GENOTYPE X ENVIRONMENT INTERACTION AND STABILITY ANALYSIS FOR YIELD IN DURUM WHEAT

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ABSTRACT

The objectives of this research were to assess genotype-environment interaction (GEI) and to determine stability of durum wheat (*Triticum durum* Desf.) cultivars for grain yield in the Sulaimani province. seven durum wheat cultivars (Iraq7, Rash gull, Sham1, Bohooth 5, Acsad 65, Sham3 and Crezo)were evaluated under rainfed conditions using a randomized complete block design with3 replications. The study was conducted for 2 sowing date and at 3 different locations around Sulaimani province, Kurdistan-Iraq. Eight parametric stability methods including: the mean of yield; **joint regression coefficient (bi), deviation from regression(S^2di); environmental variance (EV); genotypic superiority index; deviation from mean (DFM)** ; **homeostasis (H%); genotypic resultant (GR) were used to identify the stability of these cultivars at six various environments in grain yield. The results showed different response among cultivars for environments and no cultivar had superior performance in all Environments. Yield reduction was large under spring sowing (58%).The stability parameters showed a wide range of variation between cultivars for grain yield. By simultaneous selection for yield and stability the cultivars Crezo and Iraq7 had the best values according to most parameters of stability; hence, it has a wide adaptability over a range of environments of rainfall conditions in Sulaimani, Kurdistan-Iraq.**

Key Words: Durum wheat, Grain yield, Analysis, Interaction, Stability

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التداخل الوراثي× البيئي وتحليل الأستقرارية لحاصل حبوب الحنطة الخشنة

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المستخلص

أجريت هذه الدراسة لتقييم التداخل الوراثي– البيئي ودراسة تراكيب وراثية من الحنطة الخشنة. جرى زراعة سبعة أصناف من الحنطة الخشنة (عراق7، ره شكول، شام1، بحوث5، اكساد65، شام3 و كريزو) في ثلاثة مواقع مختلفة من منطقة السليمانية وهي قلياسان، حلبجة و كردجان و بموعدين زراعة، الأول زراعة خريفية للموسم 2013–2014 والثاني زراعة ربيعية للموسم2014 بمجموع ستة بيئات. تم استخدام تصميم القطاعات العشوائية الكاملة بثلاثة مكررات لغرض تقييم حاصل الحبوب. جرى استخدام ثمانية من معامل الأستقرارية هي معدل الحاصل (mean) والتباين عبر البيئات (VE) و الثبات المظهري (H) و المحصلة الوراثية (GR) و معامل الأنحدار (bi) و الأنحراف عن الأنحدار (S^2di) والتفوق (Pi) والأنحراف عن معدل الصفة (DFM) للتعرف على استقرارية هذه الأصناف عبر البيئات الستة المختلفة. بينت النتائج أنخفاض كبير للحاصل الحبوبي للزراعة الربيعية (58%). الأستجابة المختلفة للأصناف عبر البيئات المختلفة ولم يبين اي صنف اداء متفوق لجميع البيئات لحاصل الحبوب. أظهرت متلازمة معامل الأستقرارية والحاصل ان الصنفين كريزو و عراق7 امتلكا القيم الأحسن لمعظم معامل الأستقرارية، لذا هما يعبران عن امتلاكهما لمدى واسع من الأستقرارية عبر مدى من بيئات منطقة السليمانية في اقليم كوردستان العراق.

كلمات مفتاحية :الحنطة الخشنة، حاصل الحبوب،التحليل، التداخل، الاستقرارية.

