academicJournals

Vol. 10(7), pp. 260-265, 15 April, 2015
DOI: 10.5897/SRE2015.6180
Article Number:6065B9852185
ISSN 1992-2248

http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Genotype-environment interaction and stability analysis in Wheat (*Triticum aestivum* L.) for protein and gluten contents

N. Saleem, M. Ahmad*, S. A. Wani, R. Vashnavi and Z. A. Dar

Division of Genetics and Pant Breeding, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir Shalimar Campus, Srinagar -191 121, India.

Received 7 February, 2015; Accepted 1 April, 2015

Genotype-environment interaction and stability performance were investigated on protein and gluten contents in three environments. Genotypes showed important differences in quality values as reflected in the AMMI (additive main effects and multiplicative interaction) analysis biplot result. The protein content showed the similar trend of GE interaction as that of grain yield. The genotype G1 was tightly grouped with E3 as indicated by their origin on the biplot. All the genotypes except G1 were located in the point farthest from the center of the biplot (PC1), indicating high gluten content, but the length of its PC2 vector exhibits this variety's instability, while G1 was in the center of the biplot exhibiting high stability but lower gluten level than the above mentioned cultivars. However, all the genotypes were tightly grouped with E2 with regard to gluten content and as such highly stable to this particular environment. Protein and gluten content were significantly affected by the wheat varieties under various locations. The highest protein content (pooled) was exhibited by SKW-489 (13.54%) and SW-1 (13.23%) whereas the lowest protein content was observed in SKW-848 (10.31%). Similarly, highest gluten content (pooled) was observed in SKW-517 (29.65%) and SW-355 (29.14%), while lowest percentage was exhibited by SKW-489 (22.22%).

Key words: Protein content, gluten content, stability analysis, multiplicative interaction, wheat.

INTRODUCTION

Most of the currently cultivated wheat varieties belong to hexaploid wheat (*Triticum aestivum* L.), which is known as common bread wheat and valued for bread making. The greatest portion of the wheat flour produced is used for bread making. Wheat grown in dry climates is generally hard type, having protein content of 11 to 15% and strong gluten (elastic protein). The sticky gluten of bread wheat entraps the carbon dioxide (CO_2) formed during yeast fermentation and enables leavened dough to rise. The hard type of wheat produces flour best suited for bread making. The wheat of humid areas is softer, with protein content of about 8 to 10% and weak gluten. The softer type produces flour suitable for cakes, crackers, cookies, pastries and household flours. Durum wheat (*T. turgidum* L.), which is the main tetraploid type, is also important, although its large, very hard grains yield

*Corresponding author. E-mail: drmushtaqskuastk@rediffmail.com

low gluten flour that is the main source of semolina suitable for pasta, couscous, burghul and other Mediterranean local end-products (Nachit, 1992). Apparently, no economically important diploid wheat is being cultivated as a crop anywhere in the world. Although most of the wheat is grown for human food, however, 10% is retained for seed and industry (for production of starch, paste, malt, dextrose, gluten). Wheat grain contains all essential nutrients; kernel contains about 12 percent water, carbohydrates (60 to80% mainly as starch), proteins (8 to 15%) containing adequate amounts of all essential amino acids (except lysine, tryptophan and methionine), fats (1.5 to 2%), minerals (1.5 to 2%), vitamins (such as B complex, vitamin E) and 2.2% crude fibers (Anjum and Walker, 2000).

Stability performance of genotypes will be of special importance in Jammu and Kashmir where environmental conditions vary considerably and the means of modifying the environment are inadequate. The major problem of bean improvement program in this state has been the lack of genotypes that consistently perform well across different bean growing environments. Hence, the development of superior quality genotypes and information on multi location performance are of paramount importance in Jammu and Kashmir where environments vary greatly within short distances. The adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted. A genotype is considered more adoptive when it has a high mean yield and low fluctuations when grown over diverse environments (Ahmad et al., 2014a).

