Iran Agricultural Research 6:125-139 (1987).

NOTE

SELECTION OF A CHECK CULTIVAR FOR WHEAT VARIETY TRIALS IN ISFAHAN[1]

M. R. Khajehpour[2]

ABSTRACT

The yield preformance of six cultivars of wheat during 1977-1986 at Isfahan Agricultural Experiment Station was evaluated in order to select a check cultivar for wheat variety trials. Two linear regression models (through mean vs. through origin) and two independent variables (nursery mean vs. upper mean) were used for evaluation of the cultivars. Regression through origin resulted in higher r^2 values, thus was preferred to regression through the mean. Upper mean (calculated by averaging the yields equal to or higher than the nursery mean) was found advantageous to nursery mean, since the former does not strongly suffer from the default of genotypes and is a better estimate of the actual productivity potential of the environment. Three adaptation indices; mean yield, b and r^2 were used to evaluate the cultivars. Mean yield of a cultivar was taken as an estimate of its overall productivity potential. Regression coefficient was used to measure the responsiveness of a cultivar to increased environmental productivity potential and r^2 was employed to evaluate the consistency of the response. Azadi was found superior to other cultivars as a check. Roshan, which is presently used as the check, is not suitable for this purpose.

---

1. Contribution from the Department of Agronomy, College of Agriculture, Isfahan University of Technology, Isfahan, Iran. Received 13 December 1987.

2. Assistant Professor.

تحقیقات کشاورزی ایران
۶:۱۲۵–۱۳۹ (۱۳۶۶)

انتخاب شاهد جهت مقایسات ارقام گندم در اصفهان

محمدرضا خواجه‌پور
استادیار گروه زراعت و اصلاح نباتات دانشکده کشاورزی دانشگاه صنعتی اصفهان

خلاصه

عملکرد شش رقم گندم طی سالهای ۱۳۵۶ تا ۱۳۶۵ در ایستگاه کشاورزی اصفهان بمنظور انتخاب رقم شاهد جهت مقایسات ارقام گندم مورد بررسی قرار گرفت. دو مدل رگرسیون (از مبداء مختصات و از میانگین) و دو متغیر مستقل (میانگین آزمایش و میانگین بالائی) بعنوان شاخص های محیطی برای ارزیابی ارقام مورد استفاده قرار گرفتند. عبور خط رگرسیون از مبداء مختصات منجر به ضرایب تعیین بزرگتری گردید و در نتیجه مدل فوق بر عبور خط از میانگین ترجیح داده شد. میانگین بالائی تحت تاثیر شدید ارقام با عملکرد پایین قرار نداشته و تخمین بهتری از پتانسیل حقیقی محیط برای عملکرد میباشد و بدین لحاظ بر میانگین آزمایش ارجحیت دارد.

سه معیار سازگاری: میانگین عملکرد، ضریب رگرسیون و ضریب تعیین برای ارزیابی ارقام مورد استفاده واقع شدند. میانگین عملکرد رقم بعنوان تخمینی از متوسط قدرت تولیدی آن بکار گرفته شد. ضریب رگرسیون بمنظور سنجش میزان عکس العمل رقم به افزایش قدرت تولیدی محیط و ضریب تعیین برای ارزیابی ثبات روند عکس العمل مورد استفاده قرار گرفت. رقم آزادی مناسبترین رقم برای شاهد تشخیص داده شد. رقم روشن که در حال حاضر بعنوان شاهد مورد استفاده قرار میگیرد، برای این منظور مناسب نیست.

INTRODUCTION

Correct comparisons between varieties have vital importance in variety trials and require an appropriate base for the purpose. "Floating checks" like site mean and highest nursery yield (6) or upper mean (calculated by averaging the yields equal to or higher than the nursery mean) (8) have been suggested for variety comparisons. However, use of one or several cultivars as check(s) is very common. The check cultivar should be least affected by genotype-environment interaction and produce higher yields at higher producing environments.

