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Combining Ability and Selecting Elite Faba Bean Genotypes under Drought Stress Conditions Using Tolerance Indices

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Abstract

Water deficit caused reduction productivity attributes for faba bean crop. So, seven faba bean genotypes were evaluated as parents with their F_1 crosses under normal and water dificit at the Experimental Farm, Faculty of Agriculture, Benha University, Egypt, during the 2021 /2022 and 2022/2023 winter growing seasons to study heterosis, combining ability and genotype behavior under different irrigation treatments. With the exception of the number of branches plant-1, very significant differential mean squares attributable to genotypes, parents, crosses, parent vs. crosses, GCA, and SCA were found for all attributes in both and across trials. Water deficit caused reductions in plant height, number of branches plant^{-1}, number of pods plant^{-1}, weight of pods plant^{-1}, number of seeds pod-1, 100-seed weight, and seed yield plant^{-1} by 6.05, 9.86, 15.24, 11.06, 1.03, 4.77 and10.59%, respectively. GCA/SCA ratio values which exceeding largely the unity were detected for number of branches plant^{-1}, number of pod-1 and seed yield plant^{-1}, in both and across irrigation treatment, revealing that additive and additive x additive gene effects account for the majority of overall genetic variability. The cross P_1xP_5 recorded the highest significant and positive heterosis relative to mid and better parent being 40.65% and 40.27% for seed yield plant^{-1}, respectively . P_5 (Sakha 4) and P_5 (Sakha 4)xP_6 (Wadi 1) exhibited the best general combiner and best specific effects for seed yield per plant, respectively. Based on stress indices TO L and SSI, the crosses P_3xP_6 and P_4xP_5 were the most tolerant genotypes based on (RSI) index. In this study P_1 and P_3, also the cross 3x6 had desirable values for M P ,G M P, H M , STI and Yi indices. The mention genotypes might be employed in faba bean breeding programmes under water stress.

Keywords: Field bean, Water stress, Genotypes, drought, stress indices , Combining ability.

Introduction

Field bean (*Vicia faba* L.) in Egypt is most important winter leguminous crop, used as a source of food protein and certain essential amino acids in human diets (Mansour *et al*., 2021a). Faba bean is not only nutritious, but it also plays a significant role in decreasing nitrogen (N) fertilizer inputs to agricultural production systems by symbiotic fixation of atmospheric N2 (Liu *et al*., 2019).

Annual production supplies less than half of Egypt's total consumption (FAO, 2021). To fulfil national need, either the area or yield per unit area should be raised. Thus, increasing yield of this crop is the ultimate goal of plant breeders (El-Abssi *et al*. 2019).

Drought tolerance in crops is a primary goal of most crop breeding programmes, particularly in new agricultural lands. Plant breeding research is critical for developing new faba bean cultivars with excellent drought resistance (Ullah *et al*., 2019). Plant breeders must boost production potential while also increasing drought tolerance. The first approach is to identify prospective germplasm with drought tolerance genotypic variations. Faba bean breeders' major objective is to produce genotypes that use less water and are more drought resistant in order to close the gap between national output and consumption. Basic information about the breeding material must be supplied for effective development of drought-tolerant faba bean genotypes.

Drought tolerance is a complicated trait with low inheritance; consequently, it is critical for plant breeders to employ physiological variables linked with seed yield to exploit them in enhancing seed yield in water-limited situations. Using physiological characteristics to evaluate different genotypes under abiotic stress were critical for understanding the relationship between physiological processes and drought resistance (Mansour *et al*., 2021b).

Crop improvement relied heavily on combining abilities. It has the potential to assess the amount and nature of genetic impacts that govern yield qualities, as well as to prepare promising parents for use in generating genetic variability for ultimate application in variety enhancement. In terms of general and specialized combining abilities, parallel analysis was an excellent tool for learning about different parents and parental combinations (GCA and SCA) (Griffing, 1956).

Furthermore, evaluating parental genotypes is critical for enveloping superior hybrids. The estimations of combining ability impacts provide significant penetration into the choice of parents that may result in superior hybrids following crossing. Furthermore, understanding the type and extent of gene effects is critical for producing high yielding faba bean cultivars (Beyene, 2016).

Drought is a significant environmental constraint limiting faba bean output. Global water screening for drought-tolerant genotypes identifies and selects plant varieties with enhanced drought tolerance, using various methods and steps: Tolerance index (TOL) (Rosielle and Hamblin,1981), mean productivity (MP) (Rosielle and Hamblin, 1981), geometric mean productivity (GMP) (Fernandez, 1992),harmonic mean (HM) (Bidinger and Mahalakshmi, 1987),stress susceptibility index (SSI)(Fischer and Maurer, 1978), stress tolerance index (STI) (Fernandez, 1992), yield index (YI) (Gavuzzi *et al*., 1997), yield stability index (YSI) (Bouslam and Schapaugh (1984) and relative stress index (RSI) (Bouslam and Schapaugh, 1984).

This study aimed to evaluate the performance of seven different faba bean genotypes through diallel crosses under both normal irrigation and drought stress conditions. Additionally, to estimate various stress tolerance indices to identify faba bean genotypes that are tolerant to water stress and have high yield potential.

Materials and Methods

The field trials were carried out in the Agricultural Research and Experimental Centre, Faculty of Agriculture, Moshtohor, Benha University, for two seasons of 2021-2022 and 2022-2023. Seven field bean genotypes representing a wide range of variability namely; Line138 a new variety developed by Dr A.A. El Hosary (P_1), Var.Giza 716 (P_2), Var. Sakha 2 (P_3), Var. Giza 843 (P_4), Var. Sakha 4 (P_5), Var. Wadi 1 (P_6), and Var. Nubaria5 (P_7) obtained from Agriculture Research Center, Egypt

The aforementioned genotypes were crossed in diallel scheme without reciprocals in the first winter growing season, 2021- 2022, producing a total of 21 F_1 crosses. In the second season, parents and F_1 hybrids were planted on October 15, 2022, in two adjacent trials. The first experiment was watered just with planting irrigation (E1), while the second was usually irrigated three times (E2). Each experiment was grown in a three-replication randomized complete block design (RCBD). Each F_1 and parents were represented by a single 6-meter-long ridge having 30 plants in each replication. Ridge-to-ridge and plant-to-plant spacing remained constant at 60 and 20 cm, respectively. In both trial, the dry way of planting was adopted, and the rest of the cultural practices were followed as indicated for regular field beans in the location. Observations were made on 10 randomly selected plants from each genotype plot. The following variables were recorded and scored for each plant: Plant height (cm), Number of branches plant-1, Number of pods plant-1, Weight of pods per plant (g), Number of seeds per pod-1, 100-seed weight (g), Seed yield per plant (g).

The meteorological data of the experimental site was collected from Mostohor meteorological station during evaluated season of 2022/2023 is presented in Table 1. Also, the Physical and chemical analysis of soil at the experimental site in 2022/2023 seasons are presented in Table 2.

Table 1. Climatic data of the cultivated site (Moshtohor – Qalubia) in 2022/2023 winter season.

