Selection of superior advanced lines of bread wheat (*Triticum aestivum* L.) by using some stability parameters.

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Sélection des lignées adaptées et stables de blé tendre (Triticum aestivum L.) en utilisant quelques paramètres de stabilité

Résumé

L'objectif de cette étude était la sélection des lignées adaptées et stables de blé tendre (Triticum aestivum). Quatre paramètres de stabilité ont été utilisés (bi, S^2di, Pi et Wi) pour estimer la stabilité et l'adaptation des lignées. Vingt quatre lignées avancées de blé ont été testées durant les campagnes agricoles 1992-93 et 1993-94 dans six locations avec différentes conditions édapho-climatiques. Durant la campagne agricole 1992-93, une sécheresse sévère a eu lieu dans les domaines de Douyet, Jemâa Shaim et Sidi El Aidi. Après quoi, chaque combinaison du site x année est considérée comme un environnement et les données sont analysées sur un total de 9 environnements. L'analyse de la variance a montré un effet hautement significatif pour l'environnement (E), le génotype (G) et l'interaction (GxE). L'interaction est de type qualitative à cause du changement de classement des lignées d'un environnement à un autre. Tous les coefficients de régression (bi) et la déviation par rapport à la ligne de régression (S^2di) sont différents de zéro. Trois lignées (# 1, 4 et 18) ont montré un coefficient de régression significativement différent de l'unité, ceci suggère que ces dernières lignées répondent plus à des environnements favorables qu'à des environnements défavorables. Ces lignées ont été classées comme non stables. Considérant conjointement l'écovalence (Wi), le coefficient de régression (bi) et l'indice de supériorité (Pi), les lignées qui peuvent être retenues sont # 2, 6, 7, 10, 13, et 22. Ces lignées ont montré une large adaptation et elles sont stables. L'analyse en cluster a montré que le groupement tend à combiner le croisement / nom et le rendement potentiel. Il est aussi important de noter que les variétés Achtar et Jouda, utilisées comme témoins, se classent comme stables avec une large adaptation.

Mots-clés : Interaction GxE, stabilité, *Triticum aestivum*; adaptation large.

استنباط سلالات القمح الطري ذات تأقلم واستقرار الانتاج باستعمال مؤشرات للاستقرار

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ملـــخص

تستهدف هذه الدراسة استنباط سلالات من القمح الطري (*Triticum aestivum*) ذات تأقلم واستقرار الانتاج. ولهذا الغرض استعملت أربعة مؤشرات للاستقرار (bi, s2di, Pi, Wi) من أجل تقييم مدى استقرار إنتاج هذه السلالات و تأقلمها. وهكذا ضمت التجربة 24 سلالة متقدمة خلال سنتي 1992-1993 و1993-1994 في 6 مناطق ذات تباين في المعطيات المناخية. عرف الموسم الفلاحي 1992-1993 جفافا قاسيا في الميادين التجارب التالية: الضويات، جمعة السحايم وسيدي العايدي. ولهذا اعتبرنا كل موقع – موسم كبيئة على حدة وتم تحليل المعطيات حسب 9 بيئات. (environnements) أسفرت النتائج على أن كل البيئات (E)، السلالات (G)و (GxE) لها تأثير واضح على الإنتاج. ثلاث سلالات 1, 4, و18 قد أبانوا عن مؤشر bi مخالف لواحد، مما

يجعلنا نقترح على أن هذه السلالات لها قدرة للتجاوب إيجابيا مع البيئات الملائمة. وهكذا اعتبرت هذه السلالات غير مستقرة. ومن جهة أخرى إذا أخذنا بعين الاعتبار مؤشر (Wi) Ecovalence، coefficient de régression (bi) و(Pi) l'indice de supériorité معا، يمكن انتقاء السلالات التالية 2، 6، 7, 13,10و 22. أسفرت عملية cluster تقارب الهجين /الإسم مع الإنتاج الأقصى. التجاوب الذي حصل هو من نوع كيفي وذلك بسبب تغيير ترتيب السلالات حسب المناطق. تجدر الإشارة كذلك إلى أن أصناف أشطار وجودة اللذان استعملا كشاهدين خلال هذه التجربة أظهرا استقراراً عاليا ولهما تأقلم واسع.

