Plant Environment Development 7(2):10-15, 2018 (July)

Print ISSN 1994-1501
Online ISSN 2311-3529
http://plantenvdev.com

e-mail: plant.environ.dev@ru.ac.bd

Stability analysis of yield performance in wheat (*Triticum aestivum* L.)

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Abstract

In wheat four varieties viz., V1, V2, V3 and V4 were evaluated at three locations to estimate stability parameters for grain yield. Both linear and non-linear components of G x E variance were significant; however, linear component was of greater magnitude. Phenotypic regression analysis was done to select most adaptive genotypes to varying environments. The phenotypic stability of each variety was expressed by two parameters: the slope of regression line and sum of squares of deviation from regression. A stable variety was defined as 'one with unit regression (bi=1) and low deviation from linearity (S^2=0). Phenotypic regression analysis also showed that Shatabdi (V_1) had unit regression slope with low stability value for plant height, grain number/ spike, 1000-grain weight and grain yield indicating its stability to varying sowing time and soil moisture treatments. Better phenotypic stability was observed in Shatabdi (V_1) having high yield mean performance, bi=1 and S^2=0. It was found promising for wide adaptation over sites across environments. Shourav (V_3) had average mean performance with bi=1 and S^2=0 showing stability over wider range of environments. Gaurav (V_2) and Kanchan (V_4) had average mean associated with bi<1 and S^2=0 was found stability for poor environments. The objectives of this study were to evaluate the grain yield of promising wheat genotypes in different sowing time and to determine their stabilities using stability parameters. According to the stability analysis, variety Sourav was the most stable for grain yield.

The regression coefficient (bi) for Shatabdi was almost unity (bi = 1) and had one of the lowest deviations from regressions (s^2di). It was also found that middle November is the most optimum time of planting of wheat crop.

Keywords: Stability, environment, soil moisture, nutrition, population

INTRODUCTION

Wheat is a source of nutrition for 35% of the world population and currently ranks first among cultivated plants in terms of cultivation area and production. Wheat is used for both human and animal nutrition and plays an important role in the nutrition of rapidly growing populations both in our country and the world (Polat *et al*., 2016). In improving the food security of the world, wheat has played a significant role by contributing about 20 percent of the dietary calories and proteins. On an average 50% of the wheat in the world is produced in developing regions including Central Asia and China (Shiferaw *et al*., 2013). Wheat becomes very popular in Bangladesh after the liberation war of Bangladesh in 1971 when it was realized that the country’s staple food rice alone was not sufficient to meet the food demand (Hossain *et al*., 2013).

The annual mean growth rate was 24.93%. The cropping area rose from 0.126 million ha to 0.591 million ha and production from 0.11 million tons to 1.07 million tons (Islam *et al*., 2016). At present about 429.61 thousand hectares of land in our country is covered by wheat with the annual production of 1302998 Mtons (BBS, 2014). Wheat is the second major cereal crop in Bangladesh. Trials over the years have been shown that the maximum yield can be obtained from sowing made between the middle of November to early December. The farmers generally sow wheat after the Aman harvest. This in turn often delays wheat sowing in late December and early

January. This delay in wheat sowing results in reduction in crop yield as well as quality. High yields of wheat can be obtained in Bangladesh with proper irrigation, adequate fertilizer and timely sowing of seed (Joarder *et al.*, 1979, 1981; Islam *et al.*,1987), Ahmed and Meisner (1996) observed that high wheat yield can only be obtained with irrigation under adequate fertility levels. The phenomenon of genotype environment interaction in high yielding varieties of wheat under Bangladesh condition was studied by Islarn (1978), Islam *et al.* (1981, 1987) in wheat. This crop is largely grown in stored soil moisture. Irrigation is needed for its successful production, especially for the modern varieties. So the irrigated area for more production of wheat is needed to be increased day by day. The objectives of this study were to evaluate the grain yield of promising wheat genotypes in different sowing time and to determine their stabilities using stability parameters.

