International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
DOI: 10.22192/ijarbs Coden: IJARQG(USA) Volume 5, Issue 3 - 2018

Research Article

DOI: http://dx.doi.org/10.22192/ijarbs.2018.05.03.006

Combining ability for yield and its attributes in barley under stressed and non-stressed nitrogen fertilization environments

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Abstract

Five parental barley varieties were crossed according to a half diallel cross mating design in 2014/2015 season. The first generation of the evaluated ten crosses and their five parents were planted in a field experiment at the experimental Farm of the Agronomy Department, Faculty of Agriculture, Mansoura University in 2015/2016 season to estimate general and specific combining abilities for grain yield and yield associated traits. Data revealed that, mean performance of all tested genotypes (parents and crosses) recorded a clear reduction under nitrogen stress conditions for all studied traits i.e. days to heading, plant height, flag leaf area, number of tillers/ plant, number of spikes/ plant, grain yield/ plant and 100-grain weight. The analysis of variance for combining ability showed that general and specific combining abilities (GCA and SCA) mean squares were highly significant for all studied traits, indicating the importance of additive and non-additive genetic variance in determining the performance of these traits. The ratio of GCA/SCA were less than unity for all studied traits under study reflecting the important of non-additive genetic variance role in the inheritance of all studied traits, therefore a bulk method in late or advanced generations will be fruitful tool to improve these traits. Generally, parents Giza129 and Giza 131 for days to heading, parent Giza 131 for plant height, parents Giza 126 and Giza 131 for flag leaf area were good combiners under both conditions and their combined. Giza 123 and Giza 126 under both conditions and their combined, Giza 130 under nitrogen stress conditions and combined were good combiners for number of tillers/plant. Giza 123, Giza 126 and Giza 130 for number of spikes/plant, Giza 123 and Giza 126 for grain yield/ plant under different nitrogen conditions and their combined were good combiners. Besides, Giza 126 under different nitrogen conditions as well as their combined and Giza 131 under stress and combined were good combiners for 100-grain weight. According to SCA estimates, it could be stated that the best cross was P3×P5 for all studied traits under both conditions and their combined, except for plant height and 100 grain-weight.

Keywords: barley, nitrogen stress conditions, field experiment, GCA and SCA

Introduction

Barley (*Hordeum vulgare* L.), is an important cereal crop ranking fourth in the world cereal crops production with 144 million tonnes in 2014.It is considered a major cereal crop in most of dry areas all over the world. Barley has been used as a component of several health foods. It plays an important role in human feed security and also as animal fodder.

Nitrogen is the mainspring to get the high yield in cereals and it affects in growing period and yield quality. The application of nitrogen frequently is an important tool mainly used in increasing grain yield **(Ahmed *et al.*, 2002 and Janković *et al.*, 2011)**. Enhancing, nitrogen applying experimentally proved the rises of plant height, number of fertile tillers, spike length, and grain yield **(Ryan *et al.*, 2010 and Aghdam & Samadiyan, 2014).**

Most of agricultural producers all over the world live in areas under several different stress conditions (**Ceccarelli, 1996)**. The development of several cereal crops cultivars adapted to different stress conditions is of utmost importance for food security. So, breeding cereal crops to adapted stressed conditions was described as the primary reason of increased yield over the last years **(Abeledo *et al*., 2003)**. Several investigators studied the effects of combining abilities under stress and non-stressed environments for growth, yield and yield components traits in barley such as **Abdel-Moneam *et al.* (2014)** and **Sultan *et al*. (2016)** and they showed that, a biotic stress treatments decreased all means of studied traits for all genotypes and also they reported that, statistical analysis revealed highly significant effects of general and specific combining abilities for all studied traits, indicating wide range of genetic variability among the studied genotypes. Therefore, the aim of current research was to find out the superior barley parents and their crosses under normal and stress conditions, and also to specify the general and specific combining abilities effects and gene action type in the heritance of yield and some major agronomic traits.

