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BEHAVIOUR STUDY OF AUTOCHTONE AND INTRODUCED GENOTYPES OF BARLEY (*HORDEUM VULGARE* L.) UNDER SUB-HUMID CONDITIONS OF NORTH ALGERIA. STUDY OF F_1 AND F_2 GENERATIONS OBTENED BY DIALLEL CROSSING

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Abstract

Description of the subject: A complete cross diallel 6 x 6, without diagonal, including 06 varieties of barley (*Hordeum vulgare* L.) of various origonesins was carried out at the Experimental Station of the Department of Biotechnology (Blida University 1). The F_1 and F_2 generations and their parents were used to investigate (made) the subject of a comparative study of the characters that make up the grain yield.

Objective: Characterization of the parents and their hybrids F_1 and F_2. The diallel analysis allows us to quantify the importance of the heterosis, and explore the possibility of transmission of quantitative traits in the F_1 and F_2 generations.

Methods: Genetic analysis is carried out according to method 3, model I (fixed model) of Griffing (1956), and the Hayman method (1954).

Results: The results of the comparative study between the genotypes show that the difference is purely genotypic for characters: number of spikes per plant, thousand grain weight and grain yield. The hybridization released between the varieties, as the conventional form n (n-1) is given by obtaining 30 crosses. The passage to the generation F_1 to the F_2 had shown an increase of the heterosis effect that means a good specific combining ability.

Conclusion: The different genetic analysis released (Griffing, Hayman) shows that the characters: number of spikes per plant, number of grains per spike (those) are the most additives ones. The Hayman analysis has also shownthe possibilities of characters transgression from the parental forms in both (of) generations F_1 and F_2.

Key words: Heterosis; general and specific combining ability; additivity.

ÉTUDE DE COMPORTEMENT DE VARIÉTÉS D'ORGE (*HORDEUM VULGARE* L.) LOCALES ET INTRODUITES SOUS CONDITIONS SUB-HUMIDES DU NORD ALGÉRIEN. ÉTUDE DES GÉNÉRATIONS F_1 ET F_2 ISSUES DU CROISEMENT DIALLELE

Résumé

Description du sujet : Un croisement diallèle 6 x 6 complet, sans diagonale, comprenant 06 variétés d'orge (*Hordeum vulgare* L.) d'origines diverses a été effectué à la Station Expérimentale du Département de Biotechnologies (Université de Blida1). Les générations F_1 et F_2 et leurs parents respectifs ont fait l'objet d'une étude comparative des caractères qui composent le rendement en grains.

Objectifs : Caractérisation des parents et leurs hybrides F_1 et F_2. L'analyse diallèle nous permet de chiffrer l'importance de l'hétérosis, et d'explorer la possibilité de transmission des caractères quantitatifs dans les générations F_1 et F_2.

Méthodes : L'analyse génétique est réalisée selon la méthode 3, modèle I (modèle fixe) de Griffing (1956) et la méthode de Hayman (1954).

Résultats : Les résultats de l'étude comparative entre les génotypes, montre que la différence est purement génotypique pour les caractères : nombre d'épis par plant, poids de mille grains et le rendement en grains. L'hybridation réalisée entre les variétés, selon la formule conventionnelle n (n -1) s'est soldée par l'obtention de 30 croisements. Le passage de la génération F_1 à celle de la F_2, a montré une augmentation de l'effet hétérosis ce qui indique une bonne aptitude spécifique à la combinaison.

Conclusion : Les différentes analyses génétiques réalisées (Griffing, Hayman) montrent que les caractères : nombre d'épis par plants, et nombre de grains de l'épi sont les plus additifs. L'analyse de Hayman a montré aussi des possibilités de transgression des caractères à partir des formules parentales chez les deux générations F_1 etF_2.

Mots clés : Hétérosis ; aptitudes générale et spécifique à la combinaison ; héritabilité ; additivité.