Linear regression has been widely used for evaluating cultivars or genotypes. Site mean (3), deviation of the site mean from the mean of all environments (2), highest nursery yield (12), upper mean (8), yield of local cultivars (1) and average yield of commercial fields over the region (11) have been used as measures of productivity potential of environments for use as the independent variable in linear regression analysis.

Various models have been used in linear regression analysis. Regression of two intersecting lines and curvilinear regression (7), three-phase regression (10), regression through origin (M.R. Khajehpour and C.F. Konzak, unpublished results) are among the models used for genotype-environment interaction analysis. It has been practically impossible to satisfy the statistical assumptions underlying regression in these types of studies. So, the lines passed through the points by these procedures may not be considered as regression lines and not statistically compared (4, 5). However, it has generally been agreed that regression procedures may be used for evaluating the effect of genotype-environment interaction on the performance of genotypes in preliminary evaluation or for practical purposes.

Evaluation of genotypes or cultivars by a regression procedure requires that two parameters of adaptation be identified and distinguished between: 1) response to increasing yield potential of environments, and 2) consistency of this response. The regression coefficient has been used for evaluating the response of a genotype to increasing yield potential of environments (2, 3, 8, 10, 12). The sum of squared deviations from regression, s^2d_i (2), coefficient of determination, r^2 (12) and the F, ratio of mean square of regression to the mean square of error (8) have been used to compare the consistency of genotype response.

A desirable genotype must have a high mean yield (higher than the overall mean of all genotypes under comparison), respond positively to increases in environmental productivity potential ($b = 1$) and have the least deviation from regression line, i.e. smallest s^2d_i, or highest r^2 or F. However, evaluation of genotypes by this procedure is conditional: a genotype may be considered desirable only in comparison to the other genotypes and within the environments under consideration (4).

A check cultivar must have homeostatic properties and be minimally affected by genotype-environment interaction among adapted cultivars over the region (6). In this study, the selection of an appropriate cultivar as check among a group of cultivars commonly used as checks in variety trials of bread wheat in Isfahan was considered, and regression models (through mean vs. through origin) and indices of deviation from regression line (r^2 and F) were evaluated for comparing genotypes performance over test environments.

MATERIALS AND METHODS

Data from uniform wheat yield trials for cold regions at Isfahan Agricultural Experiment Station during harvest years of 1977 to 1986 (14) were used for this study. All trials were planted using a randomized complete block design with six replications. Each plot was 8.0 m long and consisted of four rows spaced 0.3 m apart. The whole plot area was harvested for yield determination. Twenty cultivars or genotypes were evaluated each year, except for 1981 and 1985, when only 16 were evaluated. Many cultivars or genotypes were not common over all years, but the cultivars Roshan, Omid, Azadi, Arvand 1, Adl and Bayat were common over most years and were used as checks in variety trials. Trials from 1977 and 1980 included a low fertilizer rate (60-30-0) in addition to the normal fertilizer rate (120-60-0) to evaluate the response of genotypes to fertilizer level. The low rate of fertilizer was considered as an independent environment in the present study. Details of materials and methods used for the conduct of uniform wheat yield trials are reported elsewhere (9, 14).

Two linear regression models, regression through mean vs. through origin (13) were used. The nursery mean (3) or upper mean of each nursery (8) was used as the independent variable in regression models, while the mean yield of each cultivar in each trial was used as the dependent variable.

The mean yield of each cultivar over all trials was used as an index of the overall productivity potential of that cultivar.

Regression coefficient was used as a measure of cultivar responsiveness to increased environmental productivity potential (3). Coefficient of determination and F were used as indices of consistency of the response (8, 12).