Materials and Methods

This study was conducted at the experimental Farm of the Agronomy Department, Faculty of Agriculture, Mansoura University during the two successive seasons of 2014/2015 and 2015/2016. Five barley parental genotypes namely; Giza 123, Giza 126, Giza 129, Giza 130 and Giza 131 were obtained from Field Crops Research Institute (FCRI), Agriculture Research Center (ARC), Ministry of Agriculture and Land Reclamation, Egypt. Names and pedigrees of barley parental genotypes are listed in Table 1.All parental genotypes were crossed according to a half diallel cross mating design during 2014/2015 season. In 2015/2016 season, the ten F_1 crosses along with their five parents were planted in two experiments. The first was fertilized by the recommended dose of Nitrogen (46 kg N/Fed.) as a normal condition, while the second one was fertilized by half of the recommended dose of Nitrogen (23 kg N/Fed.) as a stress condition. Each experiment was designated in a Randomized Complete Block Design with three replications. Plot area consisted of 4rows, each of 2 m in length, space between rows were 30 cm with 15 cm as a distance between plants. Other agricultural practices were carried out as recommended by Ministry of Agriculture and Land Reclamation. Samples of ten guarded plants were taken at random from middle rows of each plot to determine days to heading (day), plant height (cm), flag leaf area (cm^2), number of tillers/ Plant, number of Spikes/ Plant, grain yield/ plant (g) and 100-grain weight (g).

Analysis of variance technique (AOV) for the two experiments and the combined analysis across them were performed according to **Snedecor** and **Cochran(1980)** whenever homogeneity error was detected. The sum of squares of crosses was partitioned to general and specific combining abilities following method 2 model 1 (fixed effects) of **Griffing (1956)**.

Table (1): Parental barley varieties names and pedigrees.

No	Genotypes	Pedigree
1	Giza 123	Giza 117/FAO 86
2	Giza 126	BaladiBahteem/SD729-Por12762-Bc
3	Giza 129	DeirAlla 106/Cel//As46/Aths*2
4	Giza 130	"Comp.cross"229//Bco.Mr./DZ0231/3/DeirAlla 106
5	Giza 131	CM67-B/CENTENO//CAM-B/3/ROW906.73/4/GLORIA-BAR/COMEB/5/FALCON-BAR/6/LINO

Results and Discussion

Analysis of variance:

Mean squares from the analysis of variance (Ms) for all genotypes, general combining ability (GCA) and specific combining ability (SCA) for all studied traits are presented in Table 2. Results showed that, mean squares of genotypes were highly significant for all studied traits under both of normal, stress conditions and their combined. The results are in confidence with those of **Martinez *et al*. (1995), Aghdam & Samadiyan (2014)** and **Alazmani (2015)**, indicating wide range of genetic variability among the studied genotypes and this is primary requirement for further computation. General and specific combining abilities mean squares were found to be significant or highly significant for all studied traits under both of normal, stress conditions and their combined, indicating the importance of both additive and non-additive genetic variances in determining the performance of these traits. These results are in line with those of **El-Shaarawy** & **Koumber (2010)** and **Al-Naggar *et al*. (2015).** GCA/SCA ratio were found to be less than unity for all studied traits which means the important of non-additive genetic variances role in the inheritance of all studied traits, therefore a bulk method in late or advanced generations will be fruitful tool to improve these traits.

Table 2: Analysis of variance of barley genotypes, general combining ability (GCA) and specific combining ability (SCA) under both of normal and nitrogen stress conditions as well as their combined for all studied traits.

S. V	D. F		Days to heading			Plant height			Flag leaf area		
	Sing.	Comb.	Normal	N-Stress	Comb.	Normal	N-Stress	Comb.	Normal	N-Stress	Comb.
Geno.	14	14	47.87**	27.80**	70.02**	310.00**	330.33**	393.97**	109.13**	60.20**	146.56**
Error	28	70	00.38	01.47	01.87	49.30	35.68	83.26	03.39	02.03	06.72
GCA	4	4	10.01**	07.08**	08.12**	88.70**	225.06**	119.09**	81.23**	31.74**	52.71**
SCA	10	10	18.33**	10.15**	13.09**	109.19**	64.13**	44.29**	18.44**	15.40**	13.12**
Error	28	70	00.13	00.49	00.31	16.43	11.89	13.88	01.13	00.68	01.12
GCA /SCA			00.08	00.09	00.09	00.09	00.47	0.34	00.62	00.29	00.56