Month	AT ^{o}C		RH %	Rainfall (mm)
	Max.	Min.		
October 2022	33.1	18.2	50.3	0.2
November 2022	30.2	15.5	52.6	0.3
December 2022	23.2	9.6	55.7	0.8
January 2023	22.8	8.4	56.8	1.3
February 2023	25.2	9.3	47.2	0.5
March 2023	30.5	12.2	38.3	0.2
April 2023	31.2	13.6	39.9	0.1
May 2023	36.7	19.1	33.1	---

AT: Actual Temperature RH: Relative Humidity

Table 2. Soil physical and chemical studies at the experimental location in 2022/2023 season.

Soil Properties	2022/2023
Mechanical analysis	
Sand	25.7
Silt	32.5
Clay	48.6
Water holding capacity %	30.23
Wilting moisture %	14.09
Chemical analysis	
PH(1:2.5,soil: water suspension	8.24
EC (soil past, ds m^{-1})	2.61
Na^{+}	11.23
K^{+}	0.86
Ca^{++}	8.65
Mg^{++}	5.89
CO_3^{--}	0.0
HCO_3^{-}	5.32
CL^{-}	8.70
SO_4^{--}	12.6
CaCo3%	115.3
OM(gkg^{-1})	52.6

Soil Electrical Conductivity (EC) and soluble ions were determined in sutured soil before extract

The analysis of variance for combining ability and assessment of genetic influences were done using Griffing's (1956) techniques for method 2 model 1. Heterosis in F_1 plants is reported as a percentage variation from the mean performance of the mid and better parent. Table 3 shows the Drought Tolerance Indices that were computed to identify drought-tolerant genotypes:

Table 3. Drought Tolerance Indices and how calculate

abbreviation	Drought tolerance indices	Calculation	According to
TOL	Tolerance index	Yp – Ys	**Rosielle and Hamblin**, 1981
MP	Mean productivity	(Ys + Yp)/2	**Rosielle and Hamblin**, 1980
GMP	Geometric mean productivity	$\sqrt{Ys \times Yp}$	Fernandez, 1992
HM	Harmonic mean	2(Ys×Yp)/Ys+Yp	**Bidinger and Mahalakshmi**, 1987
SSI	Stress susceptibility index	[(1-(Ys/Yp)] / 1-($\bar{Y}$s/$\bar{Y}$p)]	**Fischer and Maurer,** 1978
STI	Stress tolerance index	$(Y_s \times Y_p)/(\bar{Y}_p)^2$	**Fernandez,** 1992
YI	Yield index	Ys/$\bar{Y}$s	Gavuzzi *et al*., 1997
YSI	Yield stability index	Ys/Yp	**Bouslam and Schapaugh**, 1984
RSI	Relative stress index	$Y_s/Y_p/Y_{ms}/Y_{mp}$	**Bouslam and Schapaugh**,1984

However, because they are calculated at the yielding stage, these indices are time-consuming and sensitive to environmental factors. Mohamed *et al.* (2022). where Ys is the seed yield of genotypes under stress conditions, Yp is the seed yield of genotypes under normal conditions, s and p are the mean yields of all genotypes under stress and normal conditions, respectively, and s and p are the mean yields of All genotypes under stress and normal conditions, respectively.

Results and Discussion

Table 4 displays the results of the ordinary analysis of variance and diallel analysis performed on both and across irrigation trials using the Griffing (1956) method 2 method 1 for all analyzed characteristics. ANOVA demonstrated significant mean squares for all sources of variation (genotypes, parents, crosses, parent vs crosses (heterosis), and all types of combining ability in both and across trial, except, Number of branches $plant^{-1}$. The studied materials had sufficient amount of genetic variability adequate for further biometrical assessment. Significant differences among faba bean genotypes for yield and its components traits in different sets of material were reported by Darwish *et al*. (2005), Alghamdi (2009, Hazem, *et al*. (2013), Abdalla *et al*. (2015), Abdalla *et al*. (2017), Bishnoi *et al*. (2018) and El Hosary (2020).

Table 4. Ordinary analysis of variance (ANOVA) and combining ability analysis for all analyzed features in each and across irrigation treatments.

S.O.V.	Df	Plant height (cm)	number of branches plant^{-1}	Number of pods plant^{-1}	weight of pods plant^{-1} (g)	number of seeds pod^{-1}	100-seed weight (g)	seed yield plant^{-1} (g)
Drought environment								
Rep.	2	3.46	6.04	6.19	2.27	0.53	0.92	0.53
Genotypes	27	8.01	1.24	13.63**	89.53**	247.43**	54.02**	247.43 **
Parent	6	3.97	1.74	12.58**	49.76**	220.00**	55.41**	220.00**
Cross	20	9.04	1.15	13.94**	96.88**	268.01**	53.80**	268.01**
Par.vs.cr.	1	11.57*	0.01	13.60**	181.36**	0.42	49.97**	0.42
Error	54	2.71	1.7	3.01	1.93	1.92	0.75	1.92
GCA	6	2.32**	0.76	2.46**	22.40**	120.35**	11.12**	120.35**
SCA	21	2.77**	0.32	5.14**	31.97**	71.66**	19.97**	71.66**
Error	54	0.9	0.57	1.00	0.64	0.64	0.25	0.64
GCA/SCA		0.84	-	0.48	0.7	1.68	0.56	1.68
Normal irrigation								
Rep	2	8.73	5.24	1.02	0.26	2.59	0.4	2.59
Genotypes	27	10.95*	0.97	16.31**	101.47**	353.83**	62.41**	353.83**
Parent	6	5.63	0.67	23.54*	31.97**	330.68**	59.79**	330.68**
Cross	20	12.90**	1.1	14.89**	119.14**	378.44**	60.05**	378.44**
Par.vs.cr.	1	3.81	0.11	1.12	165.09**	0.53	125.25**	0.53
Error	54	2.42	1.48	2.34	1.9	1.71	0.71	1.71
GCA	6	6.17**	0.73	9.61**	16.05**	171.43**	16.91**	171.43**
SCA	21	2.93**	0.21	4.24**	38.90**	102.66**	21.91**	102.66**
Error	54	0.81	0.49	0.78	0.63	0.57	0.24	0.57
GCA/SCA		2.11	-	2.27	0.41	1.67	0.77	1.67
Combined analysis								
Env.	1	146.72**	25.46**	290.85**	1631.43**	1359.11**	823.18**	1359.11**
Rep/E	4	6.1	5.64	3.61	1.27	1.56	0.66	1.56
Genotypes	27	16.06*	1.77	24.57**	177.72**	584.27**	97.21**	584.27**
Parent	6	8.89	1.65	30.42**	73.81**	538.12**	105.78**	538.12**
Cross	20	18.97**	1.89	23.48**	200.46**	627.33**	91.16**	627.33**
Par.vs.cr.	1	1.05	0.03	11.27**	346.26**	0	166.73**	0
G x E	27	2.89	0.44	5.37*	13.29**	16.98**	19.21**	16.98**
par./ E	6	0.71	0.76	5.70*	7.92*	12.56**	9.42**	12.56**
Cr. xE	20	2.97	0.36	5.36*	15.56**	19.11**	22.69**	19.11**
Par.vs.cr.Vs.E	1	14.34*	0.09	3.46	0.19	0.95	8.50**	0.95
Error	108	2.56	1.59	2.67	1.92	1.81	0.73	1.81
GCA	6	7.57**	1.14	9.32**	31.88**	288.01**	24.33**	288.01**
SCA	21	4.72**	0.43	7.87**	67.05**	168.11**	34.71**	168.11**
GCA x E	6	0.93	0.35	2.75**	6.57**	3.76**	3.71**	3.76**
SCA x E	21	0.98	0.09	1.51	3.82**	6.20**	7.17**	6.20**
Error	108	0.85	0.53	0.89	0.64	0.6	0.24	0.6
GCA/SCA		1.6	-	1.19	0.48	1.71	0.7	1.71
GCA xE/GCA		-	-	-	0.21	0.01	0.15	0.01
SCA xE /SCA		-	-	-	0.06	0.04	0.21	0.04

* and ** refer to significant if p> 0.05 and p> 0.01, respectively.

