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Combining Ability Analysis for Drought Tolerance in Some European and Mediterranean Faba Bean (*Vicia faba* L.) Genotypes

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Abstract: The main objective of this study was to estimate the genetic variability due to general (GCA) and specific combining ability (SCA) for drought tolerance in faba bean using 12 parental inbred lines crossed in a 3 (testers) x 9 (lines) factorial mating design. The parents and F_1 hybrids were evaluated for yield under well-watered (Yw) and drought (Yd) conditions, in 1995 and 1996, at two locations in Germany. The parental lines differed significantly in the investigated drought tolerance parameters. The parental lines ILB938 and Condor showed, respectively, the lowest and the highest values for the studied parameters, except Yd. The F_1 hybrids exhibited higher drought tolerance than the parental lines. Effects due to GCA related to the testers were significant for all parameters. The differences among the lines in GCA effects were significant for the parameters based on productivity (Yd) and geometric mean of productivity (GMP) but were not significant for the parameters measuring drought tolerance *per se* [Yd/Yw and absolute reduction (AR)]. In all parameters, the variation due to GCA was higher than that due to SCA. The tester ILB938 had the highest (5.15%) positive GCA effect for Yd/Yw. Among the lines, Condor exhibited the largest positive value of GCA effect for Yd and Yd/Yw. Since most of the genetic variation in the hybrids was attributed to GCA, caused by additive gene action, selection is expected to be effective in improving drought tolerance, and the cross LB938 x Condor could be a suitable material.

INTRODUCTION

Faba bean (*Vicia faba* L.) is a susceptible crop to drought, though it is widely grown in semi-arid areas. The crop shows a wide range of yield variability in response to water supply. Many research workers recorded large increases (50%-100%) in seed yield and total dry matter production in irrigated treaments (Farah 1981). Water shortage may be one of the major reasons for yield limitation in faba bean, and when it occurs at different stages of growth, a crop of faba bean shows a differential response (Mohammed 2003), which makes drought tolerance a very complex trait. Studies of drought tolerance are complicated by the unpredictability of drought occurrence, severity, timing and duration. Moreover, the interaction of drought with many other biotic and abiotic stresses, particularily extreme temperature and nutrients availability (Ceccarelli and Grando 1996), could complicate screening for drought tolerance.

Many yield-based parameters were suggested to evaluate drought tolerance. Some of them were constructed as indices, e.g., stress susceptibility index (SSI) suggested by Fischer and Maurer (1978). The SSI was found to be equivalent to the ratio of yield under stress (Yd) to yield under non-stress (Yw): Yd/Yw (Link *et al.* 1999). A further yield-based parameter of drought tolerance is the geometric mean of productivity (GMP), which is the square root of the product of yield under stress and yield under non-stress (Fernandez 1993). Reliability of the index to adequately differentiate genotypes and provide a basis for improvement of drought tolerance depends on the crop species, genetic variation, heritability, genotype x environment interaction, the severity of drought and the index definition of drought tolerance.

Heterosis for yield had been reported in faba bean by many research workers (Ebmeyer and Stelling 1994; Link *et al.* 1994; Abdelmula 1996; Stelling 1997). Recently, heterosis for drought tolerance, based on definition of drought tolerance as minimum yield reduction under drought, was recorded by Abdelmula *et al*., (1999). Since faba bean is a partially allogamous crop, the role of synthetic varieties in increasing yield under drought-prone conditions would be of great interests to the breeders. However, there is lack of information about the kind of gene action controlling drought tolerance traits in faba bean and the amount and cause of genetic variation involved with these traits. Therefore, the objectives of this study were (i) to assess variabilty in drought tolerance among genotypes, (ii) to determine type of gene action involved, and (iii) to identify genotypes that can be used in improvement of drought tolerance in faba bean.