Table 2. continue

S. V	D. F		Number of tillers/ Plant			Number of Spikes/ Plant		
	Sing.	Comb.	Normal	Stress	Comb.	Normal	Stress	Comb.
Geno.	14	14	27.95**	18.59**	38.75**	25.89**	13.80**	31.59**
Error	28	70	02.37	01.22	02.99	02.50	02.31	03.54
GCA	4	4	12.17**	12.70**	12.18**	10.24**	09.21**	09.45**
SCA	10	10	08.18**	03.60**	04.17**	07.99**	02.76**	03.59**
Error	28	70	00.79	00.41	00.50	00.83	00.77	0.59
GCA/SCA			00.20	00.49	00.40	00.17	00.44	00.35

Table 2. continue

S. V	D. F		Grain yield/ plant			100-grain weight		
	Sing.	Comb.	Normal	Stress	Comb.	Normal	Stress	Comb.
Geno.	14	14	610.67**	295.60**	669.99**	01.35**	01.63**	02.65**
Error	28	70	58.29	17.72	77.66	00.20	00.19	00.22
GCA	4	4	211.98**	203.62**	196.94**	00.88**	00.72**	00.75**
SCA	10	10	200.19**	56.50**	77.56**	00.28**	00.47**	00.32**
Error	28	70	19.43	05.91	12.94	00.07	00.06	00.04
GCA/SCA			00.14	00.50	00.34	00.41	00.20	00.32

Mean performance:

Mean performance of the five studied parental barley varities and their F_1 crosses under normal and stress conditions as well as their combined for all studied traits are presented in Table 3.Data reveled that, mean performance of all tested genotypes recorded a clear reduction under nitrogen stress conditions. Such reduction in all traits may be attributed to the essential role of nitrogen in plant growth and development, which in turn on increasing vegetative and yield characters **(Amanullah *et al.*, 2009; Safina, 2010 and Aghdam and Samadiyan, 2014).**

Results showed that, Giza 129 and cross P3×P5 under normal nitrogen conditions, Giza 130 and cross P3×P5 under stress nitrogen conditions, Giza 129 and cross P3×P5 in their combined recorded the lowest number of days to heading. For plant height, Giza 123 and cross P3×P5 under normal nitrogen conditions, Giza 130 and cross P4×P5 under stress nitrogen conditions, Giza 130 and cross P3×P5 in their combined were the shortest plants. The highest flag leaf area were obtained from planting Giza 126 and cross P3×P5 under normal nitrogen conditions, Giza 126 and cross P2×P4 under stress nitrogen conditions, Giza 126 and cross P3×P5 in their combined. The highest number of tillers/ plant was recorded by Giza 126 among parents and cross P1×P2 under both of normal, stress conditions as well as their combined. Planting Giza 126 and cross P1×P5 under normal conditions, Giza 130 and cross P1×P2 under stress conditions, Giza 126 or Giza 130 and P1×P2 in their combined recorded the highest number of spikes/ plant. Results also showed that Giza 126 recorded the highest grain yield/ plant among all parents under both of normal, stress conditions and their combined, cross P1×P5 under normal nitrogen conditions and cross P1×P2 under stress and combined. For 100- grain weight, it is clearly showed that heaviest grains were obtained from planting Giza 126 and cross P1×P2 under normal conditions, Giza 131 and P1×P2 under nitrogen stress conditions and combined. Such results agree with those of **Moselhy** & **Zahran (2002)**, **Zebarth *et al.* (2009), Shafi *et al.* (2011), Aghdam & Samadiyan (2014), Barati *et al.* (2014)** and **Sultan *et al.* (2016).**

Table 3: Mean performance of barley varieties and their F_1 crosses under both of normal and nitrogen stress conditions as well as their combined for all studied traits during 2016winter season.

