plant experiences in order to maintain control over those conditions.

Table 6 summarizes the number of bands and polymorphisms resulting from soluble proteins for the cultivars under study. The findings showed that there are a total of 11 distinct bands and 15 polymorphic bands for soluble proteins. Furthermore, the overall percentage of polymorphism across all cultivars was 54.5%, and the observed polymorphism was considered to be reasonably medium.

Sakha2 cultivar recorded the lowest number of total bands (6) included (3) unique bands while Nubarya1 cultivar recorded the highest number of total bands (9) included (4) unique bands while Maryot2 cultivar recorded (7) in number of total bands included (4) unique bands. Besides, the percentage of polymorphism ranged from 66.6%, 66.6% and 71.4% for Sakha2, Nubarya1 and Maryot2 cultivars respectively.

This study concluded that genetic differences between plants that develop under different environmental stressors can be detected by protein electrophoresis on a polyacrylamide gel.

Table 6. Summary of polymorphisms and number of bands pattern resulted from SDS-PAGE for the three cultivars

Cultivar	Total Bands	Monomorphic Band	Polymorphic band	Unique Band	Polymorphism %
Sakha2	6	2	4	3	66.6%
Nubarya 1	9	3	6	4	66.6%
Maryot 2	7	2	5	4	71.4%
Total	22	7	15	11	54.5%

Conclusion

The present study showed that, Maryot2 cultivar was superiority in its performance under both water deficit stress and non-stress environmental conditions, whereas Sakha2, and Nubarya1 cultivars perform poorly under stress condition for seed yield per feddan according to tolerance indices. On the other hand, protein structure diversity using SDS- PAGE technique helps to differentiate between the tested cultivars of faba beans.

Conflicts of interest: The authors declare no conflict of interest.

REFERENCES

Abo-Elwafa, A. and Bakheit, B.R. (1999). Performance, correlation and path coefficient analysis in faba bean. Assiut J. Agric. Sci., 30: 77-91.

Anil, K.S.; Naresh, C.R.M. and Anitha, P.A. (2013). Assessment of faba bean (*Viciafaba* L.) current status and future prospect. Afr. J. Agric. Res., 8 (50): 6634 – 6641.

Al-Shewailly, M.S.R. and Alpresem, W. F.F. (2019). The Effect of Environmental stress on the protein pattern of gladiolus spp. In IOP Conference Series: Earth and Environ. Sci., 388: 012066). IOP Publishing.

Arya, R.L. and Khuswaha, B.L. (2000). To study the irrigation and phosphorus management in rice chickpea cropping system. In Proc. First Int. Agron. Congress. Eds. Ahlawat, IPS and Surendrasingh. New Delhi, India, 23-37.

Asfaw, A.; Blair, M.W. and Struik, P.C. (2012). Multienvironment quantitative trait loci analysis for photosynthate acquisition, accumulation, and remobilization traits in common bean under drought stress. G3: Genes, Genomes, Genet., 2 (5): 579-595.

Badran A.E.; Abd El-Gawad, A.M. and Omar, S.A. (2013). Evaluation of some selected faba bean genotypes grown under drought conditions using some biofertilization treatments. Egypt. J. Plant Breed., 17 (5) :175-182.

Badran, A.E. and Moustafa, E.S.A. (2014). Drought resistance indices and path analysis in some wheat genotypes. World Appl. Sci. J., 30 (12): 1870-1876.

Badran, E.A. (2022). Assessment of variation and stability parameters of five quinoa genotypes under drought stress conditions. Egypt. J. Bot., 62 (1): 21-30.

Blair, M.W.; Galeano, C.H.; Tovar, E.; Muñoz Torres, M.C.; Castrillón, A.V.; Beebe, S.E. and Rao, I.M. (2012). Development of a Mesoamerican intra-genepool genetic map for quantitative trait loci detection in a drought tolerant× susceptible common bean (*Phaseolus vulgaris* L.) cross. Molec. Breed., 29: 71-88.

Blum, A.; Poyarkova, H.; Golan, G. and Mayer, J. (1983). Chemical desiccation of wheat plants as a simulator of postanthesis stress. I. Effects on translocation and kernel growth. Field Crops Res., 6: 51–58.

Darkwa, K.; Ambachew, D.; Mohammed, H.; Asfaw, A. and Blair, M.W. (2016). Evaluation of common bean (*Phaseolus vulgaris* L.) genotypes for drought stress adaptation in Ethiopia. The Crop J., 4 (5): 367-376

Daryanto, S.; Wang, L. and Jacinthe, P.A. (2015). Global synthesis of drought effects on food legume production. PloS one, 10 (6): e0127401.

Elavumoottil, O.C.; Martin, J.P. and Moreno, M.L. (2003). Changes in sugars, sucrose synthase activity and proteins in salinity tolerant callus and cell suspension cultures of *Brassica oleracea* L. Biologiaplantarum, 46:7-12.

