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Genotypic similarity of performance and stability of environmental responses of barley cultivars (*Hordeum vulgare L*)

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تحليل تشابه النتائج القياسية واستقرارية الاستجابات للمحيط عند بعض أصناف الشعير

أجريت تجربة متعددة الأماكن في منطقة شبه جافة بسطيف، الجزائر، لدراسة تشابه النتائج القياسية لمجموعة من أصناف الشعير. وتبين النتائج وجود تفاعلات مرتفعة صنف بيئي (ص xو)، مع استجابات جد مختلفة للتباين في ظروف الوسط. و يتميز أحسن طراز عرقي من ناحية الغلة بانحدار يعادل 1 و مساهمة معتبرة لمربع متوسط تفاعل الصنف x الوسط (ص x و). ويبدو على أن التباين في مركبات المردود هو السبب في عدم استقرار الاستجابات في تغير المواقع. و سمح التصنيف القائم على أساس مؤشر عدم التشابه بتجمع الأصناف حسب تشابه استجاباتها لمختلف الأماكن مع تفاعل ضعيف ص x . ويظهر بأن الأصناف المجمعة تختلف أساسا في استجاباتها للتغير في المناطق : بحيث يظهر البعض أكثر تأقلما في المناطق الصعبة، و الآخر يتحسن إنتاجه تدريجيا كلما تحسنت إنتاجية الوسط .

الكلمات المفتاحية : استقرار – الغلة – تجمع – معامل الانحدار – مؤشر عدم التشابه.

Similitude génotypique de performances et stabilité des réponses à l'environnement des cultivars d'orge (*Hordeum vulgare L*)

Une expérimentation multilocale a été conduite, dans la région semi-aride de Sétif (Algérie), pour étudier les similitudes dans les performances génotypiques d'un groupe de variétés d'orge. Les résultats indiquent la présence d'interactions génotype-environnement (GxE) très fortes, ainsi que des réponses très différentes à la variation des conditions du milieu. Les meilleurs génotypes du point de vue rendement se caractérisent par une pente égale à 1 et une forte contribution au carré moyen de l'interaction GxE. La variation dans les composantes du rendement semble être la cause de la faible stabilité dans les réponses aux changements des lieux. La classification basée sur l'indice de dissimilitude permet de grouper les cultivars selon leurs similitudes de réponses aux différents lieux, avec une faible interaction GxE. Les génotypes groupés diffèrent essentiellement dans la réponse au changement des lieux: certains semblent bien venir en milieux plutôt difficiles, alors que d'autres deviennent plus productifs à mesure que le milieu s'améliore.

Mots clés : Orge - *Hordeum vulgare* L.- Stabilité - Rendement - Groupage - Indice de dissimilitude

Genotypic similarity of performances and stability of environmental responses of barley cultivars (*Hordeum vulgare L*)

A multilocation experiment was conducted in the semi-arid region of Setif (Algeria), to assess genotypic similarity of performances of a set of barley genotypes. The results indicated the presence of high genotype-environment interactions (GxE) and different genotypic responses to varying environments. Best performing genotypes, on average, were characterized by a slope equal to 1 and a high contributiuon to GxE interaction mean square. Variation in yield components appeared to be responsible for low stability of environmental responses. Clustering based on dissimilarity index lead to the grouping of genotypes with similar responses to environmental changes and a low GxE interaction. It appeared that grouped genotypes differed in their responses to varying environments: some seemed more adapted to low yielding environment, while others were more productive as growing conditions became more favorable.

Key words : Barley - *Hordeum vulgare* L. - Grain yield - Clustering - Dissimilarity index

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INTRODUCTION

Barley (*Hordeum vulgare L.*) is traditionally grown, in Algeria, under rainfed conditions in marginal environments of the semi-arid region, where water is the most important production constraint. The area under production varies from 700,000 ha to 1,200,000 ha annually with an average grain yield of 700 kg/ha. The important barley producing directorates are Saida, Tiaret, Setif and Medea. To improve production, barley genotypes and advanced breeding lines has been evaluated in uniform trials in Setif region since 1987, as part of a research program to develop improved and well adapted cultivars. Bouzerzour & Djekoune (1995) have shown that genotype x environment interactions (GxE) are of major importance in the semi-arid region of the high plateaux. They found that environment stratification, based on differential responses of a set of barley cultivars, reduced the size of GxE interaction and identified macro-zone which appeared more homogeneous. However some residual GxE interaction subsisted, within macro-zone, even after stratification. This poses the problem of selecting those genotypes that are significantly superior in grain yield, since test cultivars cannot be assessed simply by their average effects, their pattern of responses over the various locations must be taken into consideration.