Nitrogen levels	Days to heading (day)			Plant height (cm)			Flag leaf area (cm^2)		
Genotypes	Normal	Stress	Comb.	Normal	Stress	Comb.	Normal	Stress	Comb.
P 1: (Giza123)	87.67	78.67	83.17	93.00	84.33	88.67	24.13	15.53	19.83
P 2: (Giza126)	88.33	79.33	83.83	103.00	94.33	98.67	37.33	24.87	31.10
P 3: (Giza129)	85.33	78.67	82.00	101.33	65.67	83.50	15.57	11.47	13.52
P 4: (Giza130)	87.67	77.33	82.50	94.00	58.00	76.00	19.47	10.26	14.86
P 5: (Giza131)	86.67	78.67	82.67	104.00	70.33	87.17	22.57	17.13	19.85
(P1 × P2)	82.33	77.67	80.00	110.33	85.33	97.83	23.33	20.43	21.88
(P1 × P3)	81.00	75.67	78.33	120.00	67.67	93.83	13.87	9.43	11.65
(P1 × P4)	83.00	78.67	80.83	113.33	75.33	94.33	22.73	19.23	20.98
(P1 × P5)	84.00	75.33	79.67	96.00	81.33	88.67	24.30	16.40	20.35
(P2 × P3)	79.67	72.33	76.00	120.67	70.00	95.33	24.97	13.13	19.05
(P2 × P4)	81.00	75.33	78.17	117.67	84.33	101.00	25.33	21.17	23.25
(P2 × P5)	83.00	74.33	78.67	104.33	75.67	90.00	30.57	14.17	22.37
(P3 × P4)	78.33	74.00	76.17	108.33	84.00	96.17	18.77	12.40	15.58
(P3 × P5)	74.67	68.67	71.67	90.33	63.67	77.00	30.60	20.30	25.45
(P4 × P5)	78.33	72.670	75.50	93.667	62.33	78.00	28.10	18.30	23.20
F. Test	**	**		**	**		**	**	
$BLSD_{5\%}$	0.89	1.88		11.43	9.72		2.77	2.11	
$BLSD_{1\%}$	1.18	2.51		15.37	13.08		3.67	2.80	
F.Test	**		**	**		**	**		**
$BLSD_{5\%}$	1.54		0.99	10.43		7.43	2.64		1.69
$BLSD_{1\%}$	2.06		1.30	13.96		9.91	3.53		2.23
Mean	82.73	75.82		104.67	74.82		24.11	16.28	
F. Test	**			**			**		

Table 3: continue

Nitrogen levels / Genotypes	Number of tillers/ Plant			Number of Spikes/ Plant		
	Normal	Stress	Comb.	Normal	Stress	Comb.
P 1: (Giza123)	24.67	16.67	20.67	23.33	15.33	19.33
P 2: (Giza126)	25.33	19.00	22.17	24.00	16.33	20.17
P 3: (Giza129)	17.67	13.67	15.67	17.00	13.00	15.00
P 4: (Giza130)	23.67	18.67	21.17	23.33	17.00	20.17
P 5: (Giza131)	14.67	11.33	13.00	13.67	10.00	11.83
(P1 × P2)	24.33	20.33	22.33	22.00	18.00	20.00
(P1 × P3)	18.33	16.67	17.50	17.00	14.67	15.83
(P1 × P4)	20.33	17.33	18.83	19.67	16.00	17.83
(P1 × P5)	24.00	17.00	20.50	23.00	15.67	19.33
(P2 × P3)	21.00	13.67	17.33	19.67	11.67	15.67
(P2 × P4)	20.33	18.00	19.17	18.33	16.33	17.33
(P2 × P5)	19.67	14.00	16.83	19.67	13.67	16.67
(P3 × P4)	19.67	14.67	17.17	19.00	14.00	16.50
(P3 × P5)	22.67	16.67	19.67	21.00	15.00	18.00
(P4 × P5)	23.67	13.67	18.67	22.67	12.67	17.67
F. Test	**	**		**	**	
$BLSD_{5\%}$	2.39	1.71		2.45	2.47	
$BLSD_{1\%}$	3.19	2.29		3.58	3.32	
F. Test	**		**	**		**
$BLSD_{5\%}$	2.28		1.52	2.83		1.76
$BLSD_{1\%}$	3.13		1.97	3.89		2.25
Mean	21.33	16.09		20.22	14.62	
F. Test	**			**		