Farooq, M.; Wahid, A.; Kobayashi, N.S. M.A.; Fujita, D.B.S.M.A. and Basra, S.M.A. (2009). Plant drought stress: effects, mechanisms and management. Sustainable Agric., 153-188.

Fernandez, G.C. (1992). Effective selection criteria for assessing plant stress tolerance. In Proceeding of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress, Aug. 13-16, Shanhua, Taiwan, 257-270.

Folgado, R.; Panis, B.; Sergeant, K.; Renaut, J.; Swennen, R. and Hausman, J.F. (2013). Differential protein expression in response to abiotic stress in two potato species: *Solanum commersonii* Dun and *Solanum tuberosum* L. Int. J. Molec. Sci., 14 (3): 4912-4933.

Guttieri, M.J.; Stark, J.C.; O'Brien, K. and Souza, E. (2001). Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. Crop Sci., 41 (2): 327-335.

Gwathmey, C.O. and Hall, A.E. (1992). Adaptation to midseason drought of cowpea genotypes with contrasting senescene traits. Crop Sci., 32 (3): 773-778.

Husaini, A.M. and Rafiqi, A.M. (2012). Role of osmotin in strawberry improvement. Plant Molec. Biol. Rep., 30: 1055-1064

Huseynova, M.; Rustamova, S.M.; Nasrullayeva, M.Y. and Aliyev, J.A. (2015). Screening of barley genotypes for drought tolerance using molecular markers. Int. J. Plant Sci. Ecol., 1: 88-92.

Karam, M.A.; Abd-Elgawad, M.E. and Ali, R.M. (2016). Differential gene expression of salt-stressed *Peganumharmala* L. J. Genet. Eng. and Biotechnol., 14 (2): 319-326.

Khalili, M.; Naghavi, M.R. and Yousefzadeh, S. (2018). Protein pattern analysis in tolerant and susceptible wheat cultivars under salinity stress conditions. Actaagriculturae Slovenica, 111 (3): 545-558.

Khourgami, A. and Rafiee, M.A.S.O.U.D. (2009). Drought stress, supplemental irrigation and plant densities in chickpea cultivars. In 9th Afr. Crop Sci., Conf. Proc., Cape Town, South Afr., 28 September-2 October 2009 (Afr. Crop Sci. Soc., 141-143.

Kubure, T.E.; Cherukuri, V.R.; Arvind, C. and Hamza, I. (2015). Effect of faba bean (*Vicia faba* L.) genotypes, plant densities and phosphorus on productivity, nutrients uptake, soil fertility changes and economics in Central highlands of Ethiopia. Int. J. Life Sci., 3(4): 287-305.

Lin, C.S. and Binns, M.R. (1988). A superiority measure of cultivar performance for cultivar x location data. Can. J. Plant Sci., 68: 193-198.

Ludlow, M.M. and Muchow, R.C. (1990). A critical evaluation of traits for improving crop yields in water-limited environments. Advances in Agron., 43: 107-153

Laemmli, U.K. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4.nature, 227 (5259): 680-685.

Mahalakshmi, V. and Bidinger, F.R. (1985). Flowering response of pearl millet to water stress during panicle development. Ann. Appl. Biol., 106 (3): 571-578.

Maleki, M.; Naghavi, M.R.; Alizadeh, H.; Poostini, K. and AbdMishani, C. (2014). Comparison of protein changes in the leaves of two bread wheat cultivars with different sensitivity under salt stress. Ann. Res. and Rev. in Biol., 1784-1797.

Mansour, E.; Desoky, E.S.M.; Ali, M.M.; Abdul-Hamid, M.I.; Ullah, H.; Attia, A. and Datta, A. (2021). Identifying drought-tolerant genotypes of faba bean and their agro-physiological responses to different water regimes in an arid Mediterranean environment. Agric. Water Manag., 247: 106754.

Mansur, C.P.; Palled, Y.B.; Salimath, P.M. and Halikatti, S.I. (2010). An analysis of dry matter production, growth and yield in kabuli chickpea as influenced by dates of sowing and irrigation levels. Karnataka J. Agric. Sci., 23 (3): 457-460.

Migdadi, H.M.; El-Harty, E.H.; Salamh, A. and Khan, M.A. (2016). Yield and proline content of faba bean genotypes under water stress treatments. JAPS: J. Anim. Plant Sci., 26 : 6.

Mondini, L.; Noorani, A. and Pagnotta, M.A. (2009). Assessing plant genetic diversity by molecular tools. Diversity, 1(1): 19-35.

Parvin, S.; Uddin, S.; Tausz-Posch, S.; Fitzgerald, G.; Armstrong, R. and Tausz, M. (2019). Elevated CO2 improves yield and N2 fixation but not grain N concentration of faba bean (*Viciafaba* L.) subjected to terminal drought. Environ. and Exp. Bot., 165: 161-173.

Penman, H.L. (1948). Natural evaporation from open water, bare soil and grass. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sci., 193(1032), 120-145.