Informations on adaptability and performance stability of a genotype over years are important. Farmers, in these fluctuating environments are interested primarily in adopting genotypes with high performance stability, since increased stability is equivalent to a decreased frequency of crop failure (Ceccarelli & Grando, 1991).

The purpose of this study was to determine the relative yield stability in a semi-arid region of a set barley genotypes from different geographic origins.

MATERIALS AND METHODS

10 barley genotypes were grown from 1986/87 to 1991/92 at the Agricultural Research Station of Setif, Algeria. The experimental site is located 5°21'E, 36°9'N and 1100 m altitude above sea level. 12 environments were experienced over a 6 year-period, with 3 seeding dates (October, November and December) per year, during 3 years. Each trial was conducted in a randomized complete block design with 3 replicates. Plot was 10 m long by 6 rows with 0.20 m inter-row spacing. At maturity, data on number of heads/m^2 (HN/m^2), number of kernels/head (KH), number of kernels/m^2 (KN/m^2) and kernel weight (TKW) were collected from 3 samples of one segment of 1 m-row, harvested on the diagonal from each plot. Grain yield was determined from the harvested whole plot. A combined analysis of variance was performed to determine relative magnitude of pertinent variance components (Comstock & Moll, 1963). Assumptions were made that environments as well as genotypes were random. The individual cultivar response to changing environments was determined by regressing individual cultivar mean grain yield, within environment, on the environmental index. The environmental index was calculated as the mean yield of the 10 genotypes in each environment minus the grand mean (Eberhart & Russell, 1966). The residual mean square of the regression analysis of each cultivar was tested for significance using the error from the overall analysis of variance. A significant F. value would indicate that the residual mean square from regression was significantly different from zero. The hypothesis that each regression coefficient (b) equaled unity was tested by a t-test using the standard error of the corresponding b value. Genotypes were groupes for similarity of responses to varying environments by calculating dissimilarity indices between genotypes and subset of genotypes, according to the method outlined by Lin (1982). Genotypes are considered to respond in the same way to environments if their GxE interaction mean square (equivalent to the dissimilarity index) is not significantly different from the error term of the overall analysis of variance. The advantage of this method is that genotypes within cluster could be compared by their average effect since the GxE interaction is not significant.

Based on the regression parameters, the responses of the best cultivar within cluster were predicted over a range of hypothetical environmental productivity, including poor, moderate and favorable years; at each of 500 kg increament over a yield range of 500 to 6000 kg/ha. The predicted responses were converted to percentage of the predicted responses of the local check Tichedret and ploted to show their relative behavior.

RESULTS AND DISCUSSION

Procedure of Comstock & Moll (1963) was adopted to test the significance of genotype (G), environment (E) and GxE interactions. Differences among environments, genotypes and GxE interactions were highly significant for grain yield and yield components (Table 1).

Table 1.Mean squares and pertinents variance components from the combined analysis of variance of grain yield and yield components

Source	df	mean squares GY(q/ha)	HN/m^2	KH	$KH/m^2(x10^3)$	TKW(g)
Total	359	354.6	11672.0	78.1	19.07	17.80
Environment (E)	11	9676.5**	229712.1**	1553.5**	496.9**	268.4**
Genotype (G)	9	537.5**	88367.5**	242.1**	41.9**	124.3**
GxE	99	141.3**	6214.2**	69.1**	8.9**	18.6**
Blocks/E	24	7.6	13290.0	42.9	0.91	11.8
Erreur	216	8.4	490.3	6.9	0.28	1.60
	S^2E	317.4	7449.8	49.47	16.26	8.32
	S^2G	11.0	2282.0	4.80	0.92	2.93
	S^2GxE	44.6	1907.9	20.73	2.86	5.66
	Ratio : S^2G/S^2GxE	1/4	1/0.83	1/4.31	1/3.11	1/1.93