الكلمات المفتاح : قمح طري، تحليل الاستقرار، تأقلم واسع، Interaction GxE

Abstract

The objective of this study was to select adapted and stable advanced lines of common wheat (Triticum aestivum). Four parameters were used (bi, S^2di, Pi and Wi) to assess stability and adaptation of these lines. Twenty four lines of wheat were tested during two cropping seasons 1992-93 and 1993-94 in six locations with different climatic conditions. During 1992-93, a severe drought occurred and it affected trials in three experimental stations: Douyet, Jemâa Shaim and Sidi El Aidi. For 1993-94, we have data from all the six locations. Therefore, each combination of site x year is considered as an environment and the data were analyzed over a total of 9 environments. The analysis of variance (ANOVA) showed that the effect of the environment (E), Genotype (G) and GXE interaction were highly significant. The interaction was qualitative as there was a change in performance from one environment to another. All the regression coefficients (bi) and the deviation from regression (S^2di) were different from the value zero. Only three entries (#1, 4 and 18) showed a regression coefficient significantly different from the unity, suggesting that these entries respond well to favorable environments rather than to unfavorable ones. These entries could be classified as unstable. Considering conjointly the ecovalence, regression coefficient and the superiority index, lines that could be retained were: #2, 6, 7, 10, 13 and 22. Cluster analysis was performed to show the type of GXE interaction that has occurred. From the six clusters identified, the grouping tends to combine the cross/name and yield potential meaning that there is a correlation between the yield and the cross itself. It is important to notice that the varieties Achtar and Jouda, used as checks in this experiment, were classified as stable and showed wide adaptation. The selected lines have a good yield and they were classified as stable.

Key words : GXE interaction, stability analysis, *Triticum aestivum*, wide adaptation.

Introduction

Genotype by environment interaction (GXE) is a major limiting factor for selection to increase crop yields. A successfully developed new cultivar should have a stable performance and a broad adaptation over a range of environments in addition to high yield potential (Yue Guilan *et al.*, 1990). The GXE interaction is defined as a differential genotypic expression across environments. It reduces the association between phenotypic and genotypic values. Measuring GXE is important to examine genotypic adaptation and also to determine an optimum breeding strategy for releasing genotypes with adequate adaptation to target environments. High environmental fluctuations and the presence of diseases and insects are in most cases responsible for highly significant interactions GXE (Finlay and Wilkinson, 1963).

Depending on the extent of GXE interaction should a breeding program aim for wide or specific adaptation. Ceccarelli (1989) argued that wide adaptation does not exist across different macro-ecological environments and that selection for high yield potential has not increased yield under low inputs. Similarly, Lawn (1988) stated that high yield and agronomic stability were mutually exclusive over a wide range of environments. Many breeders would contend that accumulation of tolerances to a number of stresses is the key to wide adaptation and consequently selection in multiple environments is the best way to breed stable genotypes (Romagosa and Fox, 1993).

The partition of GXE interaction remains an important indicator to selection for wide or specific adaptation. If the interaction genotype by year by site is significant, the breeder should test lines over many sites and many years in order to select varieties with wide adaptation (Amri, 1992). Brennan and Sheppard (1985) suggested that selection of varieties with specific adaptation is important when genotype by site interaction is highly significant, but if the year effect is important and genotype by year is highly significant we should look for varieties with large adaptation.

Fox and Rosielle (1982) suggested that the characterization of the environment and its subdivision into homogenous sub regions could minimize the GXE interaction and increase the efficiency of selection. Horner and Frey (1979) *obtained* a reduction of 40% of genotype by site interaction when the region of *Avena* was subdivided into five sub regions in Iowa. Austin (1993) suggested that breeding efficiency can be increased by early generation selection using trait-based selection, facilitated by integration of current knowledge in the physiology and genetics of crops. However, any trait used must be rapidly and cheaply measured. The efficiency of this kind of selection depends upon a complete understanding of target environments in terms of biotic and abiotic constraints and their frequency of occurrence (Romagosa and Fox, 1993).

Some authors use the term adaptation to refer to spatial variation, and the term stability for performance at a given site across years or management practices. Becker (1981) distinguished two types of genotypic stability. The biological stability, in the homeostatic sense, in which genotype maintains a constant yield across environments, and the agronomic stability, by which a genotype is considered stable if it yields well relatively to the potential of test environments.

Many methods of analysis of stability requiring a two table entry data, genotypes and environments, have been proposed. In this paper, we will describe those that are commonly used to assess the stability of genotypes.