The AMMI model (Gauch and Zobel, 1997) is more efficient in determining the most stable and desirable quality and high yielding genotypes in multi-environment trials compared to earlier procedures (Eberhart and Russel, 1966). Biplot analysis is possibly the most powerful interpretive tool for AMMI models. Biplots are graphs where aspects of both genotypes and environments are plotted on the same axes so that interrelationships can be visualized. The AMMI biplot where the main effects (genotype mean and environment mean) in X axis and IPCA1 scores for both genotypes and environments are plotted in Y axis. The effectiveness of AMMI procedure has been clearly demonstrated (Crossa et al., 1990 and Tarakanovas and Ruzgas 2006).

The main objectives of the present investigation are to identify desirable quality genotype and to determine the areas where these genotypes would be adapted and economically sustainable.

MATERIALS AND METHODS

The present investigation was carried out during *Rabi* season of 2012-13 at three locations. The basic material for the present investigation comprised of 10 genotypes of wheat (*Triticum aestivum* L.) are designated as G1 (SKW-848), G2 (SKW-489), G3 (SKW-490), G4 (SKW-514), G5 (SKW-515), G6 (SKW-517), G7 (SKW-519), G8 (SKW-527), G9 (SKW-530), and G10 (SKW-531) and environments as E1 (Experimental Farm of the Division of Plant Breeding and Genetics, SKUAST-K, Shalimar, Srinagar), E2 (Mountain Field Crop Research Centre, Khudwani) and E3 (Regional Research Station, Wadura, Sopore). The experiment was laid out in a completely randomized block design with 3 replications at each location. The experimental plot comprised 3 rows each of 1 m length. Row to row and plant to plant spacing was maintained at 25 cm and 10 cm, respectively. Recommended agronomic practices were followed to raise a good crop at all the three locations. Based on the performance of the cultivars three random environments, phenotypic stability was worked out by following models (i) the AMMI model of Gauch and Zobel (1988), and (ii) the linear model of Eberhart and Russel (1966).

Protein content (%)

The grains were dried in oven and ground to the fine powder to pass through, 40 mesh sieve in a 'Micro Willey Mill.' From each treatment, 0.5 g sample was weighed for chemical analysis to determine the contents of nitrogen. The total content of nitrogen was estimated by Kjeldahl method as outlined by Campbell (1986) and was expressed in %. Protein content (%) in grain was determined by multiplying the nitrogen % in grain with the conversion factor 6.25.

Gluten content (%)

Gluten in sample of flour was estimated by washing the dough free of starch, sugars, water soluble proteins and other minor components. The wet cohesive mass obtained is referred to as wet gluten while the dry product obtained from it is referred to as dry gluten. 25 g flour was kheaded with about 15 ml of water to get a dough ball. The dough ball was allowed to remain immersed in water for one hour to ensure proper hydration after which the starch is washed out by kneading gently in a gentle steam of water over a fine sieve or silk till the washed liquid is clear.

The gluten which is cohesive was pressed as dry as possible and weighed. The gluten so obtained was dried at 100°C for 24 h and weighed again to get the value for dry gluten.

$$\text{Wet gluten (\%)} = A / C \times 100$$

$$\text{Dry gluten (\%)} = B / C \times 100$$

Where,
A = Weight of wet gluten, B = Weight of dry gluten, C = Weight of flour.

RESULT AND DISCUSSION

The results of AMMI analysis for protein and gluten content traits in wheat (*T. aestivum* L.) for the 10 genotypes and 3 environments are presented in Table 1. The AMMI analysis of data revealed that the environment, genotype, and GE interaction are highly significant ($P<0.01$). The large MS of environments indicated that the environments are diverse. The large differences among environmental means caused in studied traits. In the present investigation, the AMMI analysis showed that protein and gluten content traits are highly influenced by genotype, environment and GE

Table 1. AMMI analysis of variance for protein content and gluten content in wheat (*Triticum aestivum* L.).

Source of variation	Df	Mean sum of squares	
		Protein content (%)	Gluten content (%)
Genotypes	9	3.46**	15.00**
Environments	2	2.69**	5.43**
Replications within environments	6	0.49*	4.38*
Genotype x Environment	18	0.08*	3.36*
Error	54	1.51	9.37
Total	89	1.38	8.29

*,** Significant at 5 and 1 per cent levels, respectively.