MATERIALS AND METHODS

Twelve parental inbred lines, which have been developed by 6 to 7 cycles of controlled inbreeding of different faba bean cultivars and accessions, were used in this study. These inbred lines differ from each other in morphological and phenological characters as well as in their origin. They originated in Europe and Mediterranean. Three of the twelve inbred lines (St8419, ILB938, and Blaze) were used as tester lines and were crossed with the remaining nine inbred lines in a 3 x 9 factorial mating design (North Carolina II) to produce 27 F_1 hybrids. The tester line "ILB938" was identified as drought tolerant (Riemer 1995), and the two other testers (St8419 and Blaze) were European genotypes developed in Germany and Great Britain, respectively.

A field experiment was carried out for two years (1995 and 1996) at two locations in Germany (Goettingen and Hohenheim). The experiment was laid out in a split-plot design with two replications. The two water treatments; namely, drought (stress) and well-watered (non-stress), were assigned to the main plots and the genotypes to the subplots. Each genotype was grown in a single row, 1.6 m long, with a spacing of 20 x 10 cm.

To induce drought stress, two water treatments (drought and well-watered) were used. The plants were grown under rain fed conditions for four weeks, and then rain shelters made up of polythene sheets were constructed over all plants (both treatments) to keep out the rain water. The plants which were subjected to drought treatment received no water thereafter, whereas the plants in the other treatment (well-watered) received supplementary irrigation by means of trickle irrigation system consisting of perforated plastic tubes laid on the soil and connected to a central water pump. The pump was adjusted to deliver 20 to 25 mm water at an optimum irrigation interval ranging from one week to ten days.

Drought tolerance parameters

The drought tolerance parameters were developed and measured from grain yield/plant as shown below.

Yd (g) = Grain yield/plant under drought conditions

Yw (g) = Grain yield/plant under well-watered conditions, as a reference

Yd/Yw (%) = Ratio of grain yield/plant (drought) to grain yield/plant (well-watered)

AR (g) = Absolute reduction in yield due to stress, calculated as the difference between Yw and Yd

GMP (g) = Geometric mean of productivity, measured as $(Yd \times Yw)^{0.5}$

Statistical analysis

The analysis of variance for all drought tolerance parameters was carried out, based on the means pooled over the two replications and across four environments (Goettingen 1995, Hohenheim 1995, Goettingen 1996 and Hohenheim 1996). A random model was used for statistical analysis in which genotypes were considered as a random sample of faba bean from European and Mediterranean areas.

Variation due to general (GCA) and specific (SCA) combining ability

The hybrid mean squares were partitioned into variances due to testers (σ^2_t), other lines (σ^2_l) and the interaction between testers and lines (σ^2_{tl}) (Comstock and Robinson 1952). Variance components due to effects of environments, replications, testers, lines and the interactions between testers and lines were estimated (Hallauer and Miranda 1988). According to this analysis, the estimates of genotypic variances due to testers and lines were equivalent to variances due to their GCA, and that of their interaction is equivalent to variance due to SCA. This analysis of variance and the estimated means of GCA and SCA were carried out for all drought tolerance parameters. The relative importance of GCA and SCA, as constituents of the genetic variance for each parameter, was estimated by the method introduced by Baker (1978).

RESULTS

Drought tolerance of the parents and F_1-hybrids

There was significant variation for drought tolerance parameters among the parental lines (Table 1) as well as among the F_1-hybrids (Table 2). Generally**,** the F_1-hybrids exhibited higher estimates of drought tolerance than the parental lines. The parental lines ILB938 and Condor exhibited, respectively, the lowest and the highest values for all investigated drought tolerance parameters, except Yd. For Yd, the highest value (13.8 g/plant) was attained by the line BB686wn and the lowest (6.6 g/plant) by the line ILB938. The parental line that showed the highest value (28.0 g/plant) for Yw was Condor, and the one with the lowest value (8.5 g/plant) was ILB938. The same lines exhibited the extreme values for Yd/Yw, where Condor (46%) was the most drought sensitive line and ILB938 (90%) the most tolerant.