Material and Methods

1. Material

The experimental materials used in this study are presented in table 1. Data were obtained from Advanced Yield Trials of *Triticum aestivum* that were conducted during two growing seasons 1992-93 and 1993-94 at the following experimental stations: Annoceur, Douyet, Jemâa Shaim, Marchouch, Sidi El Aidi and Tessaout. A severe drought occurred during the season 1992-93 which affected trials at Douyet, Jemâa Shaim and Sidi El Aidi. There was no data for these latter experimental stations during that year; therefore, we analyzed the data as combined effect of year and site, which gave us 9 environments in total.

2. Description of environments

Six sites were retained for the evaluation during two years. Each combination site X year is considered as an environment. For these sites the stresses are different. Thus, at Annoceur we have generally as biotic stresses: common bunt, loose smut, rusts, powdery mildew, Barley Yellow Dwarf Virus (BYDV) and Russian wheat aphid. On the other hand, the abiotic stresses are cold during tillering and drought at the end of the cycle. For Douyet, we have rusts and Septoria mainly during wet years and as abiotic stresses there is drought and heat caused by the wind called 'Chergui'. At Jemâa Shaim, the main pests are Hessian fly and sawfly, combined with drought that may occur at the beginning or at the end of the cycle. For Marchouch, located in a favorable environment (rainfall>500 mm), the main diseases are Septoria, rusts and Bareley Yellow Dwarf Virus. At Sidi El Aidi experimental station, the main stresses are Hessian fly, sawfly and root rot combined with drought at the beginning and/or at the end of the cycle. Tessaout is the only irrigated experimental station in our study, located in the arid zone of Morocco, most of wheat diseases are enhanced by such environments, but the common ones are leaf and stem rust, common bunt and powdery mildew.

The approach of using a combination site X year as an environment was justified because, during the two cropping seasons 1992-93 and 1993-94, the environmental conditions were totally different. We had a severe drought during the first season and the trials in Douyet, Jemâa Shaim and Sidi El Aidi were totally lost. Favorable and unfavorable environments are defined according to the mean yield that is directly or indirectly affected by climatic conditions (rainfall, temperature and diseases).

3. Methods

3.1 Analysis of variance (ANOVA)

The magnitude of sums of squares as well as variance components can be used to assess genotype's stability. Romagosa and Fox (1993) used a ratio of GXE sum of squares to the genotype sum of squares and was rarely less than 0.8. The ratio was preferred to variance components to avoid controversial assumptions as whether genotypes and sites were random or fixed effects.

3.2 Superiority index (*Pi*)

Pi, proposed by Lin and Binns (1988), the squared difference across sites, is the yield of a genotype compared with the highest yield of any genotype at a site. A small value for the superiority index implies general adaptation of a variety or line.

$Pij = \Sigma j\ (Yij - Yj\ max)^2$ where i= genotype, j=site and Y is the yield.

3.3 Regression

The regression technique for examining GXE interaction was first suggested by Yates and Cochran (1938). This technique was modified by Finlay and Wilkinson (1963). Later Eberhart and Russell (1966) used the same model and defined two parameters; a regression coefficient (bi) and the deviation from regression (S^2di).

The model used is: $Yij = mi + \beta i Ij + \delta ij$

$Ij = (\Sigma j\ Yij/v) - (\Sigma i \Sigma j\ Yij/vn),\ \Sigma_j\ Ij=0$

$bi = \Sigma j\ Yij\ Ij\ /\ \Sigma_j I^2 j$

The deviation from regression can be estimated as

$S^2di = \{\Sigma j\ \delta^2 ij\ /\ (n\text{-}2)\} - S^2e/r,\ S^2e/r$ = pooled error

$\Sigma j\ \delta^2 ij = [\ \Sigma j Y^2 ij - Y^2 i./n\ ] - (\Sigma j\ YijIj)^2\ /\ \Sigma j\ I^2 j.$

They defined a stable cultivar as one having a regression coefficient of unity (bi=1) and a minimum deviation from regression ($S^2di = 0$).

3.4 Convergence and non convergence:

Eagles *et al.* (1977) developed a model where the sum of squares for heterogeneity among regression was partitioned into components due to convergence of the regression lines at a point with one degree of freedom and due to non convergence. The formula used is the following: Sum of squares for convergence $S= r^2H^2$, where r is the correlation between regression coefficients and mean yield and H^2 is the sum of squares due to heterogeneity of regressions.