ns, *, **: effect non significant and significant at 5 and 1% respectively

The effect of environmental factors is evident from the large variances for environment and GxE interaction, reflecting the joint effects of climatic factors. Cultivar x environment interaction was apparent in the ranking of the genotypes in the 12 environments examined (data not shown). Certains genotypes ranked from either the first or second highest yielding in one environment to either seven or eight ranked in another environment.

Means grain yield and yield components per environment and genotypes are reported in tables 2 and 3, along with the stability parameters. The regression coefficients ranged from 0.84 to 1.21 and were all significantly different from 0 but not from unity except the one of Jaidor which was significantly superior to 1. This cultuvar appeared to be more responsive to favorable environments, than the other cultivars studied. In lower yielding environments, Jaidor leaked the ability to give acceptable grain yield. Mean square deviation from regression was significantly different from zero for all genotypes. Barberousse, Tina and Soufara contributed the largest proportion to the GxE, while the two local landraces, Tichedret and Saida contributed the smallest proportion to the mean square GxE (Table 3). R^2 values were all above 0.78, indicating that there was little deviation about the linear regression line (Table 3).

According to the definition of Eberhart & Russell (1966), a regression coefficient of unity, and a minimum deviation from regression indicated average stability. A cultivar with above average grain yield and fulfilling these two critiria would perform well in all environments.

Table 2. Means grain yield and yield components for the 12 environments experienced

Environment Year	date	Means GY (g/m^2)	HN/m^2	KH	KN/m^2	TKW (g)
86/87	Nov	570	501	25.4	13050	43.3
87/88	Nov	529	477	25.6	12250	43.6
88/89	Oct	148	306	11.1	3820	38.5
	Nov	175	332	13.2	4520	39.4
	Dec	228	323	19.4	6200	37.2
89/90	Oct	27	240	4.2	750	36.9
	Nov	198	256	17.9	4670	44.1
	Dec	221	299	20.7	5790	36.5
90/91	Oct	160	296	12.6	3970	41.0
	Nov	365	404	20.2	3250	44.7
	Dec	428	430	21.8	9920	43.7
91/92	Nov	558	458	30.2	13180	40.4
Average		300	360	18.5	7200	40.8
LSD5%		13.37	56.08	3.18	464.08	1.67

Baker (1969) suggested that the mean square deviation from regression was the most appropriate criterion for measuring phenotypic stability because this parameter measures the predictability of genotypic reaction to environments. For Langer *et al.* (1978), the regression coefficient is a measure of the response of a genotype to varying environments. Based on the stability parameters, four genotypes had above average grain yield, a regression coefficient equal to 1, a high R^2 but a relativelly large and significant deviation from regression mean square. These genotypes were Begonia, Tina, Tatiana and Soufara. The formers are Spanish cultivars and the later is a Syrian breeding line.

Table 3. Means grain yield and yield components of the 10 genotypes tested and their stability parameters

Genotype	GY (g/m^2)	HN (m^2)	Means KH -	KN (m^2)	TKW (g)	Stability parameters Slope[1] +E.T	R^2 (%)	MS Dev[2] (x 10^2)
Tichedrett	279	309	19.7	5600	42.6	0.97+0.07ns	95	17.7*
Acsad 176	268	347	17.9	6800	40.1	0.97+0.08ns	93	26.6**
Jaidor	279	333	17.6	6700	41.0	1.21+0.07*	96	21.9**
Begonia	326	342	22.4	8000	40.8	0.85+0.09ns	89	33.8**
Barberousse	289	353	19.9	7760	36.6	1.05+0.13ns	85	66.7**
Tatiana	332	352	21.9	8160	39.7	0.84+0.14ns	78	35.6**
Tina	342	402	19.2	8730	40.3	0.87+0.11ns	86	46.8**
Saida	272	354	15.4	5970	42.1	1.10+0.06ns	97	15.9*
Rihane	266	348	16.5	6160	41.5	1.13+0.09ns	92	36.4**
Soufara	352	485	14.7	8050	43.3	0.98+0.11ns	88	47.6**
Average	*300*	*360*	*18.5*	*7200*	*40.8*			
LSD5%	*13.4*	*10.2*	*2.21*	*244.4*	*1.58*			