Table 3: continue

Nitrogen levels / Genotypes	Grain yield/ plant (g)			100-grain weight (g)		
	Normal	Stress	Comb.	Normal	Stress	Comb.
P 1: (Giza123)	72.53	42.30	57.42	6.92	5.93	6.43
P 2: (Giza126)	90.23	55.07	72.65	7.24	6.31	6.77
P 3: (Giza129)	50.00	33.10	41.55	5.63	4.63	5.13
P 4: (Giza130)	53.10	35.37	44.23	5.70	4.90	5.30
P 5: (Giza131)	38.73	25.57	32.15	7.08	6.76	6.92
(P1 × P2)	70.37	60.10	65.23	7.47	6.36	6.92
(P1 × P3)	54.40	36.30	45.35	6.70	6.01	6.35
(P1 × P4)	62.27	40.17	51.22	6.87	5.40	6.14
(P1 × P5)	85.60	38.10	61.85	5.72	4.43	5.08
(P2 × P3)	58.90	26.73	42.82	6.77	4.50	5.64
(P2 × P4)	56.53	41.37	48.95	6.98	5.57	6.28
(P2 × P5)	58.07	28.37	43.22	7.20	6.02	6.61
(P3 × P4)	55.80	30.10	42.95	5.87	5.06	5.47
(P3 × P5)	64.40	37.33	50.87	5.69	5.20	5.45
(P4 × P5)	82.80	27.90	55.35	7.15	6.10	6.63
F. Test	**	**		**	**	
$BLSD_{5\%}$	11.88	6.52		0.73	0.70	
$BLSD_{1\%}$	15.86	8.71		0.97	0.94	
F. Test	**		**	NS		**
$BLSD_{5\%}$	9.88		7.02			0.49
$BLSD_{1\%}$	13.19		8.91			0.63
Mean	63.58	37.19		6.60	5.55	
F. Test	**			**		

Table 4: Estimates of general combining ability (GCA) effects (g_i) for parental barley varsities under both of normal and nitrogen stress conditions as well as their combined for all studied traits.

Parents	Days to heading			Plant height			Flag leaf area		
	Normal	Stress	Comb.	Normal	Stress	Comb.	Normal	Stress	Comb.
P 1 (Giza 123)	1.324**	1.391**	1.357**	-0.333NS	4.200**	1.933NS	-1.741**	-0.160NS	-0.950*
P 2 (Giza 126)	0.895**	0.486*	0.691**	4.429**	7.867**	6.148**	4.893**	2.990**	3.941**
P 3 (Giza 129)	-1.724**	-0.991**	-1.357**	2.000NS	-4.610**	-1.305NS	-3.615**	-2.780**	-3.198**
P 4 (Giza 130)	-0.057NS	0.057NS	0.001NS	-1.000NS	-3.848**	-2.424NS	-1.539**	-0.875**	-1.207**
P 5 (Giza 131)	-0.438**	-0.943**	-0.691**	-5.095**	-3.610**	-4.352**	2.002**	0.825**	1.414**
$LSD_{(gi)5\%}$	0.245	0.484	0.379	2.807	2.388	2.529	0.736	0.569	0.719
$LSD_{(gi)\ 1\%}$	0.331	0.653	0.505	3.787	3.222	3.372	0.993	0.768	0.958
$LSD_{(gi-gj)\ 5\%}$	0.388	0.765	0.599	4.438	3.776	3.999	1.163	0.900	1.136
$LSD_{(gi-gj)\ 1\%}$	0.523	1.032	0.798	5.987	5.094	5.332	1.569	1.214	1.515

Table 4: continue

Parents	Number of tillers/ Plant			Number of Spikes/ Plant		
	Normal	Stress	Comb.	Normal	Stress	Comb.
P 1 (Giza 123)	1.191**	1.162**	1.176**	1.000**	1.038**	1.019**
P 2 (Giza 126)	1.143**	1.067**	1.105**	0.905**	0.657*	0.781**
P 3 (Giza 129)	-1.571**	-1.076**	-1.324**	-1.524**	-0.914**	-1.219**
P 4 (Giza 130)	0.476NS	0.638**	0.557*	0.714*	0.752*	0.733**
P 5 (Giza 131)	-1.238**	-1.791**	-1.514**	-1.095**	-1.533**	-1.314**
$LSD_{(gi)0.05}$	0.615	0.442	0.480	0.632	0.607	0.522
$LSD_{(gi)\ 0.01}$	0.830	0.596	0.640	0.853	0.819	0.696
$LSD_{(gi-gj)\ 0.05}$	0.972	0.699	0.759	0.999	0.960	0.825
$LSD_{(gi-gj)\ 0.01}$	1.312	0.943	1.011	1.348	1.296	1.100