$H^2 = \Sigma j\ (bi - 1)\ \Sigma j\ C^2j$

$Ci = Y.j - Y..$

$r^2H^2 = (\Sigma j\ bi\ Ri\ )^2\ (Si\ R^2i\ )^{-1}\ \Sigma j\ C^2j$

$Ri = Yi. - Y..$

The calculation of a convergence mean square and the deviation of the point of convergence provide a convenient method for investigating the form of genotype by environment interaction that occurs when genotypes are tested in several environments.

3.5 Ecovalence (Wi):

Wricke (1962) defined the ecovalence as a stability parameter; it is a contribution of a genotype to the GXE interaction sum of squares, calculated as follows:

$Wi = \Sigma j\ [Xij - Xi. - X.j + X..\ ]^2$

Where Xij = is the yield of variety i at location j

Xi. = is the yield of variety i over all locations

X.j = is the yield of all varieties at location j

X.. = the grand mean

Wricke (1962) defined that a stable genotype is the one that has a smaller Wi than the average of all Wi's of all genotypes.

The analysis of variance for stability was done assuming fixed effects for genotypes and random effects for replications and environments. The experimental design used is a randomized complete block design (RCBD) with four replications.

For each variety the regression coefficient (bi) and the deviation from regression (S2di) as proposed by Eberhart and Russell (1966) were calculated and tested for significance. The superiority index (Pi) was obtained for each entry as well as the ecovalence defined by Wricke (1962). The sum of squares due to convergence was also estimated for each entry using the model developed by Eagles *et al* (1977) to investigate the form of GXE that took place during the experimentation. Also, correlations between stability parameters were estimated. For cluster analysis, mean grain yield of each entry at each environment was used to reveal differential responses of the entries. The two methods used were average linkage and centroid strategy. The centroid linkage was used to avoid the distortion or misleading results prone to be created by strong clustering strategies (Yau and Ortiz-Ferrara; 1994).

Results

The results of analysis of variance for this experiment are presented in table 2. The effect of environment (E), genotype (G) and GXE interaction were highly significant. The ration GXE sum of squares to the genotype sum of squares is 3.65; it's within the interval found by Delacy *et al.* (1990).

The main reasons that are responsible for the highly significant interaction GXE are environmental conditions that prevailed during testing, such as drought, diseases (rusts and Hessian fly) enhanced in some experimental stations than in the others. The experimental material used in this study has different reactions to different diseases ranging from susceptible to highly resistant.

The results of stability parameters are presented in table 3. The results showed that all the regression coefficients are significantly different from zero. Except for the following entries #1, 4 and 18, the other entries have a regression coefficient not significantly different from the unity. Also, all the deviations from regression are not significantly different from zero. According to Eberhart and Russell (1966) classification, all the entries are stable, except for the three previous entries (1, 4 and 18). The superiority index showed that Achtar (entry number 24) has the lowest index (Pi= 4.17); it can be considered as highly stable. Among the other entries that presented reasonable superiority index, we can add entries #3, 4, 13, and 18. Even the entries 4 and 18 have a good superiority index 8.05 and 7.78 respectively; they seem to perform well in good environments rather than in poor ones because of their regression coefficients that are significantly different from the unity.

From the results of the ecovalence (Wi) shown in table 3, we can say that 13 entries (#1,2,6,7,8,9,10,13,15,20,21,22 and 23) presented a Wi less than the average of Wi's of all genotypes (17.85).

The results of convergence and non convergence are presented in table 4. The calculation of convergence mean squares provide a convenient method for investigating the form of GXE that occurred when genotypes are tested in several environments. The variation due to convergence in this study is significant. Thus, we can classify this type of interaction as type-environment interaction according to Eagles *et al.* (1977). The reason for that is that we have some genotypes that are superior at high yield levels and are inferior at low yield levels (i.e. entries #4 and 18). This shows that we have qualitative interaction; there is a cross over of genotype performance from one environment to another. The point of cross over for genotypes 4 and 18 is located at the production level of 34.99 Qx/ha. The lack of significant variation among regressions for grain yield suggested that no genetic variation for this trait existed in this trial of wheat lines. The same result was reported by Eagles *et al.* (1977) using a population of oat lines. This result seems to be reliable, because all genetic material tested here is considered as fixed material (Advanced Yield Trials) and the genetic base is supposed to be narrow at this level of selection.