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INTRODUCTION

In Algeria, barley (*Hordeum vulgare* L.) is ranked as the second cereal after durum wheat where it is mainly used for livestock feed. It is used in its various forms: grain, straw and even thatch [1, 2, and 3]. The yield of this specie is generally low and irregular, due to the effects of climatic constraints and applied technical cultivation which remains poorly performing [4, 5]. Yield growth has only become noticeable and regular since the beginning of the second half of the 20th Century [6]. Genetic progress accounts for between 33% and 66% of this improvement [6, 7]. The increase in yield can be done by appropriate cultivation techniques (tillage, fertilization and phytosanitary treatments), but also by searching for high performance genotypes adapted to the different environments [8]. Therefore, the importance of a barley breeding program based on the creation and research of genotypes, integrating the best agronomic characters of local (tolerance to deficit water) and introduced varieties (high productivity and resistance to diseases) are required. Many studies have been done to improve yield, which is polygenic trait and depends on environmental conditions [9, 10]. To this end, our work consists in studying the behavior of 6 barley genotypes in the sub-humid zone (Algeria), and for which a 6 x 6 diallel crossing complete without diagonal has been realized, then a genetic analysis (General Combining Ability, Specific Combining Ability, General and Specific reciprocal effects combining, Transgression, Heterosis, Additivity is performed in F_1 and F_2 prog enies based on yield components and grain yield. Diallel cross plan has been adopted to accommodate the maximum genetic information about parents and their progenies.

MATERIAL AND METHODS

1. Conducting the experiment

The study is based on 6 parental barley lines and F_1 and F_2 hybrids from the 6x6 diallel cross without selfing (Table 1). The parents are: Bahia, Fouara, and Soufara, Rihane and the two local varieties were Saïda and Tichedrett. The parental lines were chosen to ensure high genetic variability.

Table1: Crosses made between parents

♀ \ ♂	Tichedrett	Saïda	Bahia	Fouara	Soufara	Rihane
Tichedrett	-	T/SA	T/B	T/F	T/SO	T/R
Saïda	SA/T	-	SA/B	SA/F	SA/SO	SA/R
Bahia	B/T	B/SA	-	B/F	B/SO	B/R
Fouara	F/T	F/SA	F/B	-	F/SO	F/R
Soufara	SO/T	SO/SA	SO/B	SO/F	-	SO/R
Rihane	R/T	R/SA	R/B	R/F	R/SO	-

T : Tichedrett, SA : Saïda, B:Bahia, F: Fouara, SO: Soufara, R:Rihane.

The experiment was carried out in the field, during the campaigns 2012 / 2013, 2013 / 2014 and 2014/2015, at the experimental station of the Department of Biotechnology (University of Blida1, Algeria) which is a site located in a sub-littoral zone with a relatively mild climate. Rainfall varies from year to year from 550 mm to 650 mm. The three campaigns were favorable for our crop. However, in April we didn‘t receive any precipitation.

2. Experimental design

The seedling of the varieties was carried out in December during the 2012/2013 campaign, according to a complete randomized block design with 04 replications. The elementary plot consisting of 6 lines of 3 m spaced 20 cm.

A diallel crossing with reciprocal between the six barley genotypes was carried out during the same campaign.The F_0 seed (30 combinations) to produce the F_1 generation was subdivided into two lots, one was sown in 2013/14 to produce F_1 seed and the second was sown during the following season 2014/15, to have a design containing parents, F_1 and F_2.The F_1 and F_2 generations were sown in the middle of their respective parents by adopting a complete randomized block design with 3 replications. The element plot has a row of a of 2 m length. The spaces between the plants and rows were respectively 5 cm and 20 cm.

3. Measurements

The characters measured at the mature stage are the number of spikes per plant (NSP), the number of grains per spike (NGS); thousand grain weight (TGW), and the grain yield per linear meter (GY).At complete maturity of the grain, the harvest was done manually: *(i)* For the varieties, each of them has been harvested separately, *(ii)* The hybridized spikes are harvested separately, and are placed in bags individually, *(iii)* For F_2 hybrids, based on their phenotype, the best plants were harvested individually, and the rest were harvested as a mixture for each hybrid.