MATERIALS AND METHODS

In order to determine stability of four wheat genotypes field experiments were conducted for three consecutive years (2015-2017) under two different conditions (irrigated and non irrigated) at the Research Field of Botany Department, Rajshahi University, Bangladesh. The experimental layout at each environment was randomized complete block design with three replications. Each replication field was divided into three main plots for sowing times. Each main plot was divided in to three sub plots and sub plot was divided in to three sub subplots for sowing times. Each plot consisted of five rows with five meter length. Rows distance was 20cm with seed density 400/m^2. Data on grain yield were taken from the middle three rows of each plot. The grain yield was determined for each genotype at each test environments. The environments were considered as random factors while genotypes as fixed factors. Four varieties of wheat, Shatabdi (V_1), Gaurav (V_2), Shourav (V_3) and Kanchan (V_4) were taken. The soil of the field was silty loam, with pH 7.5. The field was prepared after repeated ploughing and harrowing by removing weeds and stubbles of the previous crops. The seeds of four wheat varieties were sown on three different times, the first sowing date (S_1) was on November 15, 2015; the second (S_2) was on November 30, 2016 and the third (S_3) was on December 15, 2017. Before sowing a basal dose of nitrogen (80 kg/hectare), phosphate (40 kg/hectare) and potassium (40 kg/hectare) was applied. Two levels of irrigation treatments were adopted: irrigated at three times throughout the growing period and rain fed control. Three competitive random plants from the middle row of the experimental plots were taken for recording the observation on plant height (cm), number of grains/spike, 1000-grain weight (g) and grain yield/plant (g).

During data analysis, different sowing dates are considered as separate environment. Data were subjected to analyze by the statistical approaches provided by Eberhart and Russel (1966) for the estimation of genotype× environment interaction(Stability analysis).

The individual genotypic response i.e. regession coefficient (bi) was tested by t-test using the standard error of the corresponding bi value against the hypothesis. The individual deviations from linear regression tested by F-test using pooled error.

RESULT AND DISCUSSION

Average performances of different characters of the genotypes are shown in **Table** 1. Significant differences were found among the genotypes in respect of different characters. Highest grain yield/plant was obtained from genotype Shatapti which was followed by genotype Kanchan. Highest plant height was obtained from the genotype Shatapdi and it was followed by Shorov and statistically identical with the rest of genotypes. Another two characters were found statistically as same with these genotypes.

Table 1. Mean with standard error of heading date, plant height, yield and yield related characters of wheat.

Characters	Shatabdi	Gaurav	Shourav	Kanchan
Plant height	84.670±1.305	81.731±2.510	84.442±1.312	82.621±1.510
Number of grains/Spike	33.056±0.701	31.611±1.034	33.722±0.722	33.056±1.432
1000 Grain Weight	35.347±0.185	34.739±0.144	32.378±0.105	34.484±0.195
Grain Yield/Plant (kg/h)	3.171±0.304	2.75±0.167	2.648±0.169	2.78±0.204

Analysis of variance showed that the mean sum of squares due to genotype (G) and environment (E) difference tested against the G×E interaction were significant for all the characters studied, indicating the presence of wide variability among the genotypes and environments. The significant estimates of G×E interaction indicated that the characters were unstable and may considerably fluctuate with change in environments.

Table 2. Mean squares of combined analysis of variance for grain yield and its components.

Source of variation	df	PH MS	GNS MS	TGW MS	GY MS
Genotype	3	36.493**	3.896**	13.601**	0.042**
Environments	5	404.473**	814.573**	7.594**	9.339**
G×E	15	5.098**	0.674	0.624**	0.011**
Error	36	0.967	0.562	0.111	0.001

LEGENDS: PH=Plant height, GNS= Grain number/spike, TGW=1000-grain weight, GY= Grain yield
*, ** Significant at 0.05 and 0.01 levels of probability, respectively

The G×E (linear) interaction was significant against pooled deviation suggesting the possibility of the variation for all the characters (Table 2). The distribution of four bi values was found to be heterogeneous in most of the characters and hence all these genotypes had different response to different environments.

The regression coefficient (bi) value close to zero indicates the better performance of genotypes in the for the poor environment and when the value is significantly more than unity means the genotypes are better for the favorable environments. When a genotype shows higher mean value for a character, higher phenotypic index (Pi) with one unit bi and S^2di approaching to zero, then the genotype will be stable for the character Eberhart (1966). According to Eberhart and Russell (1996), a stable genotype is characterized by a slope not different from unity (bi =1) and the deviation from regression close to zero (S^2=0). Higher environmental index (Ij) is the indication of favorable environment for a distinct character that needs to increase to improve the yield and vice-versa. Grand mean (X), regression coefficients (bi), standard error of bi (Sbi) and stability values for different yield and its component characters are shown in Table 3.