INTRUDUCTIO

Durum wheat (*Triticum durum* Desf.) accounts for about 8 % of the global wheat production, and its cultivation is concentrated in latitudes ranging from 55ºN (Canada) to 40ºS (Argentina) (22), corresponding mostly to the Mediterranean Basin, the North American Great Plains, India and the former USSR (17).Durum wheat productivity in developing countries is generally low. This may be attributed to the fact that the crop is grown under low inputs in semi-arid regions and other marginal areas characterized by sharp annual fluctuations in cropping conditions. Under favorable environments where moisture and other resources are not limiting, higher yield levels, approaching or surpassing bread wheat, are obtained(6).Wheat is grown in the all regions of Iraq, mostly under the rain fed conditions including Kurdistan regions. Therefore, annual production is affected to large extent by the annual and seasonal distribution of precipitation, environmental states and crop managements like sowing time, soil fertility, ect. Like to the other crops, increasing the potential of yield is an important target of durum wheat improvement programs production. However, durum wheat yields in most production regions seem to be no more than the potential yields of the cultivars and far below the theoretical maximum yields (26). The improved genotypes are evaluated in multi-environment trials to test their performance across different environmental conditions. In most trials, crop yield fluctuates due to suitability of genotypes to different conditions which is known as genotype × environment interaction (G×E) (18). G ×E can be defined as the difference between the phenotypic value and the value expected from the corresponding genotypic and environmental values (3). Modern agriculture requires determining the stable genotypes and high performance (4, 5 and 11). In order to increase total production, while wheat cultivars are tested for their yield performances in the different locations and different agriculture practices viz sowing time. A large number of statistical procedures have been developed to analyze GE interactions and yield stability. Joint linear regression (13) is the most popular procedure of univariate methods because of its simplicity of calculation and application. Eberhart and Russell (8) further developed linear regression model and suggested the use of mean squares of deviations from regression as additional stability parameter. A cultivar, which has high mean of each character, regression coefficient (bi) close to unity with (S^2di) values not significantly different from zero is defined as a stable cultivar. Tai (30) proposed a regression model, which uses two distinct statistics (α and λ) as the measures of stability that are similar to the regression coefficient and the deviation from conventional linear regression. Pinthus (23) proposed the coefficient of determination (CD) for fulfillment of linear regression model for determining yield stability. Desirability index (DI), which combine both yield and regression coefficients, was proposed by Hernández *et al*. (16). Francis and Kannenberg (14) proposed the use of the coefficient of variation (CV) as a measure of cultivar stability for removing scale effect. Shukla (29) proposed a method as stability variance (SV) for measuring yield stability where a component of the GE interaction is assigned to each Cultivar. variance across environments (EV) (19). Lin and Binns (20) proposed the superiority index (PI) as the Cultivar general superiority. Homeostasis (H %) El-Sahookie (9); Genotypic resultant (GR) El-Sahookie (10).Recently two types of biplot models have been extensively used, including the additive main effects and multiplicative interaction (AMM)I analysis (15) and GGE biplot analysis (32 and 33). The success of a wheat variety depends upon its yield and adaptation potential in those environments. Several methods can be used for measuring crop yield stability. Among them, the most popular and widely used is the linear regression analysis as proposed by Eberhart and Russell (8). Thus, this study was aimed on grain yield of 7 cultivated durum to find out ones with comparatively better and consistent grain yield in differential growing conditions in Kurdistan region-Iraq.

MATERIALS AND METHODS

Seven durum wheat cultivars [*Triticum durum* Desf.] (Iraq 7, Rash gull, Sham1, Bohooth5, Acsad 65, Sham3 and Crezo) which cultivated in wide areas under rainfall conditions in Iraq were planted during 2013- 2014 autumn and 2014 spring growing seasons at three different locations (Qlyassan, Halabja and Girdjaan) at the Sulaimani province and two sowing dates [20th November-2013(favorable environments) and 1st Mars-2014(unfavorable environments)] bringing the total of six environments. The properties and the location of the experimental environments are given in Tabl 1. The experiment was conducting using Randomized Complete Block Design with three replications. The experimental unit consists of five rows of three meter length and rows were 20 cm apart. The seed rate used was 140 kg. ha^{-1}. At.

Table 1. Agro-climatic characteristics of the environments tested in Sulaimani Kurdistan-Iraq

Environment			Mean yield (t ha–1)	Latitude Longitude masl	Soil properties	Rainfall (mm)
Location	Code	Sowing date				
Qlyassan	E1	Spring 1 Mars-2014	2.227	35°34'N 45°22'E 765	pH =7.13, Silt-Clay	565.3
	E2	Autumn 20 November-2013	5.095			
Halabja	E3	Spring 1 Mars-2014	2.099	35°10'N 45°59'E 721	pH = 7.62, Silt-Clay	486.4
	E4	Autumn 20 November-2013	4.697			
Girdjaan	E5	Spring 1 Mars-2014	1.887	36°12'N 44°47'E 511	pH = 7.95, Silt-Clay	635.3
	E6	Autumn 20 November-2013	4.935			

maturity, plants were harvested of each line as a whole to calculate grain yield (g/m^2). Analysis of variance for each environment and pooled analysis over environments were computed. Eight parametric stability methods including: the mean; joint regression coefficient (bi), deviation from regression (S^2di) (8); environmental variance (EV) (19) ; genotypic superiority index (20) ;Deviation from mean (DFM) ; homeostasis (H%) (9) ; genotypic resultant (GR) (10).