The mean squares of both forms of combining ability (GCA and SCA) were very significant for all examined traits in both and across irrigation treatments. To establish an effective hybridization programme and choose the best method of selection, the relative relevance of additive and non-additive gene activity must be determined. The GCA/SCA ratio was calculated to discover the most important genetic impacts. In the drought environment, values exceeding largely the unity were detected for, number of pod^{-1} and seed yield plant^{-1}, and plant height number of branches plant^{-1}, number of pods plant^{-1}, number of pods plant^{-1} in normal irrigation, and the combined across irrigation treatment, indicating that the majority of the total genetic variability was due to additive and additive xadditive.

The importance of additive genetic action in controlling these traits was previously mentioned by Abdelmula (2006), EL-Harty (2006), Ibrahim (2010), , Farag and Afiah (2012), El-Banna *et al*., (2014), EL-Harty (2016), and Bishnoi *et al*., (2018). On the other hand, the non-additive genetic variance was previously reported to be the most prevalent for seed yield plant^{-1} by Obiadalla *et al*., (2013), El-Harty *et al*., (2016) and El-Abssi *et al* (2019) No. of branches plant^{-1} by Sattar *et al*., (2012); and Ashrei *et al* (2014) ; For 100-seed weight by Abd-Elrahman *et al*., (2012) and Farag and Afiah (2012).

The interaction between GCA and irrigation treatments significantly influenced the number of pods per plant, weight of pods per plant, number of seeds per plant, seed yield per plant, and weight of 100-seeds. This suggests that the effects of additive and additive x additive gene actions varied in different environments. In contrast, there was no significant interaction between GCA and water treatments for plant height and number of branches per plant, indicating that these traits were more stable in terms of their additive and additive x additive gene actions.

The interaction between SCA and environment was significant for plant height, number of pods plant^{-1}, weight of pods plant^{-1}, number of seeds plant^{-1}, seed yield per plant, and weight of 100-seed, showing that non additive kinds of gene activation differed across irrigation treatments.

The ratio between SCA/SCA x irrigation treatments was much higher than that of GCA/GCA x irrigation treatments for all traits, except plant height, number of branches plant^{-1}, number of pods plant^{-1} and weight of pods plant^{-1}, indicating, that non additive effects were much more influenced by environments than additive genetic one. Such results are in harmony with those obtained by **Omar *et al*., (2004).** For the exceptional cases, the ratio between GCA/GCA / irrigation treatments was much higher that of SCA/SCA x environments indicating that non additive type of gene action behaved the same under different environments.

Mean values for all traits under both and across environments are presented in Tables 5, 6 and 7. Regarding plant height (Table 5), P_1 (Super 200) in both and P_3 x P_7 in stress condition and P_1 x P_5 in non-stress and combined analysis expressed the tallest plants for plant height, While P_5 under water stress and combined analysis exhibited the lowest values for this trait, Wadi 1(P_6) gave the lowest value for this trait in non-stress conditions and P_2 x P_7 in both and across environments expressed the shortest values.

The highest value for number of branches/plants was detected for the parent Line 1 (P1) in both and across irrigation treatments, P1 x P4 under drought stress, P3 x P7 in normal irrigation treatment and combined analysis.

Regarding number of pod plant-1, parent Sakha 1 (P3), P1 x P5, P3 x P5, P4 x P5 and P4 x P6 expressed the highest value under both and across irrigation treatments (Table 5).

As shown in Table 6, Wadi-1 (P6) for weight of pods plant-1, Giza 843 (P4) for number of seeds pod-1, cross P1xP5 expressed the highest value under both and across irrigation treatments in the first trait, cross P1xP7 at drought stress, and combined analysis, P4xP5 under normal irrigation treatment gave the highest values. Parent Sakha-4 (P5) indicated the greatest value for the weight of 100 seeds when under stress and when data were merged. The greatest values for this feature are provided by the crosses P2xP6, P4xP7, and P2xP6, at E1, E2 and combined data, respectively.

For seed yield per plant, the parents Wadi 1 (P6) gave the highest value under normal condition and combined data, while parent Sakha 1 (P3) expressed the highest value for the trait under water stress (Table 7). The cross P3 x P5 gave the highest values under stress condition and combined analysis being 68.23 and 72.78 g, respectively. Moreover, the cross P5 x P6 expressed the highest means value for seed yield per plant under normal irrigation treatment.

It is clear that the studied crosses behaved differently for yield and most of its components in drought condition and normal irrigation treatment. Moreover, the average seed yield was 47.88 g in drought treatment as compared with normal irrigation treatment which was 53.66g as an average of all crosses. Such result reflects the effect of drought on the performance of faba bean seed yield over all studied crosses.

For seed yield per plant heterosis, nine, nine and nine crosses exhibited significant and positive mid parent heterosis under drought stress and normal irrigation as well as combined analysis, respectively (Table 7). The study found that under drought stress, normal irrigation, and combined analyses, nine crosses showed significant positive mid-parent heterosis for seed yield per plant. However, the cross P1xP5 had the most desirable heterotic effects, with values of 36.81** and 40.65** under drought. Significant and positive heterosis effects relative to mid parent and better parent for seed yield per plant were reported by EL-Harty (2006), Ibrahim (2010), El-Banna *et al*., (2014), Abdalla *et al.,* (2017), and EL-Hosary (2020).

Table 5. Plant height, number of branches plant^{-1}, and number of pods plant^{-1} mean performance of genotypes under drought stress (D) and normal watering (N), as well as the combined across irrigation treatments.