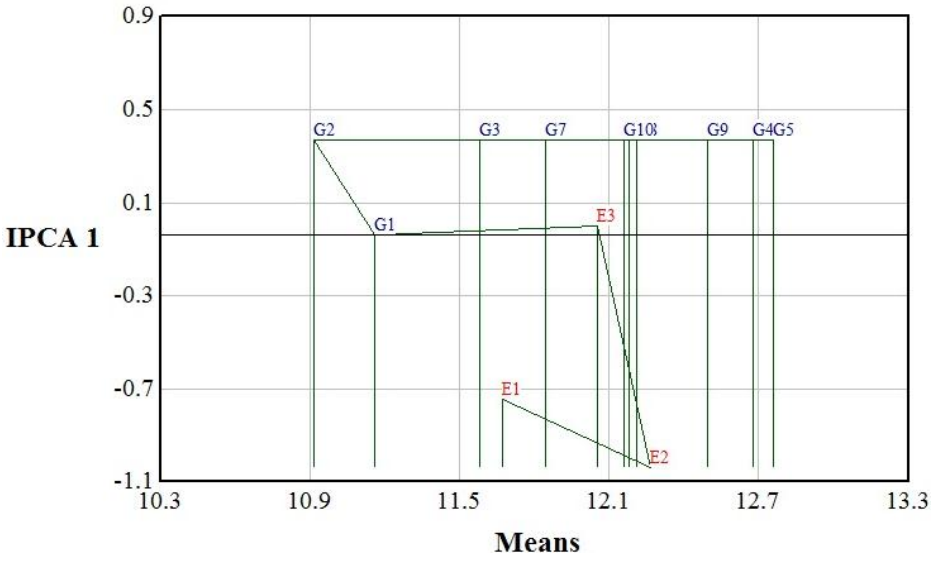

Figure 1. Biplot of the first AMMI interaction (IPCA 1) score (Y-axis) plotted against mean protein content (%) (X-axis) for 10 wheat genotypes.

interaction. Environment had the largest contribution to the total sum of squares indicating that the environments = (location and season) selected for this study are highly diverse, and this were consequently the main effect contributing most variation for these traits. The environment differences in terms of key climate attributes (temperatures and rainfall distribution), altitude and soil fertility affected the performance of wheat genotypes, justifying the need to identify high quality genotypes that are stable in a wide range of environments, or to breed for specific adaptation to specific environments. The magnitude of variation due to environments on the traits is large thereby causing genotypic response to diverse environments and suggesting the presence of mega-environments where best performing genotypes could be selected more efficiently. To characterize GE interaction, an AMMI 1 biplot are plotted using the genotype and environment mean protein content and their IPCA 1 scores (Figure 1). All the genotypes (with IPCA 1 “+”) except G1 exhibited highest contribution to GE interaction as indicated by their distance from the origin of the biplot, that is, zero. On the other hand the genotype G1 lies on the origin of the biplot, that is, with zero distance and therefore showed least contribution to GE interaction. Regarding the environments E3 exhibited minimum IPCA 1 score and led to zero interaction, whereas E2 followed by E1 (with IPCA 1 “-”) contributed maximum to GE interaction. To understand the relationships between particular genotypes and environments for protein content, AMMI 2 biplot analysis is performed, where IPCA 1 scores are plotted against IPCA 2 scores of the AMMI analysis (Figure 2). The results of this biplot showed the genotype G1 is tightly grouped with environment E3 but contributed least to GE interaction because both lies very close to the origin of the biplot. On the other hand the environments E1 and E2 and rest of the genotypes had maximum GE interaction as indicated by the distances from the origin of biplot.

From the (Figure 3), it is clear that all the genotypes (with IPCA 1 “-”) except G1 contributed maximum to GE