Adaptation analysis of cultivars, evaluation of regression models, and comparison of independent variables and consistency of response indices were performed using all available data from 1977 to 1986 trials. Since all cultivars were not common in all experiments, trials were grouped according to the highest coexistence of cultivars to provide for more precise comparisons. Based on this grouping, yield and adaptation of Roshan, Omid, Bayat, Arvand 1 and Adl over 1978 to 1984 and yields and adaptation of Roshan and Azadi over 1981 to 1986 were compared separately.

RESULTS AND DISCUSSION

Combined analysis of variance over all trials to test the significance of genotype-environment interaction was not performed because the genotypes or cultivars varied from year to year. However, examination of the cultivar yields over trials showed change of cultivars' rank from year to year (data not shown here), indicating possible effect or genotype-environment interaction.

Regression analysis of cultivar yield over nursery mean or nursery upper mean with regression through origin resulted in higher r^2 and F values than with regression through mean. Coefficients of determination for regression through mean varied from 0.689 to 0.921, while for regression through origin ranged from 0.969 to 0.993 (Table 1). Thus, regression through origin results in an improvement in goodness-of-fit to the experimental data. This conclusion is in agreement with previous studies of the author.(Khajehpour and Konzak, unpublished results). Regression through mean may also introduce difficulty in the evaluation of genotypes. The estimated performance of genotypes by regression through mean may surpass

Table 1. Average yields (Kg ha^{-1}) for six cultivars, maximum and minimum test yields (Kg ha^{-1}) obtained during harvest years 1977-1986, and regressions through means and origin with nursery mean or upper mean as the independent variable.

Entry	No. of Trials	Average yield (kg ha^{-1})	Regression through mean								Regression through origin					
			Nursery mean				Upper mean				Nursery mean			Upper mean		
			a	b	r^2	F	a	b	r^2	F	b	r^2	F	b	r^2	F
Roshan	12	4740	1.51	0.72	0.697	23	1.05	0.73	0.689	22	1.03	0.969	340	0.92	0.974	414
Omid	11	4440	1.44	0.72	0.841	48	0.70	0.79	0.882	67	1.03	0.985	652	0.93	0.993	1507
Azadi	6	5900	1.62	0.78	0.895	34	1.45	0.74	0.846	22	1.06	0.992	593	0.98	0.991	560
Arvand 1	10	3860	-1.10	1.26	0.886	62	-1.64	1.22	0.758	25	1.00	0.984	569	0.87	0.969	282
Adl	8	4490	-0.86	1.35	0.912	62	-1.41	1.32	0.869	40	1.15	0.990	678	1.02	0.984	418
Bayat	9	3920	-0.52	1.04	0.921	82	-1.11	1.06	0.892	58	0.92	0.990	773	0.84	0.983	468
Maximum	12	5570	1.26	0.96	0.952	201	0.52	1.00	0.991	1073	1.22	0.992	1345	1.09	0.999	8662
Minimum	12	3320	-0.91	0.95	0.915	108	-1.29	0.91	0.824	47	0.76	0.979	515	0.68	0.960	264

the maximum yields or may fall away from the minimum yields obtainable in sites. Figure 1a clearly shows this point. It may be estimated from Fig. 1a that Azadi (b = 0.78, Table 1) will produce higher yield than the maximum over those environments with productivity potential lower than about 1750 kg ha^{-1} (intersection point of the two corresponding lines). Conversely, it may be estimated that Adl (b = 1.35, Table 1) will produce higher yield than the maximum over those environments with productivity potential greater than about 5750 kg ha^{-1} (intersection point of the two corresponding lines). Such misleading inferences are never faced with regression through origin. Regression lines through origin (Fig. 1b) for Adl (b = 1.15) and Azadi (b = 1.06) do not intersect regression lines of maximum yields (b = 1.22) or minimum yields (b = 0.76). At very low yielding sites, an environmental factor strongly limiting growth may prohibit expression of genotype productivity potential. Thus, all genotypes produce low and essentially close yields at such sites. In contrast, in high yielding sites, opportunities for the expression of genetic differences are available and consequently the differences between the yields of genotypes will increase. These expected responses are in agreement with the regression through the origin.