Regarding Yd, the F_1-hybrids had a general mean of 15.6 g/plant and the parental lines had 10.6 g/plant; and with respect to Yd/Yw, the F_1-hybrids gave a mean of 64%, while the parental lines had a mean of 62%. The F_1-hybrids also exceeded the parental lines in the other drought tolerance parameters AR and GMP (Tables 1 and 2).

The hybrids produced from the tester ILB938 exhibited higher values of Yd/Yw, where the average was 70%, compared to the averages of the hybrids produced from the other two testers, St8419 and Blaze (Table 2). However, the opposite was true when the other drought tolerance parameters were considered (Table 2).

Table 1. Means of drought tolerance parameters of faba bean parental lines, averaged across four environments (G95, H95, G96 and H96[1])

Parental line	Parameter[2]				
	Yd (g)	Yw (g)	Yd/Yw (%)	AR (g)	GMP (g)
St8419	11.6	18.4	64	6.8	14.6
ILB938	6.6	8.5	90	1.8	7.5
Blaze	11.7	21.6	55	9.9	15.8
Giza3	9.7	11.7	89	2.0	10.5
Apollo	10.4	19.4	54	9.0	14.2
Panther	10.0	19.3	55	9.3	13.8
BB686wn	13.8	25.3	56	11.5	18.5
Hedin	9.6	18.0	55	8.4	13.1
Condor	12.5	28.0	46	15.5	18.6
332/2/91/002	11.4	19.1	64	7.7	14.4
332/2/91/015	11.5	18.5	62	7.0	14.5
Troy	8.7	16.7	53	8.0	12.2
Mean	10.6	18.7	62	8.1	14.0
LSD (0.05)	3.4	5.6	22	4.5	3.9

[1] G95= Goettingen 1995, H95=Hohenheim 1995, G96=Goettingen 1996, and H96=Hoehnehiem 1996 [2]

Yd = Yield under drought; Yw = Yield under well-watering; AR = Absolute reduction in yield

(AR = Yw - Yd); GMP = Geometric mean of productivity

Table 2. Means of drought tolerance parameters among F_1-hybrids, averaged over two replications and across four environments (G95, H95, G96 and H96[1])

F_1-hybrid	Parameter[2]				
	Yd (g)	Yw (g)	Yd/Yw (%)	AR (g)	GMP (g)
St8419 x Giza3	15.1	23.8	65	8.7	18.9
St8419 x Apollo	16.2	26.7	60	10.5	20.7
St8419 x Panther	12.8	19.0	69	6.2	15.4
St8419 x BB686wn	18.0	30.2	59	12.2	23.3
St8419 x Hedin	15.2	28.0	55	12.8	20.6
St8419 x Condor	18.7	26.9	71	8.2	22.2
St8419 x 332/2/91/002	15.6	27.4	57	11.8	20.7
St8419 x 332/2/91/015	19.0	29.3	66	10.2	23.5
St8419 x Troy	14.4	23.9	63	9.5	18.5
Average of tester	16.1	26.1	63	10.0	20.4
ILB938 x Giza3	11.5	18.9	70	5.9	16.4
ILB938 x Apollo	16.0	22.6	72	6.6	18.9
ILB938 x Panther	15.0	23.1	69	8.0	18.5
ILB938 x BB686wn	16.3	23.4	71	7.1	19.5
ILB938 x Hedin	15.8	21.4	75	5.6	18.4
ILB938 x Condor	16.7	24.0	73	6.4	19.6
ILB938 x 332/2/91/002	12.8	20.0	65	7.2	15.9
ILB938 x 332/2/91/015	12.8	21.0	63	8.2	16.3
ILB938 x Troy	12.1	19.3	68	7.2	15.8
Average of tester	14.3	21.5	70	6.9	17.7

Table 2. Cont.