All measurements were made on 10 plants per repetition.

4. Data analysis

The results obtained were analyzed by the CoStat 6.400 software for the genotype effect. Combination skills are studied according to method 3 (combinations F_1, F_2 and their reciprocals without parents), model I (fixed model), Griffing [11], A graphical analysis of Hayman [12] was also performed to estimate heritability in traits studied. This type of test can be analyzed only when certain conditions are satisfied Cousin [13], the conditions governing the Hayman method have been verified.

5. Calculation of average heterosis

The heterosis in relation to the average of the parents is calculated as follows: [(Value of the Hybrid - P1 + P2 / 2) / (P1 + P2 / 2)] × 100. It measures the gap to additivity.

RESULTS

1. Study of parental characteristics

The analysis of variance of the different parents tested shows very highly significant genotypic differences (p<0.001). The year effect is not significant (p>0.05) for the characters studied. The variety x year interaction was not significant for the number of spike per plant (NSP), one thousand grain weight (TGW) and the grain yield per linear meter (GY), indicating that the expression of the potential of measured characters is not very variable.The variety x years interaction was significant (p <0.05) for the number of grains per spike (NGS).The coefficients of variation of the error vary from 10.45% (TGW) to 14.08% (NSP). During the two years, the average number of kernels of the spike is 41.02 grains; the varieties are classified in two groups. The group "a" is formed by the varieties: Bahia, Tichedrett, Saïda, Fouara and Rihane. While group "b" is constituted by Soufara (Table 2).

Table 2: Interaction effect variety x year on the yield components of grains and yield grains per linear meter

Characte	Number of spikes/plant (NSP)	Number of grains/spike (NGS)	Thousand grain weight (TGW)	Grain yield /linear meter (GY)
Genotype				
Tichdrett	3.66	44.19 a	52.21	125.71
Saïda	2.9	40.93 a	59.42	170.55
Bahia	3.55	48.44 a	54.25	140.94
Fouara	3.5	43.93a	56.63	156.61
Soufara	3.46	25.77 b	47.79	106.06
Rihane	3.01	42.86 a	56.75	113.65
Average year 1	3.25	38.29	53	128.54
Average year 2	3.44	43.75	56.01	142.63
General average	3.35	41.02	54.51	135.59
CV%	14.08	10.52	10.45	13.64
Genotype effect	***	***	***	***
Year effect	ns	ns	ns	ns
Interaction effect	ns	*	ns	ns

*and *** significant at p <0.05 and p <0.001 respectively, ns: not significant.

2. Analysis of F_1 and F_2 of the different characters

2.1. Heterosis of F_1 and F_2 hybrids

The determination of the heterosis effect with respect to the average parent highlights the differences in additivity (partial and total dominance). The averages of the F1 hybrids are lower than those of the parents for all the characters studied. The results in Table 3 show a negative mean heterosis effect varying from -36.78% for the grain yield to -1.77% for the weight of one thousand grains.

At the F2 generation level, only the number of spikes per plant (+ 1.47%) showed a positive heterosis effect compared to the average parent.A negative heterosis effect between -25.08% and -0.70% was revealed for the rest of the characters within the F2 combinations.

Table 3: Heterosis of the different characters relative to the average parent in F_1 and F_2

Characters	Values of heterosis in F_1			Values of heterosis in F_2		
	Average F_1	Parental average	Hétérosis average (%)	Average F_2	Parental average	Hétérosis average (%)
Number of spike per plant	2.86	3.41	- 16.13	3.45	3.41	+ 1.47
Number of grains per spike	36.87	41.08	-10.25	38.44	41.08	- 6.43
Thousand grains weight	54.68	55.33	-1.17	55.14	55.53	- 0.70
Grain yield /linear meter	110.69	175.10	-36.78	131.18	175.10	- 25.08

2.2. Analysis of general and specific combining ability (GCA and SCA)

GCA is the average gametic effects of an individual; it represents the additivity effect, however, the SCA measures the gaps in CGA additivity forecasts (so it only makes sense for a zygote). This model is the simplest, the most biologically rational [14, 15].