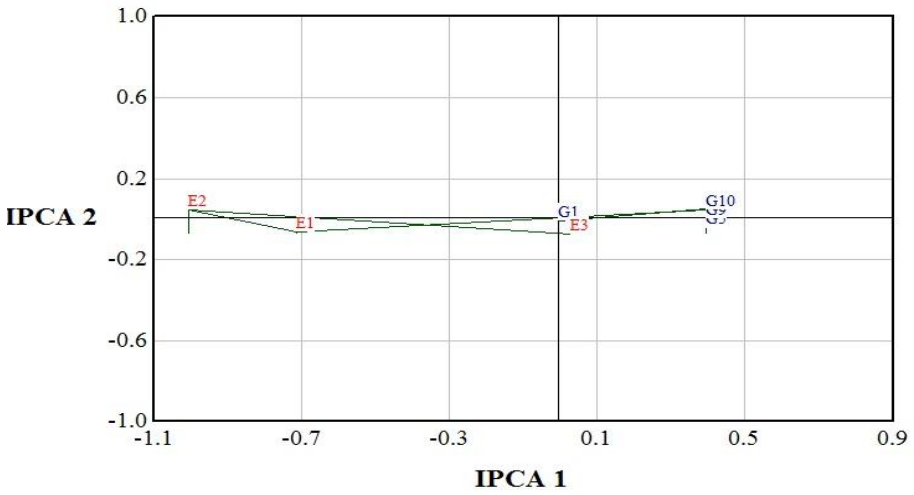

Figure 2. Biplot of the first AMMI interaction (IPCA 2) score (Y-axis) plotted against AMMI interaction (IPCA 1) score (X-axis) for 10 wheat genotypes and 3 environments

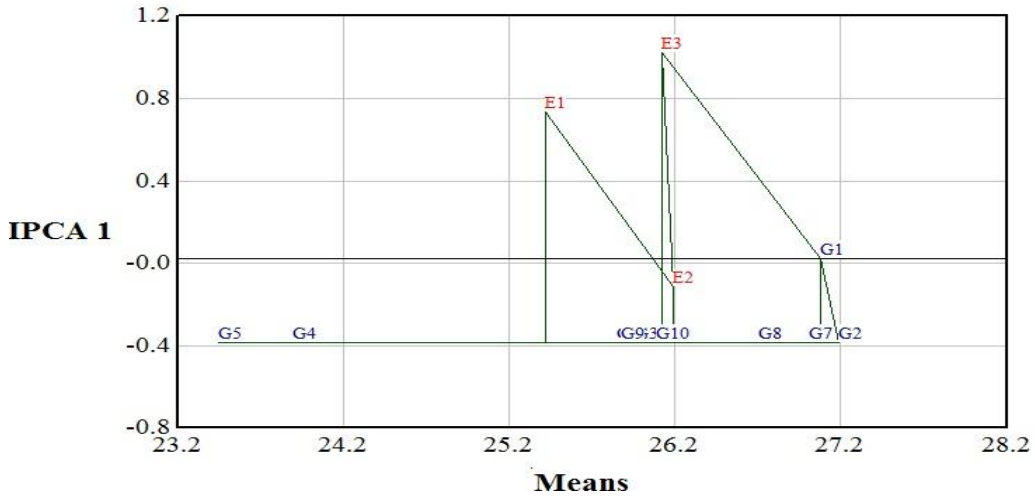

Figure 3. Biplot of the first AMMI interaction (IPCA 1) score (Y-axis) plotted against mean gluten content (%) (X-axis) for 10 wheat genotypes.

interaction. Among them the highest contribution was exhibited by G5 and G4. The environment E2 showed minimum IPCA score and led to zero interaction, whereas the environment E3 followed by E1 contributed maximum to GE interaction as indicated by their distance from the origin of biplot. The AMMI 2 biplot (Figure 4) for gluten content revealed all the genotypes were tightly grouped with E2 and were highly stable to that particular environment. The environments E1 and E3 were separated and showed maximum effect on GE interaction.

It is evident from Table 2 that both protein and gluten content are significantly affected by the wheat varieties under various locations. The highest protein content (pooled) is exhibited by SKW-489 (13.54%) and SW-1 (13.23%) whereas the lowest protein content was observed in SKW-848 (10.31%). Similarly, highest gluten content (pooled) is observed in SKW-517 (29.65%) and SW-355 (29.14%), while lowest percentage was exhibited by SKW-489 (22.22%). Phenotypic coefficient of variability is higher than genotypic coefficient of variability for both the traits, however, the differences between them is very narrow indicating the lesser role of environment. As the coefficient of variation indicates only the extent of variability, it does not reflect on heritable proportion of variation. Hence, estimation of heritability coupled with genetic advance as per cent of mean permits greater effectiveness for selection by separating out the

Table 2. Protein and gluten content (%) in 13 wheat genotypes under three environments.