Result & Discussion

The analysis of variance (ANOVA) is shown in Table 2 and the partitioning of the sum of squares of the components indicated Environments to be 85.9% of the total variation, 6.5% due to genotype x environments, 7.2% due to genotype and error were very low with 0.5%. This indicates the big influence of environment on yield performance of wheat cultivar in rainfed Kurdistan region-Iraq. Main effects due to environments, Cultivars and cultivars x environments were all highly significant (P<0.01) for grain yield. The GE interaction was highly significant (*p*<0.01), which is indicating the studied cultivars exhibited complicated GE interaction (33 and 25).The large magnitude GE interaction, cause to the more dissimilar genetic systems, which controlling the physiological processes conferring yield stability to different environments (7). The relative contribution of GE interaction effects for grain yield found in this study are similar to those found in other studies (21, 27).

Table 2 Combined ANOVA for yield and the percentage sum of squares of the 7 cultivars tested at 6 environments .

Source	df	SS	SS%	MS	F-value	Pr> F
Cultivars	6	214806.0187	7.2	35801.0031	217.74	<.001
Environments	5	2565996.4958	85.9	513199.2992	3121.19	<.001
Cultivars x Environments	30	193205.3925	6.5	6440.1798	39.17	<.001
Error	84	13811.6519	0.5	164.4244		
Total	125	2987819.5588	100.0			

The relative performance of genotypes based on the mean grain yield over sowing season and locations are presented in Table 3. Grain yield is given in m^2 ($g.\ m^{-2}$).The first ranked cultivar for grain yield is Crezo with Iraq 7 ranked second and Sham 1 ranked third. Crezo cultivar had the highest value of grain yield (586.38 $g.m^{-2}$) at autumn sowing in Halabja location, while The E2 (autumn sowing in Halabja) was the best with 509.53 $g.m^{-2}$ for environments comparing . Environmental performances showed that environments 2,4 and 6 (autumn sowing) were favorable, whereas environments 1, 3and 5 (spring sowing) were unfavorable with reduction ratio by roughly 58% due to short growing season. Sheath and Galletly (28) suggested that, with spring sowing, tiller density and/or the survival of fertile tillers was limited by the shorter tillering phase and/or the relatively earlier exposure to unfavorable moisture conditions, while Rascio, *et al*., (24) pointed that, delayed sowing (spring) reduced the number of emerged plants (from 62.2 to 46.8 plants/row) and lowered average yield (from 23.4 to 20.7 q/ha). Genotypic differences per yield were highly significant too.

Table 3. Grain yield ($g.m^{-2}$) performance of seven durum wheat cultivars at six different environments in Autumn 2013-2014 and spring sowing date 2014.

Environments / Cultivars	E1 Qlyasan - spring 2014	E2 Qlyasan autumn 2013-14	E3 Grdjan - spring 2014	E4 Grdjan- autumn 2013-14	E5 Halabja - spring 2014	E6 Halabja - autumn 2013-14	mean
Iraq 7	228.23	577.01	210.33	506.76	250.54	483.70	376.096
Rash gull	163.17	362.96	117.90	383.56	110.33	383.57	253.583
Sham1	221.31	583.41	272.18	413.55	185.91	558.01	372.393
Bohooth5	207.45	534.85	196.92	421.56	172.11	515.23	341.355
Acsad 65	217.68	511.64	249.88	553.80	174.14	427.23	355.729
Sham3	302.39	442.41	232.88	447.45	223.68	500.46	358.213
Crezo	218.60	554.39	189.47	561.53	204.85	586.38	385.869
Mean	222.69	509.53	209.94	469.74	188.79	493.51	349.03

LDS 0.05 = 20.82 for cultivars × environments, 8.500 for cultivars and 7.869 for environments

The grain yield of durum wheat cultivars varied from 110.33 g. m^{-2} in Cultivar Rash gull, grown at Halabja - spring 2014 (E5), to 586.38 g. m^{-2} in Cultivar Crezo grown in Halabja - autumn 2013-14(E6). Maximum mean yields varied from 586.38 g. m^{-2} in Crezo to 383.57 g. m^{-2} in Rash gull, while minimum mean yield varied from 110.33g. m^{-2} in Cultivar Rash gull to 223.68g. m^{-2} in Sham3 (Tab. 4). Average yield was positively correlated with minimum and maximum mean yield. Yield amplitudes were very large, from 273.24 g. m^{-2} to 396.91 g. m^{-2} and were correlated with maximum, minimum and average yield.