Nursery mean (3) and upper mean (8) were used as the independent variables in both linear regression models. Coefficients of determination and F values obtained with regression analysis were used for comparing the goodness-of-fit. Larger r^2 or F indicates a lower variance around the regression line (13). Examination of r^2 and F showed that the cultivar and maximum and minimum yields responded differently to the mean values used as the independent variable. The responses were also dependent on the regression model (Table 1). For example, Roshan showed a low variance with regression over the upper mean when the line was forced through origin, but with regression over the nursery mean when the line was forced through the mean.

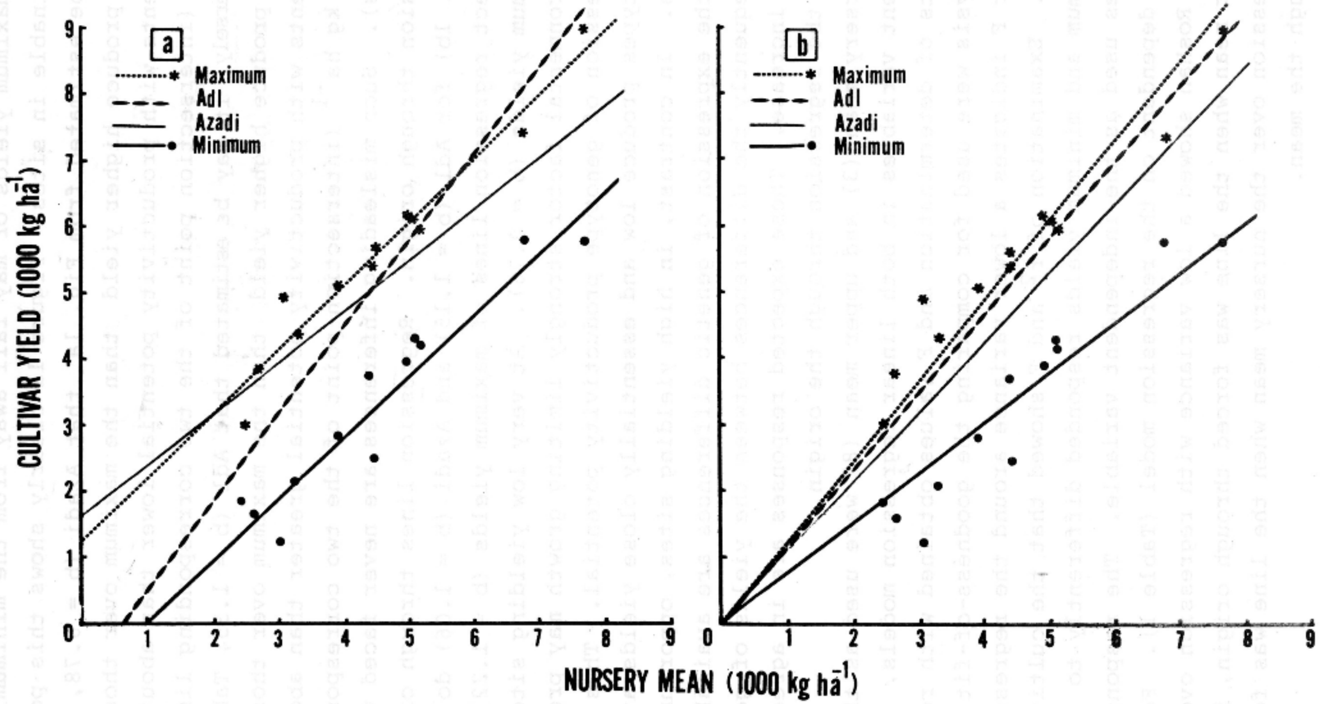

Fig. 1. Regression through mean (a) and origin (b) of maximum, minimum, Azadi and Adl yields over nursery mean.