F_1-hybrid	Parameter[2]				
	Yd (g)	Yw (g)	Yd/Yw (%)	AR (g)	GMP (g)
Blaze x Giza3	15.8	23.7	69	7.9	19.3
Blaze x Apollo	18.1	27.2	66	9.1	22.1
Blaze x Panther	15.7	27.3	57	11.6	20.6
Blaze x BB686wn	17.0	31.1	55	14.1	23.0
Blaze x Hedin	14.1	26.3	55	12.2	19.1
Blaze x Condor	18.3	28.4	64	10.1	22.7
Blaze x 332/2/91/002	15.6	25.3	61	9.7	19.8
Blaze x 332/2/91/015	18.3	32.0	57	13.7	24.2
Blaze x Troy	14.9	24.0	64	9.2	18.7
Average of tester	16.4	27.3	61	10.8	21.1
General mean	15.6	25.0	64	9.2	19.7
LSD (0.05)	3.7	6.5	12	4.5	4.3

[1] Abbreviations as in Table 1
[2] Abbreviations as in Table 1

General and specific combining ability

The differences among the testers for general combing ability (GCA) were significant for the studied drought tolerance parameters, except Yd (Table 3**)**. Among the lines, the effects of GCA were significant for Yd, Yw, and GMP and non-significant for Yd/Yw and AR. Similarly, the effects due to specific combining ability (SCA) among the F_1-hybrids were significantly different for Yd, Yw and GMP and non-significant for Yd/Yw and AR (Table 3).

Table 3. Variance components due to GCA and SCA of testers (T) and 9 lines (L) of faba bean, for drought tolerance parameters, across four environments (G95, H95, G96 and H96[1])

Parameter[2]	Variance components due to		
	T (GCA)	L (GCA)	T x L (SCA)
Yd [g]	0.913 *	1.438 *	1.008 *
Yw [g]	8.566 **	3.071 *	1.965 *
Yd/Yw [%]	18.29 **	1.652 ns	5.147 ns
AR [g]	4.226 **	0.645 ns	0.754 ns
GMP [g]	2.926 **	1.820 *	1.248 *

[1] Abbreviations as in Table 1; [2] Abbreviations as in Table 1
*, ** Significant at the 0.05 and 0.01probability levels, respectively
ns = Non-significant

Table 4. The relative importance of genetic variation due to GCA as a percentage of the total genetic variation due to testers (T) and lines (L) of faba bean and their interaction (SCA) for drought tolerance parameters, across four environments (G95), H95, G96 and H96[-1])

Parameter [2]	Testers vs. lines		GCA vs. SCA(%)	
	GCA(T)	GCA(L)	GCA(T+ L)	SCA
Yd(g)	27	43	70	30
Yw(g)	63	23	86	14
Yd/Yw(%)	73	7	80	20
AR(g)	75	12	87	13
GMP(g)	49	30	79	21

[1] Abbreviations as in Table 1
[2] Abbreviations as in Table 1

GCA accounted for a larger portion of the variation among the hybrids than SCA for all drought tolerance parameters studied (Table 4). The contribution of GCA ranged from 87% for AR to 70% for Yd. Drought tolerance, based on Yd/Yw, was also highly affected by GCA, as it accounted for 80% of the variation. In comparison to GCA, the maximum variance due to SCA was recorded for Yd (30%) and the lowest (13%) for AR. For the parameter Yd/Yw, the SCA variance contributed up to 20% of the genetic variation. When testers and the other lines are compared, the GCA variances related to testers were greater than those related to lines for all drought tolerance parameters, except for Yd (Table 4). With regard to Yd, the lines showed greater variance due to GCA than the testers.

Table 5 shows the values of GCA effects of the parental lines for all drought tolerance parameters. Among testers, St8419 and Blaze exhibited positive GCA effects for all drought tolerance parameters, except for Yd/Yw, where they exhibited negative effects. In contrast, tester ILB938 had the highest (5.15%) positive effect for Yd/Yw and negative effects for the others. Among the lines, BB686wn and Condor exhibited the highest positive GCA effects for Yd (1.43 and 2.20 g/plant, respectively). Giza3, Apollo and Condor had the largest positive values of GCA effects for Yd/Yw.