Table 4. Average, maximum and minimum grain yields (g. m^{-2}) and yield amplitude in 7 durum wheat cultivars

Cultivar	Average	Minimum	Maximum	Range
Iraq7	376.096	210.33	577.01	366.68
Rash gull	253.583	110.33	383.57	273.24
Sham1	372.393	185.91	583.41	397.50
Bohooth5	341.355	172.11	534.85	362.74
Acsad 65	355.729	174.14	511.64	337.50
Sham3	358.213	223.68	500.46	276.78
Crezo	385.869	189.47	586.38	396.91

The Eberhart & Russell (8) procedure involves the use of joint linear regression where the yield of each genotype is regressed on the environmental mean yield. The analysis of variance for the regression model is presented in Table 5. The sums of squares due to environments and genotype x environment are partitioned into environments (linear), genotype x environment (linear) and deviations from the regression model. The genotype's performance is generally expressed in terms of three parameters, mean yield, regression coefficient (*bi*) and the deviation (S^2di) from the regression. According to this model a stable genotype should have a high mean yield, b = 1.0 and $S^2di = 0$. It is however specifically the deviation from the regression (S^2di) which is used as a measure of a genotype's stability across environments. The combined analysis of variance revealed that there were significant differences between cultivars and environments indicating high variability in cultivars at different environments reflecting the differential response of cultivars in various environments (1 and 2). In Table 5 The magnitude of linear component of variation was significantly higher than the non-linear components suggesting that genotype's performance can be predicted but with caution, and that prediction needs to be based on both regression and deviation from regression. The G x E (linear) sum of squares were not as large portion of the G x E interaction when compared with the environment E (linear) sum of squares. Hence, only the deviation mean square was considered important. Genotypes were highly significant different from each other but the G x E (linear) interaction was not significant. The variation among the genotypes and for G × E interaction was significant. It means that genotypes exhibited different performance in different environments which is due to their different genetic makeup or the variation due to the environments or both.

Table 5. Analysis of variance for linear regressions of cultivar mean yield on environmental mean yield over six different environments in Autumn 2013-2014 and spring sowing date 2014

SOV	Df	Grain yield	
		SS	MS
Genotype (G)	6	71602.2	11933.7**
E + G x E	35	919734	26278.11**
E Linear	1	855332.2	855332.2*
G x E Linear	6	19940.28	3323.38
Pooled Deviation	28	44461.52	1587.91**
Pooled Error	84	4603.88	54.81

In table 6 the results of regressing the genotype mean yield on the environmental mean yield over six environment are indicated. The stability parameters according to the model of Eberhart & Russell are given. The most stable cultivar with the lowest S^2di values were Rash gull ranked first Crezo ranked second and Bohooth5 ranked third. The most unstable cultivar with the highest S^2di values were Sham1ranked last and Acsad 65 ranked second last . If the mean yield, regression coefficient value (bi) and the deviation from the regression S^2di are considered together, then the most stable cultivar would be Iraq 7with a mean yield = 376.0961 g. m^{-2} ranked first, bi = 1.026 close to 1 and the S^2di = 1291.46 ranked fifth. High value of regression (bi>1) indicates that the variety is more responsive for input rich environment, while, low value of regression (bi<1), is an indication that the variety may be adopted in poor environment. A regression coefficient below 1.0 provides a measurement of greater resistance to environmental change, and thus increases the specificity of adaptability to low yielding environments (31). Linear regression for the average grain yield of a single genotype on the average yield of all genotypes in each environment resulted in regression coefficients (bi values) ranging from 0.744 to 1.266 for grain yield. This large variation in regression coefficients indicates different responses of genotypes to environmental changes. The superiority measure of cultivars (20). A measure of cultivar general superiority for cultivar × location data is defined as the distance mean square between the cultivar's response and the maximum response averaged over all locations. Since the maximum response is the upper boundary in each location, a small mean square indicates general superiority of the test cultivar. The superior genotype would be that one with the lowest Pi value, that one which remained among the most productive in a given set of environments. Cultivars Crezo and Iraq 7 had the greatest mean general yields and the lowest Pi values, with its most part attributed to the genetic component. According to EV parameter, cultivar Sham3 was the most stable cultivar while cultivar Crezo was the most unstable cultivar. For the deviation from the mean (DFM) parameter, cultivar Crezo manifested first with 36.8.