Nevertheless, the nursery mean (an estimate of the average productivity potential of the environment) can be strongly affected by low yielding genotypes and may not estimate the actual productivity potential of the environments. The upper mean, an average of yields mostly higher than the nursery mean (e.g. mean of 7 to 11 higher yields in trials of the present study), may be a better estimate of the actual productivity capacity of the environments. The upper mean has other advantages too. In contrast to the maximum yield (12), it is not a single yield estimate and in contrast to the average yield of commercial fields in the region (11) and the yields of local check cultivars (1), it is goal oriented. The upper mean may be used as a base (check) for comparing between genotypes in variety trials (8). For these reasons, it was preferable to evaluate the performance of genotypes against the upper mean. Use of the upper mean is especially preferred over the site mean for evaluation of cultivars to serve as check, since the check of variety trials should estimate the actual productivity potential of the site.

Three parameters, s^2d_i (2), r^2 (12) and F (8) have been used as an index for comparing the consistency of genotypes response to increased yield potential of environments. A combined analysis of variance over all trials and determinations of s^2d_i for each genotype was impossible in the present study, because the genotypes or cultivars varied from year to year. The coefficient of determination and F are also mathematically interrelated. This relation for the regression through mean may be written as formula (1) and for the regression through origin as formula (2):

$$F = \frac{(n-2)\ r^2}{1-r^2} \qquad (1)$$

$$F = \frac{(n-1)\ r^2}{1-r^2} \qquad (2)$$

where n is the number of paired observations in the sample. It can be seen that a small increase in n or r^2 results in a large increase in F. Dependence of F on n and its strong sensitivity to small increases in r^2, especially when r^2 approaches 1.0, cause difficulty in making comparisons. The coefficient of determination has a limited range (0.0 to 1.0) and is not as dependent as F on n. Therefore, r^2 may be preferred to F as an index of consistency of response.

Regression of Roshan, Omid, Adl and Azadi yields over the upper mean is shown in Figs. 2a to 2d, respectively. Maximum deviation of points from the regression line (through origin and through mean) and smaller r^2 was obtained with Roshan (Fig. 2a). Maximum deviation of points from regression line and largest r^2 was obtained with Omid (Fig. 2b). As expected, larger coefficient of determinations are associated with smaller mean deviations from regression line (13). Thus, r^2 may be used as a measure of deviation from regression line. However, when two genotypes have comparable r^2, F might be used for comparison, provided that both have the same residual degrees of freedom.

A useful check cultivar should have a high potential for yield, b = 1 and r^2 very close to 1.0. Evaluation of cultivars to serve as a check was performed using the results obtained with regression of cultivar yield from all trials over the upper mean when the regression line passes through origin (Table 1). Neither Arvand 1 nor Bayat with yields lower than the overall mean (4470 kg ha^{-1}) and regression coefficients smaller than other cultivars are suitable as a check. Adl had b close to 1.0, but showed a lower r^2 than Omid and Azadi. These latter cultivars had comparably high r^2 values, but Omid had a much larger F values than Azadi. Azadi produced the highest yield and had a b close to 1.0 among the cultivars under study (Table 1).

It is seen that Azadi with an average productivity potential of 5900 kg ha^{-1}, b = 0.98, and r^2 = 0.991 is closer to an ideal check than the other cultivars. Roshan, which is