The F_1-hybrids differed in their SCA effects for the different parameters (Table 6). The hybrid ILB938 x Hedin showed the largest positive effect of SCA for Yd (2.02 g) and Yd/Yw (8.12%), and ILB938 x Panther the largest positive SCA effects for Yw (3.39 g) and GMP (2.33 g). The largest negative SCA effects were shown by the F_1-hybrids ILB938 x 332/2/91/015, St8419 x Panther and St8419 x Hedin for Yd, Yw and Yd/Yw. The F_1-hybrid St8419 x Panther showed also the largest negative SCA effect for the parameter GMP.

Table 5. Values of GCA of the faba bean parental lines (three testers and other nine lines) for drought tolerance parameters across four environments (G95, H95, G96 and H96[1])

	Parameter[2]				
	Yd (g)	Yw (g)	Yd/Yw (%)	AR (g)	GMP (g)
Tester					
St8419	0.46	1.14	-1.60	0.78	0.70
ILB938	-1.22	-3.42	5.15	-2.41	-2.03
Blaze	0.72	2.28	-3.54	1.63	1.33
LSD (0.05)	1.4	2.2	5.0	1.7	1.6
Line					
Giza3	-1.18	-2.74	3.52	-1.74	-1.51
Apollo	1.09	0.50	1.87	-0.49	0.88
Panther	-1.15	-1.87	0.85	-0.62	-1.55
BB686wn	1.43	3.26	-2.60	1.93	2.18
Hedin	-0.61	0.26	-3.12	0.98	-0.38
Condor	2.20	1.46	4.74	-0.96	1.75
332/2/91/002	-0.99	-0.75	-3.44	0.34	-0.95
332/2/91/015	1.06	2.44	-2.35	1.48	1.62
Troy	-1.85	-2.55	0.53	-0.92	-2.04
LSD (0.05)	2.4	3.8	8.0	2.9	2.7

[1] Abbreviations as in Table 1
[2] Abbreviations as in Table 1

Table 6. Values of SCA effects for 27 F_1-hybrids of faba bean for drought tolerance parameters, averaged over two replications and across four environments (G95, H95, G96 and H96[1])

F_1-hybrid	Parameter[2]				
	Yd (g)	Yw (g)	Yd/Yw (%)	AR (g)	GMP (g)
St8419 x Giza3	0.17	0.38	-1.76	0.40	-0.01
St8419 x Apollo	-1.02	0.04	-4.21	0.96	-0.55
St8419 x Panther	-2.17	-5.29	5.74	-3.22	-3.44
St8419 x BB686wn	0.42	0.86	-0.95	0.33	0.66
St8419 x Hedin	-0.31	1.59	-5.13	1.80	0.52
St8419 x Condor	0.39	-0.65	3.44	-0.82	0.05
St8419 x 332/2/91/002	0.49	2.01	-2.71	1.42	1.18
St8419 x 332/2/91/015	1.85	0.69	5.89	-1.26	1.47
St8419 x Troy	0.18	0.36	-0.30	0.40	0.12
ILB938 x Giza3	-0.78	0.42	-2.90	0.83	0.24
ILB938 x Apollo	0.46	0.55	0.62	0.30	0.36
ILB938 x Panther	1.76	3.39	-1.01	1.83	2.33
ILB938 x BB686wn	0.44	-1.45	4.34	-1.68	-0.38
ILB938 x Hedin	2.02	-0.42	8.12	-2.23	1.06
ILB938 x Condor	-0.06	1.01	-1.72	0.64	0.04
ILB938 x 332/2/91/002	-0.64	-0.82	-1.10	0.03	-0.88
ILB938 x 332/2/91/015	-2.68	-3.00	-4.21	-0.12	-2.97
ILB938 x Troy	-0.51	0.32	-2.15	0.39	0.20

Table 6. cont.