The analysis of variance of combining abilities carried out according to the model of Griffing (1956) shows very highly significant effects of GCA, SCA and reciprocal effects for the number of grains per spike and thousand grain weight (Table 4).

Table 4. Analysis of variance of general and specific combining ability and reciprocal effects of different characters in F_1.

Characters	M.S					
	GCA (df=5)	SCA (df=9)	Reciprocal effects General (df=5)	Reciprocal effects Specific (df=10)	Treatments (df=29)	Block (df=1)
Number of spikes per plant	2.08^{*}	0.75^{ns}	0.78^{***}	1.03^{**}	1.08^{**}	0.00^{ns}
Number of grains per spike	882.9^{***}	45.11^{***}	77.72^{***}	119.02^{***}	220.67^{***}	4.54^{ns}
Thousand grains weight	115.34^{***}	42.05^{***}	70.84^{***}	67.05^{***}	68.27^{***}	0.38^{ns}
Grain yield / linear meter	11820.91^{***}	2192.46^{**}	1452.24^{***}	5156.86^{***}	4747.12^{***}	193.75^{ns}

*, ** and ***, ns: significant at p <0.05, p <0.01, and p <0.001, not significant respectively.

In the F_1 generation, a highly significant (p <0.01) effect of genotypes was observed for the number of spikes per plant and a very highly significant effect (p <0.001) for the characters number of grains per spike, weight of thousand grains and grain yield. No meaning for the block effect.

General Combining Ability (GCA) effects are significant to very highly significant for all the traits studied. While, Specific Combining Ability (SCA) effects are highly to very highly significant for all traits, except for the number of spikes per plant. The general reciprocal effects are very highly significant for all measured variables. Finally, the specific reciprocal effects are highly and very highly significant for all traits. In the second generation F2, a significant genotype effect (p <0.05) could be demonstrated for the weight of one thousand grains, a highly significant effect (p <0.01) for the number of spikes per plant and very highly significant for the number of grains per spike and grain yield per linear meter (p <0.001) (Table 5).

Table 5: Analysis of variance of general and specific combining ability and reciprocal effects of different characters in F_2.

Characters	M.S					
	GCA (df=5)	SCA (df=9)	Reciprocaleffects General (df=5)	Reciprocaleffects Specific (df=10)	Traitements (df=29)	Block (df=1)
Number of spikes per plant	0.97^{*}	0.82^{ns}	0.04^{ns}	0.25^{*}	0.51^{**}	0.01^{ns}
Number of grains per spike	727.25^{***}	113.67^{***}	128.84^{***}	77.45^{***}	209.59^{***}	3.93^{ns}
Thousand grains weight	118.35^{ns}	109.49^{*}	85.84^{ns}	118.90^{*}	110.19^{*}	14.67^{ns}
Grain yield / linear meter	12550.29^{***}	2031.76^{*}	1869.19^{*}	5316.20^{***}	4949.83^{***}	2263.45^{ns}

*, **, *** and ns: significant at p <0.05, p <0.01, p <0.001 and not significant respectively.

The existence of significant genotype effect had allows to continue the analysis at the individual level. A significant effect of GCA was revealed for the number of spikes per plant, and a very highly significant GCA effect controls the characters studied except for the one thousand grain weight parameter where no GCA effect was observed (p> 0, 05).

2.3. Heredity of characters according to Hayman's analysis in F_1

The calculation of the variance (Vr) and the covariance (Wr) allows drawing graphs (parabolas and regression lines) from which a genetic interpretation (dominance, transgression ...) is realized.

In the F_1 generation, incomplete dominance characterized the number of spikes per plant, number of grains per spike, and the weight of one thousand kernels. The graphs which represent these parameters show that the regression line intersects the (Wr) axis above the origin (Fig. 1). The Wr / Vr regression line passes below the origin, which shows a super dominance effect for grain yield per linear meter.