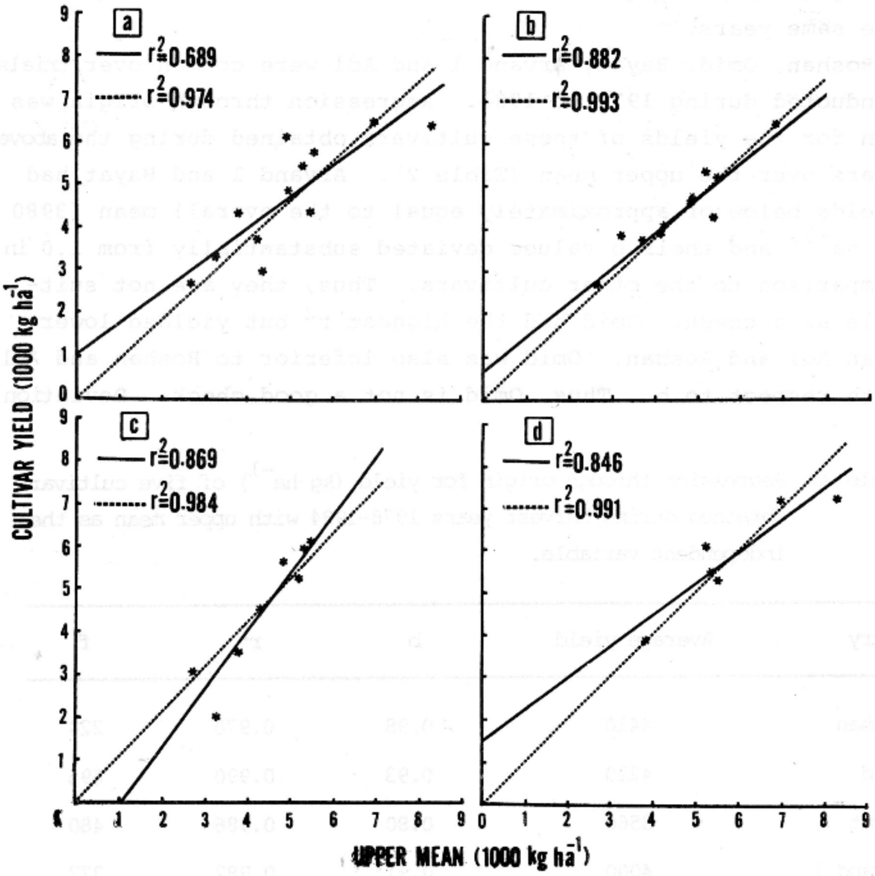

Fig. 2. Regression through mean (——) and origin (-----) of Roshan (a), Omid (b), Adl (c) and Azadi (d) yields (1977-1986) over upper mean.

presently used as the check in wheat variety trials in Isfahan (14) is a good yielding cultivar but is inferior to Azadi, Adl and Omid with respect to b and r^2. Thus, Roshan probably is not a desirable check. However, a more precise comparison among cultivars requires that all cultivars be tested over the same years.

Roshan, Omid, Bayat, Arvand 1 and Adl were common over trials conducted during 1978 to 1984. Regression through origin was run for the yields of these cultivars obtained during the above years over the upper mean (Table 2). Arvand 1 and Bayat had yields below or approximately equal to the overall mean (3980 kg ha^{-1}) and their b values deviated substantially from 1.0 in comparison to the other cultivars. Thus, they are not suitable as a check. Omid had the highest r^2 but yielded lower than Adl and Roshan. Omid was also inferior to Roshan and Adl with respect to b. Thus, Omid is not a good check. Deviation

Table 2. Regression through origin for yield (kg ha^{-1}) of five cultivars obtained during harvest years 1978-1984 with upper mean as the independent variable.

Entry	Average yield	b	r^2	f
Roshan	4410	0.98	0.970	224
Omid	4220	0.93	0.990	695
Bayat	3560	0.80	0.986	480
Arvand 1	4000	0.91	0.982	377
Adl	4490	1.02	0.984	418

of b from 1.0 is comparable for Roshan and Adl, but Adl is superior to Roshan with respect to yield and r^2. Consequently, based on cultivar performance during 1978 to 1984 (Table 2), Adl is superior to the other cultivars as a candidate for the "check" in wheat variety trials in Isfahan. Unfortunately, Adl was not included in 1985 and 1986 trials and consequently could not be compared with Azadi due to the restricted amount of data available (4 years).