F_1-hybrid	Parameter[2]				
	Yd (g)	Yw (g)	Yd/Yw (%)	AR (g)	GMP (g)
Blaze x Giza3	0.61	-0.80	4.67	-1.22	-0.24
Blaze x Apollo	0.56	-0.59	3.59	-1.26	0.19
Blaze x Panther	0.40	1.90	-4.73	1.39	1.12
Blaze x BB686wn	-0.86	0.59	-3.39	1.35	-0.28
Blaze x Hedin	-1.71	-1.18	-2.99	0.43	-1.59
Blaze x Condor	-0.33	-0.36	-1.72	0.18	-0.08
Blaze x 332/2/91/002	0.15	-1.19	3.81	-1.45	-0.30
Blaze x 332/2/91/015	0.83	2.31	-1.69	1.37	1.50
Blaze x Troy	0.33	-0.68	2.45	-0.79	-0.32

[1] Abbreviations as in Table 1
[2] Abbreviations as in Table 1

DISCUSSION

The superiority of the F_1-hybrids compared to their parental lines for drought tolerance in this study indicates the presence of heterosis for drought tolerance, particularly for parameters based on productivity. The observed heterosis for drought tolerance could be explained by the genetic variability that had been determined in faba bean for this trait (Stelling *et al.* 1994; Link *et al.* 1999). Therefore, it would be extremely attractive and promising for faba bean breeders to exploit this heterotic advantage under drought conditions, by developing synthetic varieties. The hybrids produced from the tester ILB938 (drought tolerant) exhibited the highest drought tolerance *per se* (Yd/Yw) indicating correlation between the performance of the line *per se* and its performance in crosses when additive gene action is important in determining a character. This is in accordance with the results obtained by Abdelmula *et al.* (1999).

However, the hybrids produced from the other two testers, St8419 and Blaze, exhibited higher values for the other parameters, Yd, AR, GMP, and potential yield (Yw). This could be due to the differences in the estimation and definition of drought tolerance, where each parameter describes drought tolerance from a different point of view, and also may be due to the differences in the genes of adaptation possessed by these testers. Such variation in the definition of drought tolerance had been discussed by many workers (Fischer and Maurer 1978; Abdelmula and Link 1998).

For potential yield and all the studied drought tolerance parameters, the genetic variation due to GCA was higher than that caused by SCA effects. This indicates that the additive gene actions are of great importance in the exhibited variation. This predominance of the additive gene effects indicates that selection will be effective in improving these drought tolerance traits. The variation due to SCA was significant for Yd, GMP, and Yw, suggesting that both additive and non-additive gene effects were involved in the inheritance of these drought tolerance parameters. However, the contribution of the non-additive effects to total genetic variation was low, ranging from 13% to 30%. These differences in the magnitude of additive and non-additive effects seem to be dependent mainly on the differences in the genetic constitution of the parents, although sometimes they may be influenced additionally by the environment (Górny 1999) and the degree of crossing over.

The three testers as well as the nine other parental lines have a potential for improving geometric mean of productivity (GPM) and yield under stress condition (Yd) and non-stress conditions (Yw), because they differed significantly in GCA. However, for the other drought tolerance parameters, Yd/Yw and AR, only the effects due to GCA were significant among the testers and non-significant among the lines, suggesting a need to look for more diverse material. This discrepancy in significance of GCA effects among the drought tolerance parameters could be attributed to the differences in the genes responsible for the different parameters, referring to the fact that the two parameters (Yd/Yw and AR) define the drought tolerance *per se*, i. e., minimization of yield loss under drought stress. On the other hand, Yd and GMP describe the productivity and exhibit positive correlation with the potential yield (Yw). Such positive correlation was reported by other research workers (Fischer and Maurer 1978; Riemer 1995; Schneider *et al*. 1997; Abdelmula and Link 1998).