Traits	Plant height (cm)			Number of branches plant^{-1}			Number of pods plant^{-1}		
Genotypes	**D**	**N**	**C**	**D**	**N**	**C**	**D**	**N**	**C**
Super 200 (P_1)	115.00	122.33	118.67	8.40	8.67	8.53	14.13	15.53	14.83
Giza 716 (P_2)	114.00	121.33	117.67	7.47	7.60	7.53	14.2	18.53	16.37
Sakha 1 (P_3)	105.00	120.00	112.50	6.13	8.40	7.27	18.13	20.53	19.33
Giza 843 (P_4)	104.33	112.00	108.17	6.33	7.47	6.90	12.47	17.13	14.80
Sakha 4 (P_5)	100.33	109.53	104.93	7.27	7.87	7.57	12.07	14.13	13.10
Wadi 1 (P_6)	103.67	109.00	106.33	6.87	7.53	7.20	13.90	20.07	16.98
Nubaria5 (P_7)	110.00	114.00	112.00	7.33	8.27	7.80	12.60	13.47	13.03
P_1xP_2	103.67	115.00	109.33	7.60	8.00	7.80	13.78	16.20	14.99
P_1xP_3	108.67	116.00	112.33	6.73	8.40	7.57	14.57	17.47	16.02
P_1xP_4	118.00	122.67	120.33	8.13	8.60	8.37	16.00	16.13	16.07
P_1xP_5	125.00	138.67	131.83	7.80	8.13	7.97	18.20	18.67	18.43
P_1xP_6	117.33	125.67	121.50	7.03	7.87	7.45	10.60	15.27	12.93
P_1xP_7	107.67	119.00	113.33	7.87	8.45	8.16	13.33	13.33	13.33
P_2xP_3	115.33	122.00	118.67	6.00	7.93	6.97	11.27	13.47	12.37
P_2xP_4	106.67	121.33	114.00	7.00	7.53	7.27	14.93	15.60	15.27
P_2xP_5	99.33	104.67	102.00	6.20	6.67	6.43	14.13	16.10	15.12
P_2xP_6	115.33	116.33	115.83	7.67	7.80	7.73	17.20	17.33	17.27
P_2xP_7	91.00	97.67	94.33	6.55	6.70	6.63	12.97	15.07	14.02
P_3xP_4	117.33	121.33	119.33	7.33	8.33	7.83	13.87	18.4	16.13
P_3xP_5	97.33	98.00	97.67	7.15	8.00	7.58	16.80	20.33	18.57
P_3xP_6	108.00	114.00	111.00	6.52	6.85	6.68	16.53	18.77	17.65
P_3xP_7	125.33	128.67	127.00	7.87	8.93	8.40	14.93	16.07	15.5
P_4xP_5	111.00	118.33	114.67	7.47	8.33	7.90	17.77	21.00	19.38
P_4xP_6	110.00	121.00	115.50	7.07	7.67	7.37	17.07	21.00	19.03
P_4xP_7	111.67	112.33	112.00	6.87	8.30	7.58	17.73	17.77	17.75
P_5xP_6	114.67	121.67	118.17	6.07	7.33	6.7	12.6	17.73	15.17
P_5xP_7	121.33	124.00	122.67	7.40	7.82	7.61	14.07	17.83	15.95
P_6xP_7	119.67	129.67	124.67	7.53	8.00	7.77	13.67	20.27	16.97
Mean of parents	107.48	115.46	111.47	7.11	7.97	7.54	13.93	17.06	15.49
Mean of crosses	111.63	118.48	115.06	7.14	7.89	7.51	14.86	17.32	16.09
Mean of Genotypes	110.60	117.72	114.16	7.13	7.91	7.52	14.63	17.26	15.94
LSD 5%	4.77	5.05	3.44	2.13	1.99	1.44	2.83	2.50	1.87
LSD 1%	6.34	6.71	4.56	2.83	2.65	1.91	3.77	3.32	2.48

Table 6. The genotypes' mean performance for weight of pods plant^{-1}, number of seeds pod^{-1}, and 100-seed weight under drought stress (D) and normal irrigation (N), as well as the combined analysis.

Traits	Weight of pods plant^{-1} (g)			Number of seeds pod^{-1}			100-seed weight (g)		
Genotypes	D	N	C	D	N	C	D	N	C
Super 200 (P_1)	44.23	52.34	48.28	2.70	2.77	2.73	88.03	96.41	92.22
Giza 716 (P_2)	49.43	56.66	53.05	2.97	2.73	2.85	87.73	91	89.37
Sakha 1 (P_3)	44.06	50.05	47.06	2.67	3.03	2.85	81.74	83.93	82.84
Giza 843 (P_4)	47.92	55.61	51.77	3.03	3.17	3.10	81.93	86.36	84.15
Sakha 4 (P_5)	44.09	53	48.55	3.07	2.87	2.97	94.28	95.37	94.82
Wadi 1 (P_6)	55.33	58.88	57.11	2.30	2.70	2.50	85.97	90.7	88.34
Nubaria5 (P_7)	47.69	50.65	49.17	2.73	3.10	2.92	88.41	89.88	89.15
P_1xP_2	44.97	53.93	49.45	2.70	3.27	2.98	89.13	92.75	90.94
P_1xP_3	52.44	59.9	56.17	3.40	2.63	3.02	94.13	97.07	95.6
P_1xP_4	56.42	62.95	59.69	3.37	2.93	3.15	83.99	91.91	87.95
P_1xP_5	62.07	69.99	66.03	3.03	2.70	2.87	87.37	96.31	91.84
P_1xP_6	46.30	52.4	49.35	2.87	2.73	2.80	91.1	91.48	91.29
P_1xP_7	46.26	51.28	48.77	3.50	3.03	3.27	93.97	96	94.98
P_2xP_3	46.54	51.49	49.02	2.83	2.97	2.90	93.79	97.49	95.64
P_2xP_4	49.51	57.18	53.35	2.47	3.07	2.77	87.23	88.47	87.85
P_2xP_5	46.38	54.3	50.34	2.67	3.10	2.88	84.28	94.63	89.46
P_2xP_6	49.30	50.33	49.82	2.67	2.90	2.78	96.77	97.2	96.98
P_2xP_7	41.98	50.7	46.34	2.87	2.80	2.83	85.13	85.35	85.24
P_3xP_4	43.21	49.53	46.37	2.50	2.60	2.55	86.47	94.03	90.25
P_3xP_5	50.40	58.18	54.29	2.63	2.60	2.62	82.2	83.9	83.05
P_3xP_6	51.82	56.41	54.12	2.73	2.80	2.77	83.85	89.87	86.86
P_3xP_7	54.60	65.2	59.9	2.80	3.03	2.92	86.43	91.36	88.9
P_4xP_5	58.55	62.18	60.37	3.00	3.27	3.13	93.93	95.44	94.69
P_4xP_6	52.39	53.55	52.97	2.57	2.63	2.60	90.58	98.32	94.45
P_4xP_7	58.42	58.42	58.42	3.40	2.6	3.00	87.85	99.47	93.66
P_5xP_6	45.76	49.19	47.48	3.33	3.03	3.18	85.68	97.88	91.78
P_5xP_7	53.31	66.65	59.98	2.82	3.03	2.93	92.74	94.82	93.78
P_6xP_7	58.88	65.79	62.34	2.83	3	2.92	85.07	86.4	85.74
Mean of parents	47.54	53.88	50.71	2.78	2.91	2.85	86.87	90.52	88.70
Mean of crosses	50.93	57.12	54.03	2.90	2.89	2.90	88.65	93.34	91
Mean of Genotypes	50.08	56.31	53.2	2.87	2.90	2.88	88.21	92.63	90.42
LSD 5%	3.02	2.25	1.58	0.63	0.54	0.41	1.41	1.38	0.98
LSD 1%	2.10	3	2.10	0.84	0.72	0.55	1.88	1.84	1.30

Table 7. Mean genotype performance for seed yield plant^{-1} and heterosis compared to mid- and better parent under drought stress (D) and normal irrigation (N), as well as the combined analysis.

