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ORIGINAL ARTICLE

Parametric Stability Analyses for Grain Yield of Promising Durum Wheat Genotypes in Moderate Region of Iran

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ABSTRACT
*In order to evaluate genotype-environment interactions (GEI), determine stable genotypes, and compare mean grain yield with the parametric stability parameters grain yield of 18 durum wheat (Triticum durum Desf.) genotypes with two cultivator including Dena (Durum wheat) and Parsi (bread wheat) tested in a randomized complete block design with four replications across 3 environments of moderate region of Iran in 2011-2013. In order to examine interaction and to determine stable genotypes, Romer, Fancies, Kanenberg, Wrickese, Shokla, Lin, Binns stability analysis methods were used. Based on results of above methods, genotypes No14 (INTER_16/SNITAN/...), No. 4 (SNTTAN*2/RBC), No.11 (LDN6D (6A) 3*ACONCHI / ...) showed high stability and genotype No. 14 with the highest yield showed suitable stability. Genotypes No. 20 (Parsi), No.6 (1A.1D5+106/3*MOJO//...).3/) showed very low stability.*
Keywords;*Durum wheat, Yield comparison, Stability analysis, Genotype × environment interaction*

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INTRODUCTION

Wheat is grown on more than 240 million ha, larger than for any other crop, and world trade is greater than for all other crops combined [1]. About 90% of the world wheat production is bread wheat and 10 percent are devoted to durum wheat while economic value of a kilogram of bread wheat is 0.25% than durum wheat, depending on resulting by-product. Almost 90% world durum wheat is produced at Mediterranean region and with regard to Iran is one of countries with Mediterranean climate conditions; wheat production is possible and successful [2].

Stability is often defined in different ways. In fact, according to the purpose and character of the concept of stability, there is static stability and dynamic stability that both are valuable concepts, but their use depends on studied character [3]. According to static stability concept, genotype is stable that in spite of changes in environmental conditions remain unchanged. Such a stable genotype is without any deviation from the expected character, this means that its variance at different environments is zero. Unlike dynamic stability concept that in which the genotype state has fixed rate, at dynamic stability, predictable response depends on environmental factors. According to dynamic stability concept, dynamic genotype is without any deviations from such responses to the environment. The stable genotype status in each environment is completely dependent on the estimated or predicted rate. At dynamic stability, It is not necessary that genotype response to environmental conditions be the same, what is important is that there is consistency between estimated or predicted status and real status. (In fact there is no derivation between predicted responses at different environments and real response) Baker called it agricultural stability and distinguished it from biotic stability that is synonymous with static stability [4, 5]. In most plant breeding programs, due to genotype and environment interactions, selection superior genetics for large environments is difficult. Character expression, of particular Quantitative characteristics, is resulting from genetic, environmental factors and their interaction [6, 7] which is resulting from genotypes different reactions to environmental changes [8]. Interactions cause difficulty for evaluating genotypes, heritability of traits, yield resulting from selection. Therefore examination genotype × environment interaction is very important for breeding programs. Genotype × environment interaction is the most important challenge facing plant breeders [9].

One of important purposes for examination genotypes at different years and locations are interaction interpretation, identification purpose environments, introduction stable genotype along public and private adaptability for study environment and determination stable genotypes at different years. Genotype interaction phenomena at environment helps herb reformers to evaluate genotypes at different locations, thereby eliminating unnecessary location then costs are reduced significantly [10]. Evaluating effects genotype × environment interaction provides valuable information about cultivator yield at different environments and has important role for evaluating yield stability. Stable genotypes show similar reactions in different environments [11].

Sadeghzadeh Ahari *et al.,* [12] performed experiments in six stations with 22 durum wheat cultivars and bread wheat cultivars (totally 24 genotypes) to examine dry durum wheat grain yield stability and adaptability. They used parameters type 4 method (Lin and Bineses.), yield variation coefficient (CV %) and non-ranking method (Rank) to determine stable cultivators. They finally showed that lines 9 (G-1252) and 18 (Haurani) are more suitable than the control durum wheat and other durum cultivars in this experiment for planting at mentioned areas due to suitable growth habit (winter and intermediate) and higher grain yield. Line 18 was superior to durum wheat and bread wheat according to intra spatial variance (parameter type 4) and average rank.