Genotypes	Environment I		Environment II		Environment III		Pooled environments	
	Protein content (%)	Gluten content (%)	Protein content (%)	Gluten content (%)	Protein content (%)	Gluten content (%)	Protein content (%)	Gluten content (%)
SKW-848	9.90	26.95	10.64	29.12	10.40	28.62	10.31	28.23
SKW-489	13.13	22.72	13.87	19.55	13.63	24.39	13.54	22.22
SKW-490	12.01	26.49	12.75	28.66	12.26	21.82	12.34	25.65
SKW-514	10.57	24.88	11.31	27.05	11.12	26.55	11.00	26.16
SKW-515	13.56	21.37	12.82	23.54	13.06	23.04	13.14	22.65
SKW-517	11.13	30.93	11.87	28.76	11.63	29.26	11.54	29.65
SKW-519	12.26	25.70	13.00	27.87	12.76	27.37	12.67	26.98
SKW-527	10.81	27.32	11.55	25.15	11.31	28.99	11.22	27.15
SKW-530	11.14	24.31	11.88	26.48	11.64	25.98	11.55	25.59
SKW-531	12.19	23.83	12.93	26.00	12.69	25.50	12.60	25.11
SW-1	12.82	26.89	13.56	29.06	13.32	28.56	13.23	28.17
HS-240	11.96	25.78	12.70	27.95	12.46	27.45	12.37	27.06
SW-355	12.29	29.31	13.03	27.14	12.79	30.98	12.70	29.14
GCV	8.981	9.965	7.490	10.088	7.578	9.784	7.922	8.476
PCV	8.996	9.981	7.502	10.104	8.125	9.799	8.004	8.489
H^2 (BS)	94.669	98.688	95.689	97.684	86.979	98.691	97.956	98.682
GA % Mean	18.470	20.496	15.406	20.748	14.558	20.124	16.152	17.432

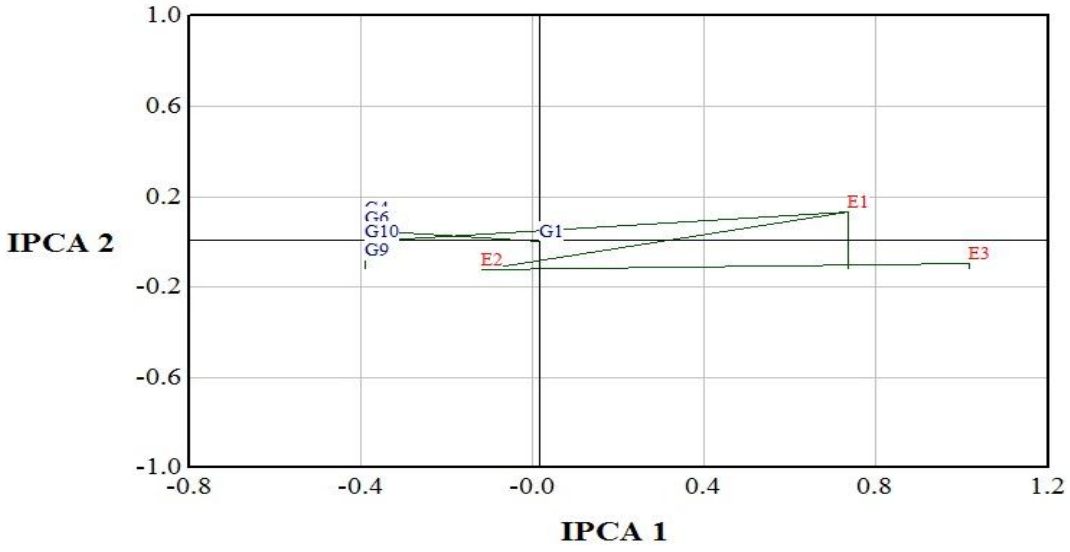

Figure 4. Biplot of the first AMMI interaction (IPCA 2) score (Y-axis) plotted against AMMI interaction (IPCA 1) score (X-axis) for 10 wheat genotypes and 3 environments.