Genotype	Seed yield plant^{-1} (g)								
	Mean performance			Heterosis % relative to					
				Mid Parent (M.P)			Better Parent (B.P)		
	D	N	C	D	N	C	D	N	C
Super 200 (P_1)	42.87	43.33	43.10						
Giza 716 (P_2)	54.00	62.73	58.37						
Sakha 1 (P_3)	58.30	63.67	60.98						
Giza 843 (P_4)	36.67	41.67	39.17						
Sakha 4 (P_5)	40.67	46.00	43.33						
Wadi 1 (P_6)	57.33	66.33	61.83						
Nubaria5 (P_7)	46.50	50.60	48.55						
P_1xP_2	46.33	54.53	50.43	-4.34	2.83	-0.59	-14.20**	-13.07**	-13.59**
P_1xP_3	45.20	50.97	48.08	-10.64**	-4.74*	-7.61**	-22.47**	-19.95**	-21.15**
P_1xP_4	44.07	48.33	46.20	10.81**	13.73**	12.32**	2.8	11.54**	7.19**
P_1xP_5	58.63	62.93	60.78	40.38**	40.90**	40.65**	36.78**	36.81**	40.27**
P_1xP_6	37.97	43.00	40.48	-24.22**	-21.58**	-22.84**	-33.78**	-35.18**	-34.53**
P_1xP_7	51.53	58.07	54.80	15.33**	23.63**	19.59**	10.82**	14.76**	12.87**
P_2xP_3	38.80	41.60	40.20	-30.90**	-34.18**	-32.64**	-33.45**	-34.66**	-34.08**
P_2xP_4	35.90	43.53	39.72	-20.81**	-16.60**	-18.56**	-33.52**	-30.61**	-31.95**
P_2xP_5	63.57	68.80	66.18	34.30**	26.55**	30.15**	17.72**	9.67**	13.39**
P_2xP_6	44.93	51.67	48.30	-19.28**	-19.94**	-19.63**	-21.63**	-22.11**	-21.89**
P_2xP_7	47.27	50.67	48.97	-5.94*	-10.59**	-8.40**	-12.47**	-19.23**	-16.11**
P_3xP_4	43.73	51.33	47.53	-7.90**	-2.53	-5.08**	-24.99**	-19.37**	-22.06**
P_3xP_5	68.23	77.33	72.78	37.89**	41.03**	39.54**	17.04**	21.46**	19.35**
P_3xP_6	60.27	62.00	61.13	4.24*	-4.62**	-0.45	3.37	-6.53**	-1.13
P_3xP_7	40.10	46.00	43.05	-23.47**	-19.49**	-21.39**	-31.22**	-27.75**	-29.41**
P_4xP_5	47.10	48.20	47.65	21.81**	9.96**	15.52**	15.82**	4.78*	9.96**
P_4xP_6	40.60	43.00	41.80	-13.62**	-20.37**	-17.23**	-29.19**	-35.18**	-32.40**
P_4xP_7	46.03	51.73	48.88	10.70**	12.14**	11.46**	-1	2.24	0.69
P_5xP_6	63.20	80.87	72.03	28.98**	43.98**	36.99**	10.23**	21.91**	16.50**
P_5xP_7	44.50	52.58	48.54	2.1	8.87**	5.66**	-4.3	3.92	-0.02
P_6xP_7	37.60	39.70	38.65	-27.58**	-32.10**	-29.97**	-34.42**	-40.15**	-37.49**
Mean of parents	48.05	53.48	50.76	-	-	-	-	-	-
Mean of crosses	47.88	53.66	50.77	-	-	-	-	-	-
Mean of Genotypes	47.93	53.61	50.77	-	-	-	-	-	-
LSD 5%	2.26	2.14	1.54	-	-	-	-	-	-
LSD 1%	3.01	2.84	2.04	-	-	-	-	-	-

* and ** refer to significant if p> 0.05 and p> 0.01, respectively.

Estimations of GCA (ĝi) and SCA **(**ŝij**)** effects for individual parental genotypes and crosses for each trait in drought stress and normal irrigation as well as their combined analysis are presented in Tables 8 and 9.

Parent variety P1 showed the highest significant effects for GCA for plant height, weight of 100-seed, number of branches/plant, and number of seeds/pods under drought stress conditions and combined data. This parent was also the best general combiner for plant height and weight of 100-seed. P2 displayed significant and positive (ĝi) effects for seed yield/plant and weight of 100-seed under drought stress and normal irrigation conditions. P3 had the highest significant effects on GCA for the number of pods/plant under drought-stress conditions. It also ranked as the second-best general combiner for seed yield/plant, showing significant and positive effects for this trait in all environments. P4 exhibited significant and positive effects for the number of seeds/pods, as well as weight of pods/plant under drought and normal irrigation conditions. It also ranked as the second-best general combiner for the weight of pods/plant under drought stress. p5 was the top combiner for seed yield/plant, with significant and positive ĝi effects of 4.8**, 5.98**, and 5.39** in the drought treatment, normal irrigation, and combined analysis, respectively. Additionally, p5 showed the highest significant and positive ĝi effects for weight of pods/plant under normal irrigation and combined data. It also ranked as the second-best for general combining effects for the weight of 100-seed in all environments. These findings highlight P5 as the best general combiner for seed yield/plant. P6 exhibited the highest significant and positive ĝi effects for number of pods/plant under normal irrigation and weight of pods/plant under drought conditions (1.61^{**}). It also showed significant and positive ĝi effects for seed yield/plant under all environments in the study. P7 expressed significant and positive (ĝi) effects for plant height under drought stress and weight of pods/plant under drought stress, normal irrigation, and combined analysis.

In conclusion, the parent P_1 was the best general combiners for plant height and weight of 100-seed in drought treatment, normal irrigation and combined analysis. However, the parent variety P5 was the best general combiner for seed yield per plant.

Specific combining ability effects (ŝij):

Specific combining effects for, plant height, number of branches plant^{-1}, number of pods plant^{-1}, weight of pods plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1} and weight of 100-seed in drought treatment, normal irrigation and combined data are presented in Table 8 and 9.

For plant height, ten, seven and twelve cross combinations expressed significant and positive ŝij effects in drought condition, normal irrigation and combined analysis, respectively. Moreover, the cross P_1 x P_5 gave the most desirable ŝij effects for plant height in normal irrigation (18.44^{**}) and combined data (15.86^{**}). However, the cross combination P_3 x P_7 gave significant and positive ŝij effects for plant height in drought stress (13.72^{**}).

For number of pods/ plant, five, five and seven crosses expressed significant and positive ŝij effects in drought stress, normal irrigation and combined analysis, respectively. However, the best ŝij effects were detected for the cross P_1 x P_5 in drought treatment (3.75^{**}) and combined analysis (3.03^{**}), and P_4 x P_5 (2.86^{**}) in normal irrigation.

Regarding weight of pods/ plant, nine, nine and eleven cross combinations expressed significant and positive ŝij effects in drought stress, normal irrigation and combined data, respectively. The cross P_1 x P_5 gave the most desirable ŝij effects for weight of pods/ plant in drought treatment, normal irrigation and combined analysis being 11.96^{**}, 11.39^{**} and 11.67^{**}, respectively.