Najafian *et al*., [13] introduced Kohdasht cultivator as adaptable cultivator in examining yield stability of 24 bread wheat genotypes in dry land areas, by using the intra spatial variance method. Haji *et al*., [14]calculated eight stability statistic (S^2_i،CV_i، σ^2_i ،W^2_i،$Ms_{y/L}$، Y_{si} وASV) to determine the stability and interaction of 18 genotypes of durum wheat along Karkhe cultivars and commercial bread wheat as control cultivator at hot and dry climate in southern Iran .according mentioned statistics, genotypes 14,5 were identified as stable and assigned suitable ranks of grain yield. Soughi *et al*., [15] performed an experiment on 19 promising lines along Tajan cultivator as control cultivator to examine grain yield stability analysis and evaluate characters at promising bread wheat lines at Gorgan for three years. In this experiment, the environmental variance method, environmental changes coefficient, non-parametric methods, the average rank, rank standard derivation were used. According to the results, it was shown that genotype 12 (PARA2 // JUP / ...) is suitable for Gorgan region.

MATERIALS AND METHODS

A field experiment was established at three locations during the 2011-2012 winter crop production seasons and continued through the 2012-2013 crop year. The experimental design for each year and location was a randomized complete block design with three replications. Three locations (Kermanshah station in the West, Neyshabur, Station in the East North and Karaj station in northern) were on producer fields and moderate regions in IRAN. Some of the stations properties are shown in (Table 1). Treatment was 18 promising genotypes of durum wheat with two Dena wheat (durum wheat) and Parsi (bread wheat) as the control cultivators (20 lines and cultivators). Code numbers and pedigrees of genotypes were summarized in table 2.

Table 1. Climate -Geographical characteristics of experimented locations

location	Latitude	Longitude	elevation above the sea (m)	Averagetemperature(C)	Average rainfall(mm)
Neyshabur	36.21°	58.79°	1220	15.5	253
Karaj	35.48°	51.00°	1429	16	300
Kermanshah	34.31°	47.06°	1420	14.3	444.7

Table 2. Code and pedigree of considered genotypes

Code	Pedigree
1	PLATA_6/GREEN_17//SNITAN/4/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN
2	RISSA/GAN//POHO_1/3/PLATA_3//CREX/ALLA/4/STOT//ALTAR 84/ALD/5/A…
3	STOT//ALTAR 84/ALD
4	SNITAN*2/RBC
5	BCRIS/BICUM//LLARETA INIA/3/DUKEM_12/2*RASCON_21
6	1A.1D 5+10-6/3*MOJO//RCOL/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1
7	ALTAR 84/CMH82A.1062//ALTAR 84/3/YAZI_10/4/SNITAN/9/USDA595/3/D67…
8	PNE/2*RASCON_37/3/ARTICO/AJAIA_3//HUALITA/4/GUANAY
9	CBC 509 CHILE/5/2*AJAIA_16//HORA/JRO/3/GAN/4/ZAR
10	SORA/2*PLATA_12//SOMAT_3/4/STORLOM/3/RASCON_37/TARRO_2//RASCON…
11	LDN6D(6A)/3*ACONCHI/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1…
12	RCOL/POHO_1/3/DIPPER_2/BUSHEN_3//SNITAN
13	GUANAY/4/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN/5/NUS/SULA//5*NU..
14	INTER_16/SNITAN/9/USDA595/3/D67.3/RABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDEN…
15	RASCON_37/4/MAGH72/RUFO//ALG86/RU/3/PLATA_16/5/PORTO_3*2/6/ARMENT..
16	CF4-JS 40/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-…
17	SABIL/3/AUK/GUIL//GREEN/4/AUK/GUIL//GREEN
18	SOOTY_9/RASCON_37/3/STOT//ALTAR 84/ALD
19	Triticum durum (Dena)
20	Triticumaestivum (Parsi)

The experimental filed was under fallow in two previous years. In order to prepare the field, it was plowed in spring and then the clods were smashed by the cultivator for two times. The field was further prepared by using vertical disks two times before planting. Seeds were disinfected with Benomyl (2‰) fungicide before planting in order to prevent common bunt. The seeds were sown in plots consisting of 6 rows with a 20 cm row space. The seeding rates were about 400 seeds m^{-2} for all genotypes. The plots were fertilized with 25 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} at planting and 50 kg N ha^{-1} in spring at stem elongation. Broadleaf and grassy weeds were controlled with a mixture of herbicides Puma Super (1 lit ha^{-1}) and Granstar (20 g a.i) in the tillering stage. The control of the weeds in the treatment was achieved by spraying by using a TEE JET knapsack sprayer with the fixed pressure of 2 atmospheres and the capacity of 400 liters per hectare in the middle of the tillering stage. All of the planting process was carried out based on the particular requirements and custom practices of the region. In growing season. Date of emergence, days to heading, days to physiological maturing, percentage of lodging, reaction to plant disease and plant height was recorded on 5 selected plants.