Table 4: continue

Parents	Grain yield/ plant			100-grain weight		
	Normal	Stress	Comb.	Normal	Stress	Comb.
P 1 (Giza 123)	5.171^{**}	5.159^{**}	5.165^{**}	0.141^{NS}	0.114^{NS}	0.127^{NS}
P 2 (Giza 126)	6.112^{**}	6.233^{**}	6.173^{**}	0.471^{**}	0.256^{**}	0.364^{**}
P 3 (Giza 129)	-6.856^{**}	-3.799^{**}	-5.327^{**}	-0.471^{**}	-0.463^{**}	-0.467^{**}
P 4 (Giza 130)	-2.548^{NS}	-1.842^{*}	-2.195^{NS}	-0.188^{*}	-0.193^{*}	-0.190^{**}
P 5 (Giza 131)	-1.881^{NS}	-5.751^{**}	-3.816^{**}	0.047^{NS}	0.286^{**}	0.167^{*}
$LSD_{(gi)0.05}$	3.052	1.683	2.443	0.178	0.167	0.129
$LSD_{(gi)\ 0.01}$	4.118	2.270	3.257	0.240	0.225	0.173
$LSD_{(gi-gj)\ 0.05}$	4.826	2.661	3.863	0.282	0.272	0.205
$LSD_{(gi-gj)\ 0.01}$	6.510	3.590	5.149	0.380	0.368	0.273

Estimates of general combining ability (GCA) effects (g_i) for parental barley varsities under normal and stress conditions and their combined for all studied traits are listed in Table 4.Estimates of GCA effects showed that, the parents P3 (Giza 129) and P5 (Giza 131) were found to be good general combiners for number of days to heading, P5 (Giza 131) for plant height, where they showed negative and highly significant GCA effects for these traits under normal, stress conditions and their combined. In the contrary, the other parents were found to be bad general combiners for these traits, where they showed positive significant or highly significant GCA effects. With respect to flag leaf area, parents P2 (Giza 126) and P5 (Giza 131) showed positive and highly significant GCA effects under both of normal, stress and their combined, indicating that these parents proved to be a good general combiners for increasing flag leaf area under such conditions. Parents P1 (Giza 123), P2 (Giza 126) and P4 (Giza 130) showed positive significant and highly significant GCA effects under all conditions except with P4 (Giza 130), where it showed no significant GCA effects under normal conditions for number of tillers. Parents P1 (Giza 123), P2 (Giza 126) and P4 (Giza 130) showed positive significant and highly significant GCA effects under all conditions for number of spikes per plant, P1 (Giza 123) and P2 (Giza 126) under all conditions for grain yield/ plant, P2 (Giza 126) under all conditions and P5(Giza 131) under both of stress and combined only for 100-grain weight. Indicating that, these parents were the best general combiners for increasing these traits under such conditions. These results are in line with those of **Okeno & Chittenhelm (1999), Górny& Ratajczak (2008), Al-Naggar *et al*. (2015), Khan & Mohammad (2016)** and **Sultan *et al*. (2016).**

Table 5: Estimates of specific combining ability (SCA) effects (s_{ij}) for all F_1 crosses under normal and nitrogen stress conditions as well as their combined for all studied traits.

Crosses	Days to heading			Plant height			Flag leaf area		
	Normal	Stress	Comb.	Normal	Stress	Comb.	Normal	Stress	Comb.
P1 × P2	-2.619**	-0.032NS	-1.325**	1.57NS	-1.556NS	0.008NS	-3.910**	1.305NS	-1.303NS
P1 × P3	-1.333**	-0.556NS	-0.944NS	13.67**	-6.746*	3.460NS	-4.878**	-3.905**	-4.392**
P1 × P4	-1.000**	1.397*	0.198NS	10.00**	0.159NS	5.079NS	1.899NS	3.992**	2.946**
P1 × P5	0.381NS	-0.937NS	-0.278NS	-3.24NS	5.921NS	1.341NS	-0.086NS	-0.547NS	-0.316NS
P2 × P3	-2.238**	-2.984**	-2.611**	9.57*	-8.079*	0.746NS	-0.412NS	-3.341**	-1.877*
P2 × P4	-2.571**	-1.032NS	-1.802**	9.57*	5.492NS	7.532*	-2.121*	2.773**	0.326NS
P2 × P5	-0.190NS	-1.032NS	-0.611NS	0.33NS	-3.413NS	-1.540NS	-0.443NS	-5.920**	-3.181**
P3 × P4	-2.619**	-0.889NS	-1.754**	2.67NS	17.635**	10.151**	-0.203NS	-0.237NS	-0.220NS
P3 × P5	-5.905**	-5.222**	-5.563**	-11.24**	-2.937NS	-7.087*	8.089**	6.000**	7.044**
P4 × P5	-3.905**	-2.270**	-3.087**	-4.90NS	-5.032NS	-4.968NS	3.530**	2.064**	2.797**
$LSD_{(S_{ij})5\%}$	0.633	1.250	0.978	7.248	6.166	6.531	1.900	1.470	1.855
$LSD_{(S_{ij})1\%}$	0.854	1.686	1.304	9.777	8.318	8.707	2.563	1.983	2.474
$LSD_{(S_{ij}-S_{ik})5\%}$	0.950	1.874	1.467	10.872	9.249	9.797	2.850	2.205	2.783
$LSD_{(S_{ij}-S_{ik})1\%}$	1.281	2.528	1.956	14.666	12.477	13.061	3.844	2.974	3.710
$LSD_{(S_{ij}-S_{kl})5\%}$	0.867	1.711	1.339	9.924	8.443	8.943	2.601	2.012	2.541
$LSD_{(S_{ij}-S_{kl})1\%}$	1.170	2.308	1.786	13.388	11.390	11.923	3.509	2.715	3.387