Four, one and two crosses expressed significant and positive ŝij effects for number of seeds/ pod in stress, non-stress condition and combined data, respectively. However, the cross P_5 x P_6 gave the best ŝij effects in stress condition and combined analysis being 0.54^{**} and 0.36^{**}, respectively. Also, the cross P_1 x P_2 (0.36*) was the only cross which expressed the significant and negative ŝij effects for this trait in the normal irrigation treatment (Table 9).

Significant and positive ŝij effects for seed yield per plant were detected in nine, nine and nine crosses in drought stress, normal irrigation and combined analysis, respectively. However, the cross combination P_5 x P_6 recorded the best ŝij effects in normal irrigation and combined analysis, Also the best ŝij effects were detected for the cross P_3 x P_5 in drought treatment (12.23^{**})

For weight of 100-seed, nine, twelve and ten crosses exhibited significant and positive ŝij effects in stress and non-stress environment as well as combined analysis, respectively. However, the best ŝij effects were detected for the cross P_2 x P_6 (7.95^{**}), P_4 x P_7 (7.79^{**}) and P_2 x P_3 (6.99^{**}) in drought stress, normal irrigation and combined analysis, respectively (Table 9).

From such results it could be concluded that the best crosses for specific combining ability were P_1 x P_5 for plant height, number of pods plant^{-1} and weight of pods plant^{-1}, P_5 x P_6 for number of seeds pod^{-1} and seed yield plant^{-1}. Therefore, these combinations would be of prime importance in faba bean breeding program to drought tolerant varieties using traditional breeding procedures.

Mean seed yield / plant under normal (Yp) and drought stress (Ys) and different drought tolerance indices for 28 faba bean genotypes:

Several drought tolerance indices were investigated for screening of faba bean genotypes under both normal and drought conditions. Seed yield of genotypes under both conditions were measured for calculating different sensitivity and tolerance indices (Table 10). Genotypes with high values of mean productivity (MD), geometric mean productivity (GMP) harmonic mean productivity (HM) and stress tolerance index (STI) can be selected as tolerant genotypes to water stress.

Data showed that STI index ranged from 0.52 to 1.84 the higher values of up to 1 indicate high stress tolerance. Data in Table 10 revealed that the highest values of these indices were found with theP_2, P_3, P_6, crosses P_1x P_5, P_1xP_7, P_2xP_5, P_3xP_5, P_3xP_6 and P_5xP_7, which had the highest yield under both conditions, they might be the best promising tolerant, While, genotypes, such as parental P_4, and the crosses P_1xP_6, P_2xP_3 an P_2xP_4 were identified as susceptible genotypes, because of their low values for Mp , GMP , HM and STI indices .

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Table 8. Estimate of general and specific combining ability under both and across environments

Traits	Plant height (cm)			Number of pods plant^{-1}			weight of pods plant^{-1} (g)		
Genotype	**D**	**N**	**C**	**D**	**N**	**C**	**D**	**N**	**C**
GCA effect									
g1 super200	2.84**	4.43**	3.64**	-0.25	-1.10**	-0.68**	-0.41	0.52*	0.05
g2 G716	-2.83**	-2.46**	-2.64**	-0.48	-0.80**	-0.64**	-2.57**	-2.14**	-2.35**
g3 Sakha1	-0.31	-0.2	-0.25	0.80*	0.83**	0.82**	-1.50**	-1.08**	-1.29**
g4 G843	-0.16	-0.09	-0.12	0.59	0.68*	0.63**	1.52**	0.50*	1.01**
g5 Sakha4	-1.71**	-1.93**	-1.82**	0.08	0.21	0.14	0.44	1.78**	1.11**
g6 Wadi1	0.84	0.51	0.67**	-0.17	1.38**	0.61**	1.61**	-0.56*	0.52**
g7 Nubaria5	1.32*	-0.27	0.53*	-0.57	-1.20**	-0.88**	0.91**	0.98**	0.95**
L.S.D gi 0.05	1.04	1.1	0.45	0.62	0.54	0.25	0.5	0.49	0.21
L.S.D gi 0.01	1.38	1.46	0.62	0.82	0.72	0.34	0.66	0.65	0.28
L.S.D gi-gj 0.05	1.59	1.68	0.8	0.94	0.83	0.44	0.76	0.75	0.37
L.S.D gi-gj 0.01	2.11	2.24	1.09	1.26	1.11	0.59	1.01	1	0.5
SCA effects									
P_1xP_2	-6.94**	-4.70**	-5.82**	-0.11	0.85	0.37	-2.13**	-0.76	-1.45
P_1xP_3	-4.46**	-5.96**	-5.21**	-0.61	0.48	-0.07	4.28**	4.15**	4.21**
P_1xP_4	4.72**	0.6	2.66*	1.04	-0.7	0.17	5.24**	5.62**	5.43**
P_1xP_5	13.28**	18.44**	15.86**	3.75**	2.30**	3.03**	11.96**	11.39**	11.67**
P_1xP_6	3.06*	3.01	3.03**	-3.60**	-2.27**	-2.94**	-4.98**	-3.86**	-4.42**
P_1xP_7	-7.09**	-2.88	-4.99**	-0.47	-1.62*	-1.05	-4.31**	-6.53**	-5.42**
P_2xP_3	7.87**	6.93**	7.40**	-3.68**	-3.82**	-3.75**	0.53	-1.61*	-0.54
P_2xP_4	-0.94	6.15**	2.60*	0.2	-1.53	-0.67	0.47	2.51**	1.49**
P_2xP_5	-6.72**	-8.67**	-7.70**	-0.09	-0.56	-0.33	-1.58*	-1.65*	-1.61**
P_2xP_6	6.72**	0.56	3.64**	3.23**	-0.5	1.36*	0.18	-3.28**	-1.55**
P_2xP_7	-18.09**	-17.33**	-17.71**	-0.61	-0.19	-0.4	-6.44**	-4.46**	-5.45**
P_3xP_4	7.20**	3.89*	5.55**	-2.15*	-0.37	-1.26*	-6.89**	-6.21**	-6.55**
P_3xP_5	-11.24**	-17.59**	-14.42**	1.29	2.03*	1.66**	1.37	1.17	1.27*
P_3xP_6	-3.13*	-4.03*	-3.58**	1.28	-0.71	0.28	1.63*	1.73*	1.68**
P_3xP_7	13.72**	11.41**	12.57**	0.07	-0.83	-0.38	5.11**	8.98**	7.05**
P_4xP_5	2.28	2.63	2.45*	2.48**	2.86**	2.67**	6.50**	3.58**	5.04**
P_4xP_6	-1.28	2.86	0.79	2.02*	1.68*	1.85**	-0.82	-2.70**	-1.76**
P_4xP_7	-0.09	-5.03**	-2.56*	3.09**	1.03	2.06**	5.91**	0.62	3.26**
P_5xP_6	4.94**	5.37**	5.16**	-1.93*	-1.11	-1.52*	-6.37**	-8.34**	-7.35**
P_5xP_7	11.13**	8.48**	9.80**	-0.07	1.57	0.75	1.88*	7.57**	4.72**
P_6xP_7	6.91**	11.71**	9.31**	-0.22	2.83**	1.30*	6.28**	9.06**	7.67**
LSD5%(sij)	3.03	3.2	2.16	1.8	1.58	1.17	1.44	1.43	0.99
LSD1%(sij)	4.03	4.26	2.93	2.39	2.11	1.59	1.91	1.9	1.35
LSD5%(sij-sik)	4.5	4.76	3.21	2.67	2.35	1.74	2.14	2.12	1.48
LSD1%(sij-sik)	5.98	6.33	4.35	3.55	3.13	2.37	2.84	2.83	2
LSD5%(sij-skl)	4.21	4.45	1.13	2.5	2.2	0.62	2	1.99	0.52
LSD1%(sij-skl)	5.6	5.92	1.54	3.32	2.93	0.84	2.66	2.64	0.71

* and ** refer to significant if p> 0.05 and p> 0.01, respectively.