environmental influence from the total variability and thereby allowing accurate selection of a potential phenotype. The results indicated high heritability coupled with high genetic advance for both the traits, thus indicates the predominance of additive genetic variance for these traits. Hence, these characters are amenable for simple selection of superior segregants (Ahmad et al., 2013b). High heritability with high genetic advance was also reported for protein content by Noorka et al. (2009) and Mueen-ud-Din (2009). Anjum and Walker (2000) observed that dry and wet gluten contents of Pakistani wheats were significantly influenced by cultivars but not by crop years or growth locations. In the present investigation, the AMMI analysis showed that quality traits were highly influenced by genotype, environment and GE interaction. Other studies have reported similar

observations on wheat (Hintsa et al., 2011). The high protein percentage of SKW-489 and SW-1 indicates their stability for hard wheat products like yeast-leavened bread. The dough made from this type of varieties increases dough strength, resulting in increased loaf volume after baking. High protein levels are related to undesirable cookie textured. Protein content of rest of the genotypes is low to medium in range and characterize as semi hard wheat. Dough from these varieties will be strong, stretchable, elastic and non-sticky, that is, suitable for un-leavened bread like chapatti. All varieties used in this study are found to have medium to high gluten content. High gluten content observed in SKW-517 and SW-355, interprets strong gluten matrix which may during backing increases the viscosity of cookie dough, which in un-desirable because cookie spread is restricted but it is good for bread.

Conclusion

The genotype G1 was tightly grouped with E3 as indicated by their origin on the biplot. All the genotypes except G1 were located in the point farthest from the center of the biplot (PC1), indicating high gluten content, but the length of its PC2 vector exhibits this variety's instability, while G1 was in the center of the biplot exhibiting high stability but lower gluten level than the above mentioned cultivars. However, all the genotypes were tightly grouped with E2 with regard to gluten content and as such highly stable to this particular environment.

Conflict of Interest

The authors have not declared any conflict of interests.

REFERENCES

Ahmad M, Zaffar G, Dar ZA, Saleem N, Habib M (2014a). Parametric Stability Analysis for green forage yielding Traits in Oats (*Avena sativa* L.). Afr. J. Agric. Res. 9(11):1008-1011.

Ahmad M, Zaffar G, Mir SD, Razvi SM, Dar ZA, Iqbal S, Habib M. (2014b). Genetic analysis for fodder yield and its important traits in oats (*Avena sativa* L.). Indian J. Genet. Plant Breed. 74(1):112-114.

Anjum FM, Walker CE (2000). Grain, flour and bread making properties of eight Pakistani hard white spring wheat cultivars grown at three different locations for two years. Int. J. Food Sci. Tech. 35:407-416.

Crossa J, Gauch HG, Zobel RW (1990). Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. Crop Sci. 30:493-500.

Eberhart SA, Russell WA (1966). Stability parameters for comparing varieties. Crop Sci. 6:36-40.

Gauch HG, Zobel RW (1988). Predictive and postdictive success of statistical analyses of yield trials. Theor. Apps. Genet. 76:1-10.

Gauch HG, Zobel RW (1997). Identifying mega-environments and targeting genotypes. Crop Sci. 37(2):311-326.

Hintsa G, Mariam AH, Belay T (2011). Genotype by environment interaction and grain yield stability of early maturing bread wheat (*Triticum aestivum* L.) genotypes in the drought prone areas of Tigray region, Northern Ethiopia. EJAST 1(2):3-7.

Mueen-ud-Din G (2009). Effect of wheat flour extraction rates on physico-chemical characteristics of sourdough flat bread. Ph.D Thesis, National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

Nachit MM, Nachit G, Ketata H, Gauch HG, Zobel RW (1992). Use of AMMI and linear regression models to analyze genotype-by-environment interaction in durum wheat. Theoret. Appl. Genet. 83:597-601.

Noorka IR, Rehman S, Haidry JR., Khaliq I, Tabassum S, Mueen-ud-din G (2009). Effect of water stress on physico-chemical properties of wheat (*Triticum aestivum* L.). Pak. J. Bot. 41(6):2917-2924.

Tarakanovas P, Ruzgas V (2006). Additive main effect and multiplicative interaction analysis of grain yield of wheat varieties in Lithuania. Agron. Res. 4(1):91-98.