At the end of the growing season, the yield of the seed was measured after eliminating the margins of 1*1 m areas from the two middle stacks. The yield was determined and expressed in ton per hectare (t. ha^{-1}).

In combined analysis of variance genotype was considered as constant effect while year and location were considered as random effect. SAS software was used for variance analysis and Duncan multiple range test used for mean comparison of the data collected. The tables and figures were drawn using Office Word and Excel.

The grain yield data were subjected to analysis of variance in each environment. Then the combined analysis performed. Coefficient of variance (CVi) estimated in combined analysis of variance. Thus univariate analysis method applied to investigate genotypes stability. Stability parameters were performed in accordance with Francis and Kannenberg's (1978) coefficient of variability (CVi) and genotypic variance(S_i^2), Romer environmental variance, Francis and Kantelberg environment changes

coefficient, Wricke's covalence (W_i^2), Shukla's stability variance (σ_i^2) and Finaly and Wilkinson's regression coefficient (b_i).
All statistical analyses were carried out using of Excel, SAS, JMP and GENSTATE.
To define genotypic stability, a genotype which had higher or equal mean grain yield than grand mean yield as a precondition was considered stable for grain yield, if it appeared stable in more than five out of nine stability analyses. Genotypes that proved to be stable for more than half stability analyses were then selected as promising ones [16].

RESULTS AND DISCUSSION

Combined analysis of variance showed that year, place, place×year, place×genotype and year× genotype effect was not significant whereas the effect of genotype and place×year×genotype were significant for grain yield (table 3). In other words, physical and chemical properties of soil, climate and management factors at different times in different places, there was not much fluctuation. Classified according to the research institute, Neyshabur research station, Kermanshah Branch and the variable component of the country's temperate weather stations have many similarities with each other. Shamohammadi, [17] also suggests a significant interaction effect between genotype× location× year for barley genotypes, respectively.

Table 3: variance analysis of grain yield of durum wheat genotypes at three places and two years (2011-2013)

Change resources	Free degree (df)	Squares sum (SS)	Average sum (MS)
year	1	35.124	35.124 ^{ns}
place	2	107.549	53.774 ^{ns}
place× year	2	145.430	72.715 ^{ns}
Year ×repeat ×place	12	15.665	1.305 ^{ns}
genotype	19	7.309	0.385*
year× genotype	19	5.454	0.287 ^{ns}
genotype×place	38	8.851	0.233 ^{ns}
place× genotype×Year	38	13.680	0.360*
error	228	55.870	0.245
total	359	394.932	

CV=10.89 *, ns representing significance difference at 5%probability level and non-significance respectively

Table4: comparison average yield of studied durum wheat genotypes at different environments.

Genotype number	Average yield ($t.ha^{-1}$)	genotype rate according to yield	Average yield ($t.ha^{-1}$)
1	7.441 abcd	14	7.871 a
2	7.801ab	16	7.863 a
3	7.728abcd	2	7.801 ab
4	7.646abcd	6	7.793 ab
5	7.365abcd	17	7.77 abc
6	7.793ab	12	7.755 abcd
7	7.346abcd	3	7.728 abcd
8	7.096d	13	7.696 abcd
9	7.156bcd	20	7.65 abcd
10	7.618abcd	4	7.646 abcd
11	7.61abcd	18	7.636 abcd
12	7.755abcd	10	7.618 abcd
13	7.696abcd	11	7.61 abcd
14	7. 871a	19	7.575 abcd
15	7.113cd	1	7.441 abcd
16	7.863a	5	7.365 abcd
17	7.77abc	7	7.346 abcd
18	7.636abcd	9	7.156 bcd
19	7.575abcd	15	7.113cd
20	7.65abcd	8	7.096 d

Average yield of genotypes (ton/hectare): $\bar{M}$=7/576

Means with different letters are significantly different at p≤0.05 (Duncan's test)