Table 9. Estimate of general and specific combining ability under both and across environments

Traits	number of seeds pod^{-1}			100-seed weight (g)			seed yield plant^{-1} (g)		
Genotypes	**D**	**N**	**C**	**D**	**N**	**C**	**D**	**N**	**C**
GCA effects									
g1	0.14*	-0.04	0.05	1.12**	1.92**	1.52**	-1.55**	-2.71**	-2.13**
g2	-0.09	0.04	-0.03	0.68**	-0.36*	0.16*	0.16	0.82**	0.49**
g3	-0.08	-0.05	-0.07*	-1.70**	-2.17**	-1.93**	3.28**	3.07**	3.18**
g4	0.04	0.03	0.04	-1.30**	-0.08	-0.69**	-5.85**	-6.60**	-6.23**
g5	0.07	0.03	0.05	1.01**	1.40**	1.21**	4.80**	5.98**	5.39**
g6	-0.15*	-0.07	-0.11**	-0.07	0.16	0.04	1.76**	2.67**	2.21**
g7	0.08	0.06	0.07*	0.26	-0.88**	-0.31**	-2.60**	-3.22**	-2.91**
L.S.D gi 0.05	0.14	0.12	0.05	0.31	0.3	0.13	0.49	0.47	0.2
L.S.D gi 0.0	0.18	0.16	0.07	0.41	0.4	0.18	0.66	0.62	0.28
L.S.D gi-gj 0.05	0.21	0.18	0.1	0.47	0.46	0.23	0.75	0.71	0.36
L.S.D gi-gj 0.01	0.28	0.24	0.13	0.63	0.61	0.31	1.00	0.95	0.49
SCA effects									
P1xP2	-0.22	0.36*	0.07	-0.88	-1.45**	-1.16**	-0.2	2.81**	1.31*
P1xP3	0.47*	-0.17	0.15	6.50**	4.68**	5.59**	-4.46**	-3.01**	-3.73**
P1xP4	0.31	0.05	0.18	-4.04**	-2.56**	-3.30**	3.54**	4.04**	3.79**
P1xP5	-0.05	-0.19	-0.12	-2.97**	0.36	-1.31**	7.46**	6.05**	6.76**
P1xP6	0.01	-0.05	-0.02	1.84**	-3.24**	-0.70*	-10.17**	-10.57**	-10.37**
P1xP7	0.41*	0.12	0.26*	4.37**	2.33**	3.35**	7.75**	10.38**	9.07**
P2xP3	0.14	0.08	0.11	6.60**	7.37**	6.99**	-12.56**	-15.90**	-14.23**
P2xP4	-0.35	0.1	-0.13	-0.35	-3.73**	-2.04**	-6.33**	-4.29**	-5.31**
P2xP5	-0.18	0.13	-0.03	-5.62**	0.95*	-2.34**	10.69**	8.39**	9.54**
P2xP6	0.04	0.03	0.04	7.95**	4.75**	6.35**	-4.91**	-5.43**	-5.17**
P2xP7	0.01	-0.2	-0.09	-4.02**	-6.05**	-5.04**	1.78*	-0.55	0.62
P3xP4	-0.33	-0.27	-0.30*	1.26**	3.65**	2.46**	-1.63*	1.25	-0.19
P3xP5	-0.23	-0.28	-0.25	-5.32**	-7.98**	-6.65**	12.23**	14.67**	13.45**
P3xP6	0.1	0.03	0.06	-2.59**	-0.76	-1.67**	7.30**	2.65**	4.97**
P3xP7	-0.07	0.13	0.03	-0.34	1.77**	0.72*	-8.51**	-7.47**	-7.99**
P4xP5	0.01	0.31	0.16	6.02**	1.48**	3.75**	0.23	-4.79**	-2.28**
P4xP6	-0.19	-0.22	-0.21	3.75**	5.60**	4.67**	-3.24**	-6.67**	-4.96**
P4xP7	0.41*	-0.38*	0.01	0.69	7.79**	4.24**	6.55**	7.94**	7.25**
P5xP6	0.54**	0.18	0.36**	-3.46**	3.68**	0.11	8.72**	18.61**	13.66**
P5xP7	-0.2	0.05	-0.08	3.26**	1.66**	2.46**	-5.63**	-3.79**	-4.71**
P6xP7	0.04	0.12	0.08	-3.32**	-5.52**	-4.42**	-9.49**	-13.36**	-11.42**
LSD5%(sij)	0.4	0.34	0.26	0.89	0.88	0.61	1.43	1.36	0.97
LSD1%(sij)	0.53	0.46	0.35	1.19	1.17	0.83	1.91	1.8	1.31
LSD5%(sij-sik)	0.6	0.51	0.38	1.33	1.3	0.91	2.13	2.02	1.44
LSD1%(sij-sik)	0.79	0.68	0.52	1.77	1.73	1.24	2.83	2.68	1.95
LSD5%(sij-skl)	0.56	0.48	0.14	1.24	1.22	0.32	1.99	1.88	0.51
LSD1%(sij-skl)	0.74	0.63	0.18	1.65	1.62	0.44	2.65	2.51	0.69

* and ** refer to significant if p> 0.05 and p> 0.01, respectively.

Table 10. Estimation of sensitivity rate of 28 faba bean genotypes by different drought tolerance indices under normal and stressed conditions