Table 5: continue

Crosses	Number of tillers/ Plant			Number of Spikes/ Plant		
	Normal	Stress	Comb.	Normal	Stress	Comb.
P1 × P2	0.667^{NS}	2.016^{**}	1.341^{*}	-0.127^{NS}	1.683^{*}	0.778^{NS}
P1 × P3	-2.619^{**}	0.492^{NS}	-1.063^{NS}	-2.698^{**}	-0.079^{NS}	-1.389^{*}
P1 × P4	-2.667^{**}	-0.556^{NS}	-1.611^{*}	-2.270^{**}	-0.413^{NS}	-1.341^{NS}
P1 × P5	2.714^{**}	1.540^{**}	2.127^{**}	2.873^{**}	1.540^{NS}	2.206^{**}
P2 × P3	0.095^{NS}	-2.413^{**}	-1.159^{NS}	0.063^{NS}	-2.698^{**}	-1.317^{NS}
P2 × P4	-2.619^{**}	0.206^{NS}	-1.206^{NS}	-3.508^{**}	0.302^{NS}	-1.603^{*}
P2 × P5	-1.571^{NS}	-1.365^{*}	-1.468^{*}	-0.365^{NS}	-0.079^{NS}	-0.222^{NS}
P3 × P4	-0.571^{NS}	-0.984^{NS}	-0.778^{NS}	-0.413^{NS}	-0.460^{NS}	-0.437^{NS}
P3 × P5	4.143^{**}	3.444^{**}	3.794^{**}	3.397^{**}	2.825^{**}	3.111^{**}
P4 × P5	3.095^{**}	-1.270^{*}	0.913^{NS}	2.825^{**}	-1.175^{NS}	0.825^{NS}
$LSD_{(S_{ij})5\%}$	1.588	1.141	1.239	1.632	1.568	1.347
$LSD_{(S_{ij})1\%}$	2.142	1.540	1.651	2.201	2.116	1.796
$LSD_{(S_{ij}-S_{ik})5\%}$	2.382	1.712	1.858	2.448	2.352	2.021
$LSD_{(S_{ij}-S_{ik})1\%}$	3.213	2.309	2.477	3.302	3.173	2.694
$LSD_{(S_{ij}-S_{kl})5\%}$	2.175	1.563	1.696	2.234	2.147	1.845
$LSD_{(S_{ij}-S_{kl})1\%}$	2.934	2.108	2.261	3.014	2.897	2.459