The results for the correlation between different stability parameters used in this study are summarized in Table 5. The results showed a very high correlation coefficient between the mean yield and the coefficient of regression (r = 0.522 ***). The same result was reported by Eagles *et al.* (1977) and Fatunla and Frey (1974). Also, a very high correlation (r =-0.934***) was recorded between mean yield and superiority index (Pi), but negative, because the lower values of Pi are associated with high performance of genotypes. However, the mean yield and the deviation from regression were independent. This result suggests that it is possible to select genotypes that are high yielding and stable. Another significant correlation between the coefficient of regression and Pi was obtained (r=-0.607***).

To illustrate the results of the cluster analysis, the crosses of the entries are provided in Table 6. From the six clusters identified, the grouping tends to combine the name/cross and yield potential. As in cluster A, the relative mean yield is around 0.96 and the name/cross is characterized by the gathering of well known varieties: Nasma, Marchouch and Seri. For cluster B, the relative mean yield is around 1.01 and there is no obvious relationship among name/cross. Cluster C is characterized by a relative mean yield around 1.02 higher than clusters A and B and the most common name/cross is Potam and Jouda. They are crosses that are mainly resistant to Hessian fly. The cluster D has the relative mean yield of 1.11, the highest one among clusters, characterized by a high yielding group. The famous variety in this cluster is Achtar. In cluster E, the relative mean yield is about 1.01 similar to cluster B, but the two main crosses that form this group are Sais and Cno79/Prl's'. The entries 4 and 18, as showed by the regression analysis before, have a regression coefficient significantly different from one, and they responded well to favorable environments. The last cluster was formed by only one entry, considered as low yield potential; the relative mean yield was 0.82.

Discussion

The genetic material used in this study is considered as a fixed onematerial. The lines tested are from advanced yield trails that are supposed to go to National catalogue for further testing. Among the objectives of this study was the identification of stable lines. The range of the environment used is very large and these environments differ in their level of productivity. The grain yields varied from 6.14 to 87.92 Qx/ha;, this will influence the genotypes performances. The Eberhart and Russell method is based upon regression of the entries at a given set of environments (entries potential, number of genotypes and the productivity level of the environments). Except for the entries #1, 4 and 18, the regression coefficients are all not significantly different from the unity. Also, all the deviations from regression are not significantly different from zero. Therefore, the b values provide some information to the breeders who are searching for lines that have adaptability to special environments. Becker *et al*. (1982) considered the deviation from regression as the most appropriate parameter for measuring phenotypic stability in an agronomic sense, because this statistic measures predictability of genotypic reaction to various environments. Langer *et al*. (1979) also considered the regression coefficient as a measure of genotypic responses to various environments. It appears reasonable that regression coefficient is a measure of the linear response or the adaptability of a genotype to various environments, and the deviation from regression is an estimate of the consistency of that response (Guilan Yue *et al*.; 1990).

First, if we consider the superiority index, the following entries #2,3, 4,6,7, 10,13, 16,17, 18,22 and 24 presented an index less than the average of all genotypes. Using other stability parameters, we can deduce that the genotypes #4 and 18 have a regression coefficient significantly superior to the unity. Therefore, these entries seem to perform well in good environments; they can be classified as genotypes with specific adaptation (they respond well to high input environments). Considering the ecovalence, regression coefficients and superiority index conjointly, the genotypes that could be retained are #2, 6, 7, 10, 13 and 22. All these latter entries have a good superiority index, a regression coefficient equal to 1 and a deviation from regression equal to zero, and an ecovalence less than the average of Wi's of all genotypes. All these entries have a wide adaptation and a good stability. The variety Achtar (included as check number 24 in this study) has the best superiority index, a regression coefficient equal to 1, a deviation from regression equal to zero and Wi of 18.00 hardly superior to the average of Wi's of all genotypes (17.85). This variety can be considered as stable with very wide adaptation. Another check (entry #22), Jouda, is classified as stable with a wide adaptation.

In this study, the cluster analysis offered some supplementary information according to the type of interaction GXE. Clusters of entries reflected different cross/name to some extent. Also, the relative mean yield could be an important factor for discrimination between different genotypes.

As a conclusion, the strategy and the several selection environments, adopted by the national program in selecting varieties, has given good results, and a large number of advanced lines, have wide adaptation and good yield stability. The impact of these results depends upon the diffusion of these new releases and a fast adoption by the farmers. All the parameters used in this study are seemingly useful in estimating stability; however, the regression coefficient and the superiority index seem to give as much the information needed to assess stability and adaptation.