Genotype	Yp	Ys	Drought tolerance indices								
			SSI	**TOL**	**MP**	**GMP**	**STI**	**YI**	**YSI**	**HARM**	**RDI**
P1	43.33	42.87	0.1	0.47	43.1	43.1	0.65	0.89	0.99	43.1	1.11
P2	62.73	54	1.31	8.73	58.37	58.2	1.18	1.13	0.86	58.04	0.96
P3	63.67	58.3	0.79	5.37	60.98	60.92	1.29	1.22	0.92	60.87	1.02
P4	41.67	36.67	1.13	5	39.17	39.09	0.53	0.77	0.88	39.01	0.98
P5	46	40.67	1.09	5.33	43.33	43.25	0.65	0.85	0.88	43.17	0.99
P6	66.33	57.33	1.28	9	61.83	61.67	1.32	1.2	0.86	61.51	0.97
P7	50.6	46.5	0.76	4.1	48.55	48.51	0.82	0.97	0.92	48.46	1.03
1x2	54.53	46.33	1.42	8.2	50.43	50.27	0.88	0.97	0.85	50.1	0.95
1x3	50.97	45.2	1.07	5.77	48.08	48	0.8	0.94	0.89	47.91	0.99
1x4	48.33	44.07	0.83	4.27	46.2	46.15	0.74	0.92	0.91	46.1	1.02
1x5	62.93	58.63	0.64	4.3	60.78	60.75	1.28	1.22	0.93	60.71	1.04
1x6	43	37.97	1.1	5.03	40.48	40.41	0.57	0.79	0.88	40.33	0.99
1x7	58.07	51.53	1.06	6.53	54.8	54.7	1.04	1.08	0.89	54.61	0.99
2x3	41.6	38.8	0.63	2.8	40.2	40.18	0.56	0.81	0.93	40.15	1.04
2x4	43.53	35.9	1.65	7.63	39.72	39.53	0.54	0.75	0.82	39.35	0.92
2x5	68.8	63.57	0.72	5.23	66.18	66.13	1.52	1.33	0.92	66.08	1.03
2x6	51.67	44.93	1.23	6.73	48.3	48.18	0.81	0.94	0.87	48.07	0.97
2x7	50.67	47.27	0.63	3.4	48.97	48.94	0.83	0.99	0.93	48.91	1.04
3x4	51.33	43.73	1.4	7.6	47.53	47.38	0.78	0.91	0.85	47.23	0.95
3x5	77.33	68.23	1.11	9.1	72.78	72.64	1.84	1.42	0.88	72.5	0.99
3x6	62	60.27	0.26	1.73	61.13	61.13	1.3	1.26	0.97	61.12	1.09
3x7	46	40.1	1.21	5.9	43.05	42.95	0.64	0.84	0.87	42.85	0.98
4x5	48.2	47.1	0.22	1.1	47.65	47.65	0.79	0.98	0.98	47.64	1.09
4x6	43	40.6	0.53	2.4	41.8	41.78	0.61	0.85	0.94	41.77	1.06
4x7	51.73	46.03	1.04	5.7	48.88	48.8	0.83	0.96	0.89	48.72	1
5x6	80.87	63.2	2.06	17.67	72.03	71.49	1.78	1.32	0.78	70.95	0.87
5x7	52.58	44.5	1.45	8.08	48.54	48.37	0.81	0.93	0.85	48.21	0.95
6x7	39.7	37.6	0.5	2.1	38.65	38.64	0.52	0.78	0.95	38.62	1.06
mean	53.61	47.93	**0.97**	**5.69**	**50.77**	**50.67**	**0.93**	**1**	**0.9**	**50.57**	**1**

Where : Yp & Ys; Seed yield under normal and stress irrigation, TOL, Tolerance index; MP, mean productivity; GMP, geometric mean productivity;; HM, harmonic mean; SSI, stress susceptibility index STI, stress tolerance index; YI, yield index; YSI, yield stability index; RSI, Relative Stress Index

Genotypes having a low tolerance index (TOL) would be more drought resistant. Furthermore, the stress sensitivity index (SSI) estimates the rate of change in yield between normal and drought conditions for each genotype compared to the mean change for all genotypes. (SSI) values less than one indicate low drought susceptibility (high yield stability), whereas values greater than one indicate high drought sensitivity (low yield stability). Data in Table 10 showed that the lowest values of these indices (TOL and SSI) were P_1 and the crosses P_3xP_6, P_4xP_5 reached 0.47 and 0.10, 1.73 and 0.26, and 1.10 and 0.22 for TOL and SSI, respectively and could identify as the promising tolerant genotypes.

Yield index (YI), the genotypes with high values of (YI) will be suitable for drought stress condition (tolerant genotypes). So the parental genotypes P_2, P_3, P_6, also the crosses P_1xP_5, P_2xP_5, P_3xP_6, P_3xP_5 and P_5xP_6 were identified as drought tolerant genotypes, and can be selected as tolerant genotypes to water dificit. With respect to yield stability index (YSI), the genotypes with high (YSI) values can be selected regarded as stable genotypes under normal and drought conditions. Data in table 10 revealed that P1 and the crosses P_3xP_6 and P_4xP_5 and P_6xP_7 with high values of this index (YSI) can be selected as tolerant genotypes to water stress. Regarding relative stress index (RDI), the crosses P_3xP_6 and P_4xP_5 were the most tolerant genotypes based on (RDI) index. In this study P_1 and P_3, also the cross P_3xP_6 had desirable values for M P, G M P, H M, STI and Yi indices.

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القدره علي التالف و انتخاب التراكيب المتميزه من الفول البلدي تحت ظروف الإجهاد باستخدام مؤشرات تحمل الجفاف

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يؤدى الإجهاد المائى الى إنخفاض الصفات الإنتاجية لمحصول الفول البلدي. لذلك، تم تقييم سبعة تراكيب وراثية من الفول البلدى وهجن الجيل الأول الناتجة عن التهجين بينهم تحت ظروف الإجهاد المائي والظروف العادية بمزرعة كلية الزراعة جامعة بنها خلال موسمي النمو الشتوي 2022/2021 و2023/2022. وتهدف الدراسة لتقدير قوة الهجين والقدرة على الأتلاف والسلوك الوراثي للتراكيب الوراثية و تقدير دلالات تحمل الإجهاد. وجد إختلافات عالية المعنوية للتباين الراجع الى التراكيب الوراثية والآباء والهجن والآباء xالهجن والقدرة العامة و الخاصة على التآلف لجميع الصفات باستثناء عدد فروع/ نبات. أدى الإجهاد المائي إلى انخفاض في ارتفاع/ نبات، عدد الأفرع/ نبات، عدد قرون/ نبات، وزن قرون/ نبات، عدد البذور /قرن، وزن 100 بذرة، ومحصول البذور/ نبات بمقدار 6.05. 9.86، 15.24، 11.06، 1.03 ،4.77 و 10.59 %على التوالي. وجد ان قيم نسبة GCA/SCA تتجاوز الوحدة لعدد القرون/نبات وانتاج البذور/ نبات في كلا من معاملات الري ، مما يشير إلى أن الجزء الأكبر من إجمالي التباين الوراثي كان بسبب التأثيرات الجينية المضيفة و المضيفة x المضيفة. سجل الهجين P1xP5 أعلى نسبة لقوة هجين معنوية وإيجابية بالنسبة لمتوسط الأبوين والأب الأفضل بنسبة 40.65% و40.27%. أظهر P5 (سخا 4) وP5 (سخا 4) x P6 (وادي 1) أفضل تأثير للقدرة العامة على الأتلاف والقدرة الخاصة على الأتلاف لصفة محصول البذور لكل نبات، على التوالي. إستنادا إلى مؤشرات الإجهاد TOL وSSI، كانت الهجن P_3XP_6 وP_5XP_4 هي التراكيب الوراثية الأكثر تحملا للإجهاد المائي. في هذه الدراسة P1 وP3، الهجين P_3XP_6 اعطي قيم مرغوبة لمؤشرات MP وG M P وH M وSTI وYi. ويمكن استخدام هذه التراكيب الوراثية في برامج تربية الفول البلدي تحت الإجهاد المائي.