Average grain yield of genotypes according Duncan's multiple rand test method showed that the highest and lowest grain yield were related to genotype No. 14 with 7.78 t.ha^{-1} and genotype No. 8 with 7.096 t.ha^{-1} (Table 4). One of the genotypes assessment critical problems in laboratory in place and year is that place effect can be remarkably variable from year to year. Thus for more accurate survey of interaction and achieving genotypes with stable yield in different environmental conditions , stability degradation of genotypes yield in surveyed place and Romer environmental variance shows stable statistic concept, it use in characteristics such as live and nonliving stress durability that their amount should be invariable. Romer environmental variance shows the variance in all environments; and according this method genotypes No. 9, 14, 11 and 7 respectively, with a less environmental variance have more biological stability and yield; and genotypes No. 6, 4 , 16, and 19 respectively, with a greater environmental variance have lower stability yield (Table 5). According to Francis and Kannenberg [18] environmental changes coefficient, genotypes No. 14, 11, 18 and 13, respectively with the lowest coefficient of environmental changes have more stability yield and genotypes No. 6, 4, 19 and 16 respectively with the highest coefficient of environmental changes have lower stability yield (Table 5) .

Table5: results from Romer's environment variance methods and Fransis and Kanteberg's environment changes coefficient

genotype	Romer environment variance	Genotype rank	Fransis and Kanteberg environment changes coefficient	Genotype rank
1	4.0430	8	28.88	9
2	4.1673	12	28.24	6
3	4.8206	16	30.46	16
4	5.4637	19	32.69	19
5	4.1298	10	30.06	12
6	5.9892	20	33.59	20
7	3.7691	4	28.18	5
8	3.8206	5	30.15	13
9	3.5972	1	28.46	7
10	4.6063	14	30.04	10
11	3.7125	3	27.13	2
12	4.1672	11	28.51	8
13	4.0081	7	27.75	4
14	3.7015	2	26.26	1
15	4.0991	9	30.3	15
16	5.4089	18	31.63	17
17	4.7408	15	30.18	14
18	3.8997	6	27.71	3
19	5.2694	17	32.63	18
20	4.5234	13	29.5	11

According to both environmental variance (S_i^2) and environmental changes coefficient (Cv_i) genotypes No. 14 and 11 respectively with 7.871 and 7.61 t.ha^{-1} were showed more yield stability in different environments; and since genotype No. 14 has the most average yield among genotypes in different environments and genotype No. 11has more yield than average level of genotypes, according to two methods, both genotypes were selected stable and high yield genotypes in different environments. Primary forms of first kind stability factors are genotypes with uniform yield in all environments have usually low product , we cannot find the most stable and most product of genotype by this feature ; this feature is correct about genotype No. 11. Because this genotype with yield 7.61 t.ha^{-1} has yield thirteen rank among genotypes but this was not correct about genotype No. 14, because this genotype has first yield rank among genotypes.

Soughi *et al.*, [15] for surveying yield stability of bread wheat promising lines in warm and humid northern climates of IRAN were used different methods such as changes coefficient and environmental variance and introduced 5 stable genotypes and reported the same result. Haji Mohammad Ali Jahromi et al., [15] for stability degradation of 20 Durum wheat genotypes in southern harm and dry climate of IRAN was used different methods such as Romer environmental variance and environmental changes coefficient and obtained similar results.

Rick equivalence and Shukla stability variance (the second parameter)

According to Rick equivalence and Shukla stability variance parameters genotype is stable if it's responses against different test environments was similar average response of all present genotypes in he experiment. Under both methods, Rick and Shukla, genotypes No.2, 4, 3 and 11, respectively, with the lowest equivalence and variance were identified the most stable genotypes and genotypes No. 8, 20, 18 and 15, respectively, with most equivalence and variance were identified the most unsustainable genotypes (Table 6).

Table 6: Results of Rick covalence and Shoka stability variance

genotype	(W^2_i) covalence	Genotype rank	Shoka stability variance	Genotype rank
1	0.9439	6	0.2149	6
2	0.3091	1	0.0 813	1
3	0.6347	3	0.1499	3
4	0.5528	2	0.1326	2
5	1.0174	7	0.2304	7
6	1.2971	10	0.2893	10
7	1.7700	16	0.3889	16
8	3.9433	20	0.8464	20
9	1.2859	9	0.2869	9
10	1.7461	15	0.3838	15
11	0.8206	4	0.1890	4
12	1.4163	13	0.3144	13
13	1.3912	12	0.3091	12
14	1.0635	8	0.2401	8
15	1.8151	16	0.3984	17
16	1.3199	11	0.2941	11
17	0.8236	5	0.1896	5
18	1.8738	17	0.4107	18
19	1.5843	14	0.3498	14
20	2.2070	19	0.4809	19