Rani, C.; Bishnoi, S.; Kumar, B. and Datta, S. (2007) Changes in protein profile under sodium chloride and boron toxicity stress in seedlings of two cultivars. Indian J. Plant Physiol., 12 (1): 13-17.

Rasti, M.; Ganjeali, A.; Lahouti, M. and MousaviKouhi, S.M. (2018). Morphological and physiological responses of two common bean cultivars to drought stress. J. Plant Proc. and Function, 6 (22): 37-46.

Sanchez-Reinoso, A.D.; Ligarreto-Moreno, G.A. and Restrepo-Diaz, H. (2018). Physiological and biochemical responses of common bush bean to drought. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 46 (2): 393-401.

Shikazono, N.; Suzuki, C.; Kitamura, S.; Watanabe, H.; Tano, S. and Tanaka, A. (2005). Analysis of mutations induced by carbon ions in Arabidopsis thaliana. J. Exp. Bot., 56 (412): 587-596.

Siddiqui, M.H.; Al-Khaishany, M.Y.; Al-Qutami, M.A.; Al-Whaibi, M.H.; Grover, A.; Ali, H.M. and Bukhari, N.A. (2015). Response of different genotypes of faba bean plant to drought stress. Int. J. Molec. Sci., 16 (5): 10214-10227.

Waller, R.A and D.B. Duncan (1969).A bays rule for the symmetric multiple comparison problem. Ame. State. Assoc. J. Dec., 1485-1503.

Trivedi, D. and Patel, I. (2016). Effect of brassinosteroids on protein profiling of salinity susceptible and resistance cultivars of groundnut under salinity stress. Europ. J. Biotechnol. and Biosci., 4 (8): 38-46.

Wu, B.; Munkhtuya, Y.; Li, J.; Hu, Y.; Zhang, Q. and Zhang, Z. (2018). Comparative transcriptional profiling and physiological responses of two contrasting oat genotypes under salt stress. Scientific Reports, 8 (1): 16248.

الملخص العربي

دلائل التحمـــل والإختـــلافـــات البيوكيميـــائية لبعـض أصنـــاف الفول البلدي تحت اجهاد الجفاف

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أجريت التجربة الحقلية بمحطة البحوث الزراعية بالعريش بشمال سيناء - مصر خلال موسمي زراعة (2021/2020 و 2022/2021). تم تقييم ثلاثة أصناف من الفول البلدي (سخا 2 ، نوبارية 1 ومريوط 2) تحت مستويات الإجهاد المائي (الإجهاد الشديد (50%) ، الإجهاد المتوسط (75%) وبدون إجهاد مائي (100%) من البخر نتح لتقدير مدلولات تحمل الجفاف والصفات البيوكيميائية. أظهرت النتائج زيادة محصول البذور بزيادة مستوي المياه ، فكلما زاد مستوى الري زادت كمية المحصول، كان الانخفاض في المحصول/الفدان خطيًا مع زيادة إجهاد نقص المياه ، وتفوق صنف مريوط 2 على الأصناف الأخرى في عدد القرون/نبات ووزن 100بذره ومحصول البذور ، من ناحية أخرى ، اعطي الصنف سخا2 أقل قيم لهذه الصفات في نفس الظروف بينما سجلت أعلى قيم لصفة وزن 100 بذرة. كان تأثير التفاعل بين إجهاد نقص المياه والصنف معنوياً في محصول بذور الفول للفدان ، كما أدى إجهاد نقص المياه إلى انخفاض معنوي في محصول البذور للفدان في الأصناف الثلاثة ، وتم دراسة مؤشرات تحمل الإجهاد لتقييم أصناف الفول تحت ظروف الإجهاد المائي. وأشار دليل تحمل نقص المياه الماء (DTI) الي ان الصنف مريوط 2 يعتبر الصنف الأكثر تحملاً نسبيًا وفقًا لإجمالي محصول البذور/فدان (0.87 و 0.88) في كل من الموسم الاول والثاني، بينما سجل الصنف سخا 2 أقل قيم تحمل نسبي (0.75 و 0.75) خلال الموسم الاول والثاني علي الترتيب. بالنسبه لمؤشر نقص المحصول (%)، سجل الصنف مريوط 2 أعلى قيمه لنقص المحصول (21.51) في الموسم الأول بينما حصل نوباريه1 على أعلى قيمة لنقص المحصول في الموسم الثاني (21.10). وعلي الجانب الاخر ، كان صنف سخا 2 الأقل تضررا. أظهرت بيانات التفريد الكهربي للبروتين تحت إجهاد نقص الماء وجود اختلافات بين الأصناف استجابة لإجهاد نقص المياه وتم ظهور عدد قليل من الحزم الحديثة فقط في النباتات تحت ظروف الإجهاد المائي لكل صنف واختفت أعداد قليلة من الحزم مقارنة بالمعامله القياسيه.

الكلمات الاسترشادية : الفول البلدي ، دلائل التحمل ، تفريد البروتين.

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