Bibliographic references

Amri A., 1992. Caractérisation de l'environnement et stratégies d'amélioration génétique de l'orge. Mémoire présenté pour l'accès au grade d'Ingénieur en Chef, INRA, Maroc.

Austin, R.B. 1993. Augmenting yield-based selection. Plant breeding: principles and prospects. Edited by M.D. Hayward, N.O. Bosemark and I. Romagosa. Pp: 391-404.

Becker, H.C. 1981. Correlations among some statistical measures of phenotypic stability. Euphytica 30: 835-840.

Becker, H.C., H.H. Geiger, and K. Morgenstern. 1982. Performance and phenotypic stability of different hybrid types in winter rye. Crop Sci. 22: 340-344.

Brennan, P.S., and J.A. Shappard. 1985. Retrospective assessment of environments in determination of an objective strategy for the evaluation of the relation yield for wheat cultivars. Euphytica 34: 397-408.

Ceccarelli, S. 1989. Wide adaptation: how wide? Euphytica 40: 197-205.

Delacy ,I.H., Eisemann, R.L., and Cooper M.1990. The importance of genotype-by-environment in regional variety trials. In Genotype-by-Environment Interaction and Plant Breeding , Kang, M.S. (ed.). Louisiana State University, Baton Rouge, pp: 287-300.

Eagles, H.A., P.N. Hinz, and K.J. Frey. 1977. Selection of superior cultivars of Oats by using regression coefficients. Crop Sci. 17: 101-105.

Eberhart, S.A., and W.A. Russell. 1966. Stability parameters for comparing varieties. Crop Sci. 6: 36-40.

Fatunla, T., and K.J. Frey. 1974. Stability indexes of radiated and non radiated Oat genotypes propagate in bulk population. Crop Sci. 14: 719-724.

Finlay, K.W., and G.N. Wilkinson. 1963. The analysis of adaptation in a plant breeding programme. Austr. J. Agric. Res. 14: 742-754.

Fox, P.N., and A.A. Rosielle. 1982. Reducing the influence of environmental main-effects on pattern analysis of plant breeding environments. Euphytica 31: 645-656.

Horner, T.W., and K.J. Frey. 1979. Methods for determining natural areas for Oat varietal recommendation. Agron J. 52: 396-399.

Langer, S., K.J. Frey, and T. Bailey. 1979. Associations among productive, production, and stability indexes in Oat varieties. Euphytica 28: 17-24.

Lawn, R.J. 1988. Breeding for improved plant performance in drought-prone environments. In drought research priorities for the dry land tropics. F R. Bidinger and C. Johansen (Eds.), ICRISAT, Patancheru.

Lin, C.S., and M.R. Binns. 1988. A superiority method for cultivar performance for cultivar x location data. Can J. Plant Sci. 68: 193-198.

Romagosa I., and P.N. Fox. 1993. Genotype X environment interaction and adaptation. Plant breeding: principles and prospects. Edited by M.D. Hayward, N.O. Bosemark and I. Romagosa. Pp: 373-390.

Yates and Cochran (1938). The analysis of groups of experiment. J. Agric. Sci. Camb. 28: 556-580.

Yau, S.K., and G. Ortiz-Ferrara. 1994. Regression and cluster analysis of elite wheat lines grown in rainfed environments. J. genet. & Breed. 48: 183-190.

Yue Guilan, S.K. Perng, T.L. Walter, C.E. Wassom, and G.H. Liang. 1990. Stability analysis of yield in Maize, Wheat and Sorghum and its implications in breeding programs. Plant Breeding 104: 72-80.

Wricke, G. 1962. Estimate of genotypic value: a proposed method. Euphytica 22: 121-123.

Table 1. Name and crosses of the advanced lines of wheat.

Entry number	Name/cross
1	Maya74'S'/ON//II60-147/3/BB/Gll/4/Chat's'
2	Cham4
3	Punja85=Lira's'
4	Cno79/Prl's'
5	Cno79/Prl's'
6	Seri
7	Bysra
8	Bow's'/Buc's'
9	Ttr's'/Jun's'
10	Kwz/7C//Jun's'
11	Shi#4414/crow's'
12	K1.H63F2600/SR//Tob/Cno's'/3/Bun's
13	Thb's'/Bow's'
14	Nasma*2/14-2
15	Potam*3/KS811261-5
16	Potam*3/KS811261-5
17	Sais*3/14-2
18	Sais*2/14-2
19	Bow's'/Vee's'
20	Nasma
21	Jouda
23	Marchouch
24	Achtar

Table 2. Results of the Analysis of Variance.