All stable genotypes based on the above two methods, the average yield of the genotypes were higher than average genotypes. So at different locations can be selected but genotype No. 2 with 7.801 $t.ha^{-1}$ has third yield rank among genotype and was found the most stable genotypes ; this genotype can be selected as high genotype. Roustaie *et al.*, [19] by comparing different stability methods for stable and high-yielding wheat and barley varieties concluded that Rick equivalence criteria and Shukla stability variance cause selection of high yielding and stable varieties. The results from rating two methods showed that both statistics are similar and can use one of the parameters that it confirms with [20] results. Because stability variance is linear combination of equivalence, therefore genotypes calibrations have identical values [4]. It should be mentioned that genotype No. 11 on the basis of first kind stability parameters is stable genotype; But genotype No. 4 is unstable genotype, according to two methods has devoted second rank stability.

Inter spatial variance and changes coefficient of Lin and Baines

Based on the parameters of Lin and Baines (parameter type IV) genotypes No. 18, 7, 11 and 14 ,respectively were knew the least variance and coefficient of inter spatial variation and were identified as stable genotypes. Also genotypes No. 12, 6, 17 and 16 respectively with the highest variance and coefficient of inter spatial changes were identified unstable genotypes (Table 7 and 8). Genotype No.7 with yield average of 7. 346 t.ha-1 despite second rank of stability between genotypes has devoted lower yield than genotypes average (7.576 $t.ha^{-1}$), but genotype No. 14 with fourth rank of stability yield, has first rank of stability average; It can select as high genotype. Roustaie et al., [19] by comparing different stability methods for selecting high-yielding product and grain yield stability of bread wheat genotypes at moderate and cool regions concluded that inter spatial variance because inheritance and non effecting of other genotypes in variance change of genotype, is suitable factor for yield stability.

Table 7 - Results of the inter spatial variance and changes coefficient of Lin and Bains.

genotype	Inter place variance	Change coefficient	Genotype rank
1	2.7599	37.20	**10**
2	4.7495	46.55	**16**
3	4.5992	46.24	**15**
4	3.9253	43.18	**13**
5	3.5279	42.50	**12**
6	5.3433	49.43	**19**
7	1.6720	29.33	**2**
8	2.9933	40.63	**11**
9	2.5258	37.01	**9**
10	2.4599	34.31	**6**
11	2.0143	31.08	**3**
12	5.8935	52.17	**20**
13	2.4612	33.97	**5**
14	2.1495	31.14	**4**
15	2.2262	34.95	**7**
16	4.8604	46.72	**17**
17	5.083	48.36	**18**
18	1.5351	27.04	**1**
19	4.2108	45.14	**14**
20	2.8144	36.54	**8**

Table 8-Ranking of durum wheat genotypes based on univariate methods analysis of variance analysis.

variance and changes coefficient 0f Lin and Baines	Rick equivalence and Shukla stability variance	Fransis and Kanteberg environment changes coefficient	Romer environment variance	**genotype**
10	6	9	8	**1**
16	1	6	12	**2**
15	3	16	16	**3**
13	2	19	19	**4**
12	7	12	10	**5**
19	10	20	20	**6**
2	16	5	4	**7**
11	20	13	5	**8**
9	9	7	1	**9**
6	15	10	14	**10**
3	4	2	3	**11**
20	13	8	11	**12**
5	12	4	7	**13**
4	8	1	2	**14**
7	17	15	9	**15**
17	11	17	18	**16**
18	5	14	15	**17**
1	18	3	6	**18**
14	14	18	17	**19**
8	19	11	13	**20**

CONCLUSION

According to the results based on univariate methods of used variance analysis in this study can emphasize the following findings as the final results and propose following cases: Since in different methods, genotypes which obtained first rank statistic were differed ; genotype No.14 showed suitable stability and this genotype with the 7.871 $t.ha^{-1}$ yield (first rank of yield) showed more suitable stability and genotypes No.20 and 6 based on results of the most methods showed poor and unsuitable stability .We can use mentioned stable varieties in modification for genetic source enrichment that these varieties had devoted suitable ranks of yield and stability. The best presented genotypes in this study were genotypes No.14, 4, 11 and 9. According to the same ranks of genotypes in both Rick equivalence and Shukla stability variance methods ,we can use only one of them .

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