2.4. Heredity of characters according to Hayman's analysis in F_2

In F_2 hybrids, the number of spikes per plant and the number of grains per spike are influenced by incomplete dominance. A superdominance effect governed the characters: thousand grain weight and grain yield per linear meter (Fig. 2). The distant position of the parabola of the points representing the parents tested indicates that transgressive forms can be obtained in the offspring of the crosses made between the parents included in this test [13].The graphs (Wr + Vr, t) show that the negative-action dominance (b> 0) is unfavorable for the expression of the characters studied (Fig. 2). The graphs (Wr + Vr, t) show that the negative-action dominance (b> 0) is unfavorable for the expression of the characters studied (Fig. 2).

DISCUSSION

The analysis of the parental genotypes indicates the presence of a rather important variability which justifies the genetic analysis and the utility of the selection.

The year effect and even the interaction variety x year are not significant for the majority of the characters studied which suggests that the expression of the potential of these characters is not very variable.

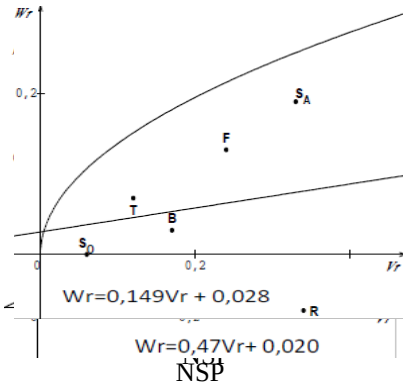
The calculation of the heterosis relative to the average parent is negative for the majority of the characters measured.According to Jung and Lelly [16], the absence of heterosis or its low value in barley probably reflects an important additive action of the genes.The average heterosis increased from (-16.13%) to (+ 1.47%) between F1 and F2 for the number of spikes, the same results are observed in durum wheat, by Bousalhih [17].

In barley, according to Fejer and Fedak 1978 In Ramage [18], the heterosis for the number of spikes per plant parameter reached 10% compared to the average parent in a very low density seedling.

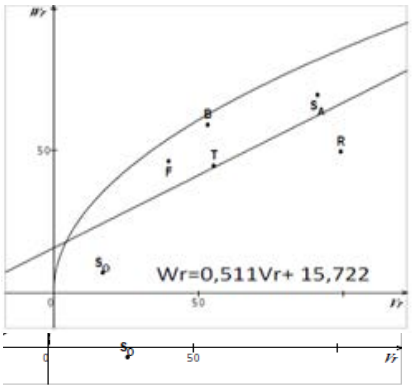
The analysis of variance of the General and specific combining abilities indicates a significant difference between genotypes, which suggests that genes present effects of additivity and dominance for the control of the characters studied.

A strong GCA effect reveals the preponderance of additive effects for character control. According to Lefort-Buson, and Dattée, 1985, Samad and al. [19, 20], selection may be performed on the GCA of the lines even before the production phase of the hybrid. The analysis of grain yield per linear meter, in both F1 and F2 generations, showed a very highly significant GCA effect which indicates the dominance of the additive type genes, the same result is found by Lee and Brewbaker [21] in corn, for this trait.

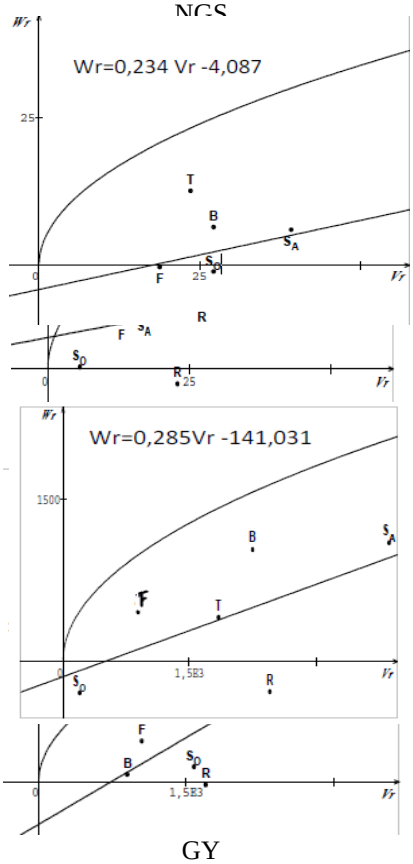
The SCA effect is significant for all traits except the number of spikes per plant. Houshmand and al. [22] found a significant SCA effect for all traits studied in durum wheat except flag leaf length. The analysis of heredity of characters according Hayman showed the possibilities of transgression from parental formulas in both F1 and F2. Superdominance is found in both generations for grain yield per linear meter.