Effects due to SCA for Yd/Yw and AR were not significant, and little heterosis could be expected upon crossing. Similar results were reported in sunflower (Alza and Fernandez-Martinez 1997). This suggested that the non-additive gene effects could be more important when drought tolerance was defined in term of productivity rather than drought tolerance *per se*. Most of the variation due to GCA for drought tolerance (Yd/Yw and AR) came from the testers, reflecting the fact that they were widely different for drought tolerance traits, especially the tester ILB938. This tester showed the highest positive value of GCA for Yd/Yw and would be a good combiner to render genes for drought tolerance *per se*. The advantage of ILB938 is due to the fact that it was originally developed in Syria under drought conditions. Therefore, much improvement in drought tolerance would be expected to come from lines of similar origin. The nine other parental lines contributed less variability for drought tolerance, because most of them were developed in the favourable conditions of Europe and were not subjected to pre-selection for differential drought tolerance *per se*, but they accumulated the genes for adaptation and performance under the favourable conditions. However, the line Condor had relatively high GCA effects for drought tolerance parameters, based on both productivity and drought tolerance *per se*, and could be a very promising line for improving drought tolerance.

Based on the observed values of SCA alone, the hybrid ILB938 x Hedin had the highest positive value for Yd/Yw, but Hedin had a negative value of GCA for Yd/Yw. This high heterosis could be due to the high genetic divergence between the two parents in relation to this parameter. This hybrid would tend to concentrate the favourable alleles; and since faba bean is partially cross-fertilized, there will be good genetic complementation and exploitation of heterosis to improve drought tolerance. Similar results have been reported in common bean (Franco *et al*. 2001). However, high SCA value of the hybrid is not always a guarantee for successful selection, especially if the crop is not completely cross-fertilized.

Consequently, GCA values of the parents should be given due consideration in selecting material for improvement. Accordingly, crosses between genotypes such as ILB938 and Giza3 with lines like Condor would constitute a suitable material for improving drought tolerance in faba bean.

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تحليل قدرة التآلف لصفة تحمل الإجهاد المائي في بعض أصناف الفول المصري الأوربية والبحر أوسطية

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موجز البحث: هدفت هذه الدراسة لتقدير التباين الوراثي العائد للقدرة العامة والخاصة للتآلف لصفة تحمل الإجهاد المائي لأثنتي عشرة سلالة أبوية من الفول المصري والتى هجنت فيما بينها بنظام تهجين 3 (إختباريات) × 9 (سلالات) . تم تقييم إنتاجية الآباء وهجن الجيل الأول (F_1) فى عامي 1995 و 1996 تحت ظروف ري جيد وإجهاد مائي فى موقعين بالمانيا. أظهرت السلالات الأبوية اختلافاً معنوياً في كل معايير صفة تحمل الإجهاد المائي وتميزت السلالة الأبوية ILB938 بأقل القيم والسلالة الأبوية Condor بأعلاها بالنسبة لكل معايير صفة تحمل الإجهاد المائي . أظهرت الهجن تحملاً للإجهاد المائي أعلى من الآباء . كانت التأثيرات للقدرة العامة للتآلف المتعلقة بالآباء الإختبارية ذات فروقات معنوية لكل معايير صفة تحمل الإجهاد المائي. أما الإختلافات بين السلالات الأبوية في تأثيرات القدرة العامة للتآلف فقد كانت معنوية للمعايير التى تعتمد على الإنتاجية(Yd) والمتوسط الهندسي للإنتاجية (GMP) وغير معنوية للمعايير التى تقيس درجة التحمل المطلقة للإجهاد المائي (AR و Yd/Yw) . وكان التباين الذي يعود للقدرة العامة للتآلف أكبر من ذلك العائد للقدرة الخاصة للتآلف فى كل معايير صفة تحمل الإجهاد المائي . وأظهرت السلالة الأبوية ILB938 أعلى قيمة موجبة (5.15%) للقدرة العامة للتآلف لـ Yd/Yw . ونظراً لأن معظم التباين الوراثي يعود للقدرة العامة للتآلف التى تعود إلى التأثير الإضافي للجين فمن المتوقع أن يكون الانتخاب فعالاً فى تحسين صفة تحمل الإجهاد

المائي فى الفول المصري وأن يكون الهجين ILB938×Condor مصدراً مناسباً لذلك الإنتخاب .