Source	Df	MS	F value	Pr>F
E	8	50544	1488.52	0.0001
G	23	184	5.41	0.0001
GXE	184	84	2.47	0.0001
Rep	3	553	-	-
Rep(Env)	24	239	-	-
Error	621	34	-	-
Total	863	51638	-	-

CV= 16.65 and R2= 0.95

Table 3. Estimated parameters of stability.

Entry	Mean	R^2	bi	S^2di	Pi	Wi
1	32.80	0.96	0.91	-1.82	18.24	5.32
2	36.30	0.91	1.01	-4.02	11.24	8.75
3	38.84	0.93	1.03	-1.55	6.35	20.88
4	36.89	0.94	1.17	-2.12	8.05	28.84
5	32.15	0.91	1.13	-3.45	20.84	27.90
6	35.69	0.93	1.00	-3.88	10.05	2.51
7	36.01	0.93	1.02	-2.80	11.52	9.28
8	34.54	0.91	0.99	-4.02	15.19	9.75
9	33.58	0.94	0.97	-1.59	16.12	10.37
10	35.11	0.88	1.09	-7.57	11.20	11.64
11	35.12	0.90	0.89	-2.27	17.57	23.92
12	35.53	0.79	0.93	-7.67	18.33	39.74
13	36.69	0.94	1.02	-2.23	8.82	8.94
14	28.60	0.84	0.86	-3.22	39.54	39.29
15	34.18	0.95	0.92	-2.05	14.83	5.54
16	35.93	0.87	0.99	-5.23	12.82	19.21
17	35.21	0.91	0.99	-2.10	12.98	21.68
18	37.42	0.93	1.15	-1.70	7.78	37.65
19	34.89	0.91	1.09	-1.95	14.34	10.21
20	32.53	0.89	0.89	-4.79	19.54	7.49
21	32.44	0.88	0.90	-5.62	20.63	13.79
22	36.08	0.89	1.02	-5.46	9.15	8.94
23	34.47	0.89	0.94	-4.72	14.43	18.00
24	38.88	0.93	-1.06	-2.53	4.173	8.67

Table 4. Results of convergence and non convergence analysis.

Source	Df	SSquares	MS	F value	Pr>F
Environment	1	404429	404429	8030.38	0.0001
Entry	23	4228	183	3.65	0.0001
Env. X Entry	23	2812	122	2.43	0.0002
Het. Regress.	23	716	31	0.62	ns
Converg.	1	236	236	4.71	s
N-Converg.	22	479	21	0.43	ns
Residual	816	41095	50		
Total	863	452567	-	-	-

Env: environment, Het regress: heterogeneity of regression, converg: convergence, N-converg: non convergence, ns: non significant, and s: significant at 5%.

Table 5. Correlation between different stability parameters.

	bi	Wi	Pi	S2di
bi	-			
Wi	0.28	-		
Pi	-0.607***	0.259	-	
S^2di	0.175	0.070	-0.146	-
Mean yield	0.552***	-0.030	-0.934***	0.148

Table 6. Results of cluster analysis.

Entry	Name/cross	Relative mean yield*
Cluster A		
9	Ttr's'/Jun's'	0.96
6	Seri	1.02
23	Marchouch	0.98
15	Nasma*2/14-2	0.98
21	Nasma	0.93
20	Bow's'/Vee's'	0.93
1	Maya74's'/On//II60-147/3/..	0.94
Cluster B		
12	K1.H63F2600/Sr//Tob/Cno..	1.01
11	Shi#4414/Crow's'	1.00
8	Bow's'/Buc's'	0.99
7	Byrsa	1.03
2	Cham4	1.04
Cluster C		
17	Potam*3/KS811261-5	1.01
16	Potam*3/KS811261-5	1.03
22	Jouda	1.03
13	Shi#4414/Crow's'	1.05
10	Kwz/7C//Jun's'	1.00
Cluster D		
24	Achtar	1.11
3	Punja85=Lira's'	1.11
Cluster E		
4	Cno79/Prl's'	1.05
18	Sais*3/14-2	1.07
19	Sais*2/14-2	1.00
5	Cno79/Prl's'	0.92
Cluster F		
14	Thb's'/Bow's'	0.82

Relative mean yield= yield of each entry divided by grand mean.