Table 6 - Estimates of the stability parameters proposed by Eberhart and Russell (8), Lin *et al* (19), Lin and Binns (20) and El-Sahookie (9,10) for grain yield (g.m^{-2}) of 7 durum wheat cultivars evaluated in 6 environments

No	Cultivars	bi	S^2di	EV	Pi	H%	GR	DFM	Mean	
									g. m^{-2}	t.ha^{-1}
1	Iraq7	1.026 II	1291.46 V	26825 IV	1636 II	0.56 II	0.61 II	27.1 II	376.0961 II	3.761
2	Rash gull	0.862 V	484.74 I	18572 II	13160 VII	0.46 VII	0.34 VII	-95.5 VII	253.5833 VII	2.536
3	Sham1	1.052 III	3208.93 VII	29664 VI	2390 III	0.54 III	0.57 III	23.7 III	372.3928 III	3.724
4	Bohooth5	1.064 IV	761.15 III	28308 V	3417 VI	0.51 V	0.50 VI	-7.8 VI	341.3550 VI	3.414
5	Acsad 65	0.987 I	3196.77 VI	26378 III	3146 V	0.54 IV	0.55 IV	6.7 V	355.7289 V	3.558
6	Sham3	0.744 VI	1099.41 IV	14442 I	3039 IV	0.66 I	0.62 I	9.2 IV	358.2128 IV	3.582
7	Crezo	1.266 VII	689.25 II	39756 VII	1199 I	0.48 VI	0.53 V	36.8 I	385.8689 I	3.859

Grand mean 349.03.
Latin numbers as Ranking indicated.

Statistically concept according to Estimates of (H%) and (GR) according to Elsahookie (10), who mentioned if the value of homeostasis is less than 85%, it means that the cultivar was unstable across environments, and if the value of genetic resultant was high and close to unity, it means that the cultivar has a good performance under varying environments. Accordingly on this role, the results showed that all cultivars are unstable across different environments depending on these two parameters. Sham3 cultivar had the highest value whith 0.66 and 0.62, respectively. We can conclude from this study that the old cultivar (Rash gull) was characterized by a minimal responsiveness to improved environmental conditions, showing an almost stable grain yield in agreement with the concept of stability. In contrast, the modern cultivars (Crezo and Iraq7) were highly responsive to normal sowing date (autumn) improvements and showed a pronounced adaptation to high-input environments. Crezo and Iraq7 cultivars had the best values according to the most parameters of stability (bi, S^2di, Pi, DFM, EV and mean); hence, it has a wide adaptability over a range of environments and may be considered as a future wheat cultivar for wide range cultivation under varying of rainfall conditions in Iraq.

REFERENCES

1. Ali. I. H. and Sadallah H. A. 2008. Genetic stability in seven varieties of durum wheat. *Zanco Journal*, 20 (1): 85-94. (In Arabic).

2. Ali, I. and Hussain M. 2014. Genetic Stability in Some Bread Wheat Cultivars. Jordan Journal of Agricultural Sciences, Vol 10, No 2**.**

3. Baker, R. J. .1988. Different response to environmental stress. In: Weir, B. S., Eisen, E. J., Goodman, M. M. and Namkoong, G. (eds) Proceedings of the Second International Conference on Quantitative Genetics. Sinauer, Sunderland, Massachusetts, pp. 492-504.

4. Becker, H. C. and J. Leon. 1988. Stability analysis in plant breeding. Plant Breed. 101: 1-23.

5. Ceccarelli, S. 1996. Positive interpretation of genotype by environment interactions in relation to sustainability and biodiversity. In: Cooper M, Hammer GL (eds) Plant adaptation and crop improvement. CABI, Wallingford, UK.

6. CIMMYT, 1992. Durum Wheats: Challenges and Opportunities. Mexico, D.F Kang M.S. (1998). Using genotype-by-environment interaction for crop cultivar development. Advanced Agronomy 62: 199–252, DOI: 10.1016/S0065-2113 (08) 60569-6.

7. Cooper M, Woodruff DR, Phillips IG, Basford KE, Gilmour AR. 2001. Genotype-by-management interactions for grain yield and grain protein concentration of wheat. Field Crops Res 69:47-67.

8. Eberhart, S. A. and W. A. Russell. 1966. Stability parameters for comparing varieties. *Crop Science*, 6:36-38.

9. El-Sahookie, M. M. 1985. Homoestasis estimation for crop germplasm adaptation *Journal of Agriculture and Water Resourses*.4:1-15.