(1) ns, * : b non significantly different from 1 and significantly diffrent from 1
(2) *, ** : MS deviation significantly different from 0 at 5 and 1% respectively

A cultivar-location experiment is one important step for cultivar assessement. Yield stability is a measure of variation between potential and actual yield of a genotype accross changing environments. Poor grain yield may be associated with low stability. Yield stability could result from genetic heterogeneity, stress tolerance, ability to recover from stress, yield components compensation or a combinaison of these traits (Fisher, 1985; Bansal & Sinha, 1991).

Grain yield was negatively correlated with the regression coefficient and with the coefficient of determination indicating that genotype with above average grain yield tended to have a b value less than unity and had a sizeable proportion of the variation in grain yield which is not ascribed to the linear response to varying environments. Grain yield was not significantly correlated with deviation from regression, but was highly and negativelly correlated with variation in its components. The correlation coefficients between Grain yield and the coefficients of variation of yield components were -0.63**, -0.84**, -0.82** and -0.07ns with HN, KH, KN/m^2 and TKW respectively. High variation in the means of the yield components was associated with below average grain yield over environment. Grain yield was highly correlated with its components (Table 4). This indicated that variation in climatic growth conditions affected grain yield through the number of kernels/m^2. As the number of grains produced per unit land area is the product of head number x kernels per head, then grain yield was affected through these two paths. The correlation coefficient between kernels/m^2 and head number/m^2 and between kernels/m^2 and kernels/head were 0.78** and 0.86** respectively.

Table 4. Correlation coefficients between grain yield and yield components and between grain yield and stability parameters

Yieds components	r	Stability parameters	r
HN	0.81**	b	-0.69**
KH	0.81**	R^2	-0.71**
TKW	0.40**	MSDev.	0.45ns
KN/m^2	0.96**		

ns, *, ** : coefficient non significant and significant at 5 and 1% respectively

The ideal genotype is one with a regression coefficient equal to unity, a low deviation from regression and above average grain yield (Finlay & Wilkinson, 1963; Eberhart & Russell, 1966; Sharma *et al.* 1987). The present results indicated that genotypes which fulfilled critiria concerning regression coefficient and above average grain yield had a high deviation from regression. They could not be compared by their average effect. A further step would be to compare genotypes within cluster of similar response pattern. Clustering based on dissimilarity index gave three groups (Table 5).

Table 5. Dissimilarity indices for genotype clustering and critical F. value

Cluster cycle	Genotypes [1] grouped	Smallest index	F. value calculated	Tabulated F. value 5%
1	8, 9	4.4	0.52ns	1.79
2	2(8, 9)	7.3	0.86ns	1.55
3	3(2, 8, 9)	8.1	0.95ns	1.46
4	1(3, 2, 8, 9)	9.2	1.08ns	1.39
5	5(1, 2, 3, 8, 9)	21.4	2.52*	1.35
6	4, 6	6.5	0.76ns	1.79
7	7(4, 6)	9.3	1.09ns	1.55
8	10(7, 4, 6)	10.5	1.24ns	1.46
9	5(10, 7, 4, 6)	28.5	3.34*	1.39

(1) genotypes in the order give in table 3.
ns, **, ** : F value non significant and significant at 5% level

Comparing means over environments according to Newman Keul's test (Steel & Torrie, 1960) indicated that in cluster 1, Jaidor, Saida and Acsad 176 did not yieded significantly more than the check Tichedret. In cluster 2, Soufara appeared to give best performances within this groupe (Table 6). The relative behavior of Soufara and Jaidor relatively to Tichedret are indicated in Figure 1. It appeared that Soufara had its greatest advantage in low producing environments (Year x seeding date), where Jaidor seemed vulnerable, but this cultivar responded more as environment became more favorable, relatively to Soufara which appeared less sensitive to this change.