NSP

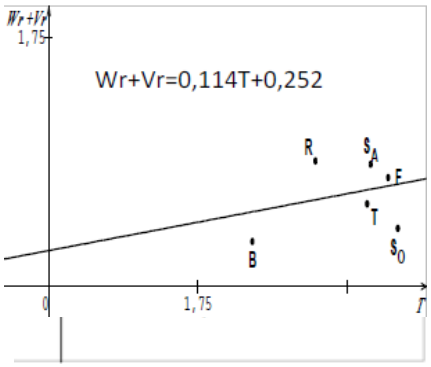


NGS

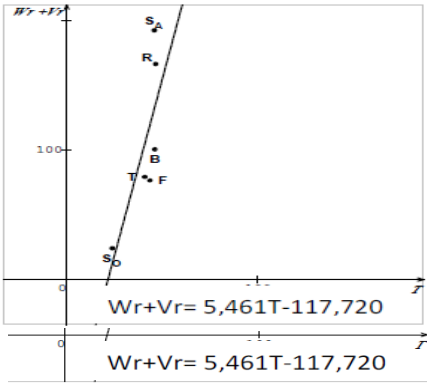


GY

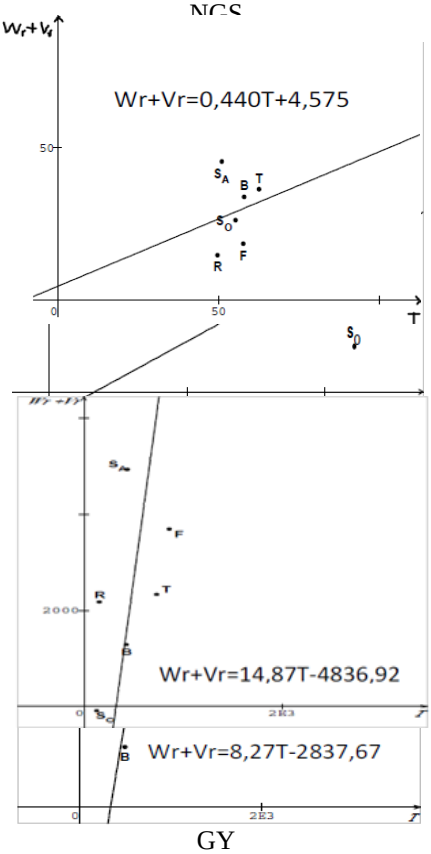
Figure1: Graphical analysis of Hayman in F_1



NSP



NGS



GY

Figure 2: Graphical analysis of Hayman in F_2

CONCLUSION

The results indicate the presence of variability between the different genotypes for the variables analyzed. The absence of genotype x year interaction for grain yield indicates stability in the behavior of parent genotypes.

The heterosis effect compared to the average parent is negative except the number of spikes per plant (+1.47%) at the level of the F_2 generation. The transition from the F_1 generation to that of F_2, showed an increase in the heterosis effect which shows the importance of additive genes.

The mean squares of the GCA are higher than those of the SCA, which indicates that the choice of parents before hybridization remains a priority.

The number of spikes per plant, and the number of grains of the spike show effects of partial dominance, which tends to confirm the strong additivity of these characters.

The super dominance of grain yield suggests the non-additivity of this trait, while its components (number of spikes per plant, number of grains of the spike and the weight of a thousand grains) are more additive, therefore, it would be more effective to make the selection on these components.

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