Table 5: continue

Crosses	Grain yield/ plant			100-grain weight		
	Normal	Stress	Comb.	Normal	Stress	Comb.
P1 × P2	-4.52^{NS}	11.51**	3.496^{NS}	0.255^{NS}	0.447*	0.351*
P1 × P3	-7.48^{NS}	-2.28^{NS}	-4.878^{NS}	0.427^{NS}	0.813**	0.620**
P1 × P4	-3.92^{NS}	-0.33^{NS}	-2.122^{NS}	0.321^{NS}	-0.067^{NS}	0.127^{NS}
P1 × P5	18.73**	1.51^{NS}	10.122**	-1.072**	-1.512**	-1.292**
P2 × P3	-3.92^{NS}	-12.91**	-8.415**	0.174^{NS}	-0.839**	-0.333^{NS}
P2 × P4	-10.60*	-0.19^{NS}	-5.396^{NS}	0.101^{NS}	-0.043^{NS}	0.029^{NS}
P2 × P5	-9.76*	-9.31**	-9.534**	0.082^{NS}	-0.068^{NS}	0.007^{NS}
P3 × P4	1.64^{NS}	-1.48^{NS}	0.084^{NS}	-0.070^{NS}	0.169^{NS}	0.050^{NS}
P3 × P5	9.55*	9.71**	9.631**	-0.483*	-0.169^{NS}	-0.326^{NS}
P4 × P5	23.65**	-1.67^{NS}	10.989**	0.695**	0.464*	0.579**
$LSD_{(S_{ij)5\%}}$	7.881	4.345	6.308	0.460	0.445	0.334
$LSD_{(S_{ij)1\%}}$	10.632	5.862	8.409	0.620	0.600	0.445
$LSD_{(S_{ij}-S_{ik)5\%}}$	11.822	6.518	9.461	0.690	0.667	0.501
$LSD_{(S_{ij}-S_{ik)1\%}}$	15.947	8.793	12.613	0.930	0.900	0.668
$LSD_{(S_{ij}-S_{kl)5\%}}$	10.792	5.950	8.637	0.630	0.609	0.457
$LSD_{(S_{ij}-S_{kl)1\%}}$	14.558	8.027	11.514	0.849	0.822	0.610

Estimates of specific combining ability (SCA) effects (s_{ij}) for all F_1 crosses under normal, stress conditions and their combined are listed in Table 5.Based on SCA effects, it could be concluded that, cross i.e. P2×P3, P3×P5 and P4×P5 under both nitrogen fertilizer conditions, cross i.e. P1×P2, P2×P4 and P3×P4 under normal conditions and their combined, cross P1×P3 under normal conditions only, showed highly negative significant SCA effects for number of days to heading, indicating that these crosses were the best combinations for improving this trait. For plant height, crosses i.e. P3×P5 under normal conditions and combined, cross i.e. P1×P3 and P2×P3 under stress conditions only showed negative significant SCA effects. Crosses i.e. P3×P5 and P4×P5 under all conditions, Crosse P1×P4 under nitrogen stress conditions and combined and cross P2×P4 under stress conditions only showed highly positive significant SCA effects for flag leaf area. According to number of tillers/plant, crosses P1×P5 and P3×P5 under both nitrogen fertilizer conditions and their combined, cross P1×P2 under stress and combined, cross P4×P5 under normal conditions only showed positive significant or highly significant SCA effects. Crosse P3×P5 under both nitrogen fertilizer conditions and their combined, cross P1×P5 under normal and combined, cross P1×P2

under stress conditions only and cross P4×P5 under normal conditions only showed positive significant or highly significant SCA effects for number of spikes/plant, indicating that these crosses are the best combinations for improving this trait. Crosses P3×P5 under both conditions and their combined, crosses P4×P5 and P1×P5 under normal and combined and cross P1×P2 under stress only are considered promising for increasing grain yield/ plant as they recorded positive significant or highly significant SCA effects. With respect to 100-grain weight, results confirmed the superiority of crosses i.e. P4×P5 under both nitrogen fertilizer conditions and their combined and crosses P1×P2 and P1×P3 under nitrogen stress conditions and combined, where they showed positive significant or highly significant SCA effects. Many researchers have found the same results, such as **Okeno & Chittenhelm (1999), Górny & Ratajczak (2008)** and **Khan & Mohammad (2016)** and also, **El-Shaarawy** & **Koumber (2010) and Al-Naggar *et al*. (2015)** in their study on wheat crosses to estimate combining ability under low nitrogen fertilizer conditions.

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Access this Article in Online	
	Website: www.ijarbs.com
Quick Response Code	Subject: Agricultural Sciences
DOI:10.22192/ijarbs.2018.05.03.006	

How to cite this article:
Abdel-Moneam, M. A. and A. A. A. Leilah. (2018). Combining ability for yield and its attributes in barley under stressed and non-stressed nitrogen fertilization environments. Int. J. Adv. Res. Biol. Sci. 5(3): 37-50.
DOI: http://dx.doi.org/10.22192/ijarbs.2018.05.03.006