Table 6. Grouping means grain yield within cluster

Cluster 1		Cluster 2	
Genotype	GY (g/m^2)*	Genotype	GY(g/m^2)*
Tichedret	278 a	Soufara	351 a
Jaidor	277 ab	Tina	342 ab
Saida	271 ab	Tatiana	332 bc
Acsad 176	267 ab	Begonia	326 c
Rihane	264 b		

* : means followed by the same letter are not significantly different according to Newman-Keul's test

CONCLUSION

This investigation makes apparent the magnitude of genotype x environment interactions that must be confronted in a barley breeding or evaluation program, in a semi-arid region. It demonstrates cultivar differences in response to various environmental conditions. These findings suggest that genotypes should be compared within cluster of similar response pattern to environmental conditions; as they suggest also that cultivars should be developped for regional rather than general adaptability.

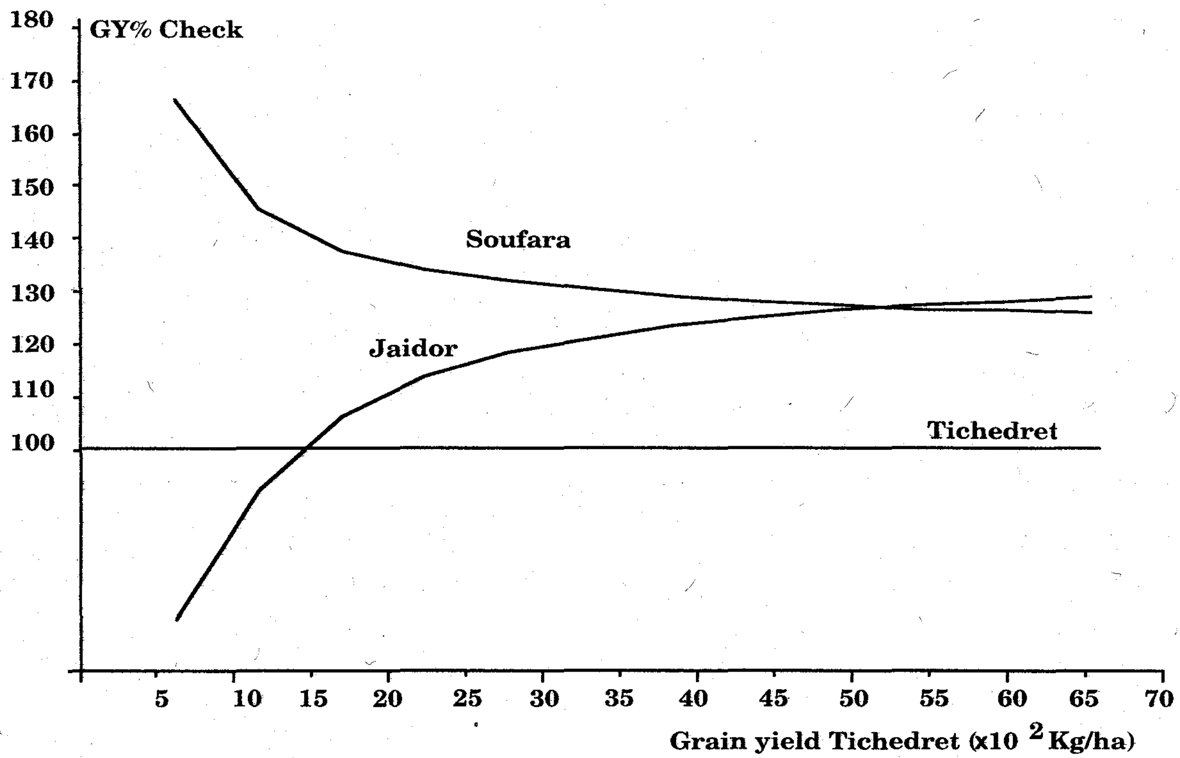

Figure 1. Performances of the best varieties, per cluster, Soufara and Jaidor relatively to the check Tichedret

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