A comparison was made between Roshan and Azadi (Table 3) using test results from six years (1981 to 1986). A higher yield, r^2 and b values closer to 1.0 obtained for Azadi indicate superiority of this cultivar over Roshan for use as the "check" in Isfahan wheat variety trials.

Table 3. Regression through origin for yield (kg ha^{-1}) of two cultivars obtained during harvest years 1981-1986 with upper mean as the independent variable.

Entry	Average yield	b	r^2	f
Roshan	5510	0.90	0.982	278
Azadi	5900	0.98	0.991	560

Results of the present study show that the average yield of cultivars over several years does not explain different aspects of adaptation. Linear regression of cultivar yield over an appropriate measure of environmental productivity potential might be used to compare adaptability of cultivars to a restricted range of environments (2, 3, 4, 5). Regression through the origin was found superior to regression through the mean for this purpose. Upper mean, an estimate of the actual productivity potential of the environment (8) was preferred over site mean, which is an estimate of the average productivity level of the environment (3).

Azadi was found superior to the other cultivars for use as the "check" in wheat variety trials conducted at Isfahan Agricultural Experiment Station. Further testing and evaluation of Adl and Azadi is suggested. Roshan, presently used as the "check", may not be appropriate for this purpose.

ACKNOWLEDGEMENT

The author is grateful to Dr. M. Rezai and Dr. M. Zokai for their comments on a draft of the paper.

LITERATURE CITED

1. Bogyo, T.P., T.S. Russell and C.F. Konzak. 1973. The analysis of genotype-environment interaction on durum wheat: Proceedings of the symposium on genetics and breeding of durum wheat. Italy, pp. 413-435.
2. Eberhart, S.A. and W.A. Russell. 1966. Stability parameters for comparing varieties. Crop Sci. 6: 36-40.
3. Finlay, K.W. and G.N. Wilkinson. 1963. The analysis of adaptation in a plant-breeding programme. Aust. J. Agric. Res. 14: 742-754.
4. Freeman, G.H. 1973. Statistical methods for the analysis of genotype-environment interactions. Heredity 31: 339-354.
5. Freeman, G.H. and J.M. Perkins. 1971. Environmental and genotype-environmental components of variability. VIII. Relation between genotypes grown in different environments and measures of these environments. Heredity 27: 15-23.
6. Jensen, N.F. 1976. Floating checks for plant breeding nurseries. Cereal Res. Commun. 4: 285-295.
7. Jinks, J.L. and H.S. Pooni. 1979. Non-linear genotype X environment interactions arising from response thresholds. I. Parents, F_1s and selections. Heredity 43: 57-70.

8. Khajehpour, M.R. 1979. Growth and productivity analysis of facultative (coldhardy) spring wheat varieties. Ph.D. Thesis, Washington State University, Pullman, WA, U.S.A.

9. Mahlooji, T. and A. Akbari. 1983. Technical guide for planting, nursing and harvesting of wheat and barley experiments. Breeding Investigations and Seedling and Seed Production Organization. Ministry of Agriculture and Natural Resources. 41 p. (in Persian).

10. Mariani, B.M., P.N. Manmana and R. Stefanini. 1983. Efficiency of linear and multi-phase regression methods to evaluate genotype-environment interaction for grain yield and protein content in Italian durum wheat varieties. Z. Pflanzenzuchtung 90: 56-57.

11. Pederson, D.G. 1974. The stability of varietal performance over years. I. The distribution of seasonal effects for wheat grain yield. Heredity 32: 85-94.

12. Sadam, M. 1970. Environmental adaptation in wheat response of yield and plant height. M.S.Thesis, Washington State University, Pullman, WA, U.S.A.

13. Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. The Iowa State University Press, Ames, Iowa, U.S.A. 593 p.

14. Yearly reports of wheat and barley breeding investigations, 1977-1986. Available from Breeding Investigations and Seedling and Seed Production Organization. Ministry of Agriculture and Natural Resources (in Persian).