10. El-Sahookie, M. M. 1990. Maize, Production and Breeding. Higher Education Presses, Iraq (In Arabic).

11. El-sahookie, M.M and O.H. Al-Rawi. 2011. Efficiency of some equations to analyze genotypes ×environment interactions Iraqi. J.Agric.Sci. 42 (6): 1-18.

12. Fan XM, Kang MS, Chen H, Zhang Y, Tan J, Xu C. 2007. Yield stability of maize hybrids evaluated in multi-environment trials in Yunnan, China. *Agronomy Journal* 99, 220–228.

13. Finlay, K. W. & G. N. Wilkinson. 1963. The analysis of adaptation in a plant breeding programme. Australian Journal of Agricultural Research 14: 742–754.

14. Francis TR, Kannenberg LW. 1978. Yield stability studies in short-season maize: I. A descriptive method for grouping genotypes. Canad J Plant Sci 58:1029-1034.

15. Gauch HG.1992. ‘Statistical analysis of regional yield trials: AMMI analysis of factorial designs.’ (Elsevier: Amsterdam).

16. Hernández CM, Crossa J, Castillo A.1993. The area under the function: an index for selecting desirable genotypes. Theor Appl Genet 87:409-415.

17. International Wheat Council 2001. World production of durum wheat. The Council, London.

18. Kang M. S. 1998. Using genotype-by-environment interaction for crop cultivar

development. Advanced Agronomy 62: 199–252, DOI: 10.1016/S0065-2113(08)60569-6.

19. Lin, C. S. M. R. Binns and L. P. Lefkovitch. 1986. Stability analysis where do we stand. *Crop Sci.*, 26: 894-900.

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

21. Mohammadi, M., Karimizadeh, R., Hosseinpour, T., Falahi, H. A., Khanzadeh, H., Sabaghnia, N., . & Hosni, M. H. 2012. Genotype× Environment Interaction and Stability Analysis of Seed Yield of Durum Wheat Genotypes in Dryland Conditions. *Notulae Scientia Biologicae*, *4*(3), 57-64.

22. Palamarchuk A. 2005. Selection strategies for traits relevant for winter and facultative durum wheat. In: Royo C, Nachit.International Wheat Council (2001) World production of durum wheat. The Council, London.

23. Pinthus J. M. 1973. Estimate of genotype value: a proposed method. Euphytica 22:121-123.

24. Rascio, A., Picchi, V., Naldi, J. P., Colecchia, S., De Santis, G., Gallo, A., ... & De Gara, L. 2015. Effects of temperature increase, through spring sowing, on antioxidant power and health-beneficial substances of old and new wheat varieties. *Journal of Cereal Science*, *61*, 111-118.

25. Rasul, M. Zulkiffal,J. Anwar, S.B. Khan, M. Hussain and Riazuddin. 2006. Grain Yield Stability of Wheat Genotypes under Different Environment in Punjab. Journal of Agriculture & Social Sciences 1813–2235/2006/02–4–222–224.

26. Rharrabti, Y., L. F. Carcia Del Moral, D. Villegas and C. Royo. 2003. Durum wheat quality in Mediterranean environments. III. Stability and comparative methods in analysing G × E interaction. *Field Crops Res.*, 80: 141–146.

27. Sabaghnia N, Dehghani H, Sabaghpour SH. 2006. Nonparametric methods for interpreting genotype × environment interaction of lentil genotypes. Crop Sci 46:1100-1106.

28. Sheath, G. W.; Galletly, W. S. 1980: Effects of sowing time and nitrogen on the grain yield and quality off our wheat cultivars grown in North Otago. NewZealand journal of experimental agriculture 8 : 235- 241.

29. Shukla G K.1972. Some statistical aspects of partitioning genotype environmental components of variability. *Heredity* 29, 237–245. doi: 10.1038/hdy.1972.87.

30. Tai GCC. 1971. Genotypic stability analysis and application to potato regional trials. Crop Sci 11:184-190.

31. Wachira, F., N.G. Wilson, J. Omolo and G. Mamati. 2002. Genotype x environment interactions for tea yields. Euphytica 127: 289-296.

32. Yan W, KangMS. ‘GGE Biplot analysis: Agraphical tool for breeders, geneticists, and agronomists. 2003. (CRC Press: Boca Raton, FL).

33. Yan W, Tinker NA. Biplot analysis of multi-environment trial data: Principles and applications. 2006. *Canadian Journal of Plant Science* **86**, 623–645.

34. Zubair, M. and Abdual Ghafoor. 2001. Genotype Environment interaction in Mungbean. *Pakistan J. Bot.*, 33: 187–90.