In case of plant height two genotypes viz., Shatabdi and Shourav showed above average responses (bi>1) at the maturity stage. The grand mean ranged from 78.501 to 84.397 and the maximum grand mean was shown by Shatabdi and Gaurav showed the minimum grand mean. The regression coefficients ranged from 0.797 to 1.202. All the varieties showed highly significant regression coefficients (bi) values. On the other hand, genotype Shatabdi had higher mean performance than the overall mean, regression value nearly one (bi=1.069) and stability value nearly zero (S^2=0.213). Shatabdi genotype had been regarded as stable and widely adapted.

Table 3. Estimates of stability parameters [Grand mean (X), regression coefficients (bi) and stability (S^2)] for plant height, number of grains/spike, 1000-grain weight and grain yield.

Character	Stability parameter	Variety			
		V_1	V_2	V_3	V_4
Plant height (cm)	×	84.397	78.501	82.583	81.907
	bi	1.069**	0.797**	1.202**	0.931**
	Sbi	0.056	0.084	0.057	0.038
	S^2	0.213	2.612	0.704	-0.242
Grain number/spike	×	33.417	31.917	33.394	32.611
	bi	1.000**	0.980**	1.047**	0.972**
	Sbi	0.023	0.015	0.013	0.027
	S^2	0.034	-0.318	-0.395	0.155
1000-grain weight	×	37.391	36.965	34.010	36.270
	bi	1.110**	1.275**	1.129**	0.487**
	Sbi	0.178	0.213	0.272	0.058
	S^2	0.192	0.319	0.592	-0.198
Grain yield (kg/ha)	×	2.214	2.027	2.190	2.153
	bi	1.020**	0.923**	1.027**	1.029**
	Sbi	0.023	0.029	0.012	0.005
	S^2	0.001	0.010	0.002	0.003

LEGENDS: Shatabdi=V_1, Gaurav=V_2, Shourav=V_3 and Kanchan=V_4

For number of grains/spike, all the regression coefficient (bi) values were highly significant. The grand mean ranged from 31.917 to 33.417 and regression coefficients ranged from 0.972 to 1.047. The highest grand mean was shown by Shatabdi and the maximum regression value was shown by Shourav, On the other hand, the lowest grand mean was shown by Gaurav and Kanchan showed the lowest regression value. Two varieties showed below average response (bi<1). For number of grains /spike only one genotype viz.,-Shatabdi possessing higher mean than the overall mean, regression value (bi=1.000) and stability value nearly zero (S^2=0.034) showed wider stability over all sites across environments.

In case of 1000-grain weight, three genotypes viz., Shatabdi, Gaurav and Shourav showed above average responses (bi>1). The grand mean ranged from 34.010 to 37.391, the regression coefficients ranged from 0.487 to 1.275 and stability ranged from -0.198 to 0.592.The lowest grand mean and the maximum stability value were recorded for Shourav. However, Shatabdi had higher mean performance, regression value nearly one (bi=1.110), and stability value nearly zero (S^2=0.192), indicating its stability for favourable environments. All the varieties showed highly significant regression coefficient (bi) values.

For grain yield three genotypes viz., Shatabdi, Kanchan and Shourav showed above average responses (bi>1). The grand means ranged from 2.027 to 2.214 and the regression values ranged from 0.923 to 1.029. The maximum grand mean was shown by Shatabdi but the same variety showed the bi value nearly one (bi-1.020). On the other hand, Gaurav showed the lowest grand mean and bi value. For this character, all the four varieties tested showed more, less or similar values.

Only one genotype viz. Shatabdi had higher mean, regression value nearly one (bi=1.020) and stability value nearly zero (S^2=0.001), indicating its stability for favorable environments. In case of grain yield all the regression coefficient values were found to be highly significant.

In the present investigation phenotypic regression coefficients (bi) and stability parameters were calculated to evaluate highly stable genotype over a wide range of environments. Regression coefficients were found to be highly significant in most cases indicating that the genotypes were highly responsive with the environmental variations. Phenotypic expression of a particular genotype in a specific environment depends on three properties: a mean expression, a linear response to environment and residual deviations from regression. A number of studies (Islam *et al.,* 2016; Anisuzzaman *et al*., 2007; Islam *et* a/., 2003; Alam *et* a/., 2002; Bucio Alanis and Hill, 1966; Jinks and Perkins, 1970; Paroda and Hayes, 1971; Westerman, 1971; Fripp, 1972) have shown that the determination of the sensitivity aspects of phenotype also involves genetical components.

The results of the present investigation show that genotype-environment interaction was significant against pooled deviation suggesting the possibility of the variation for all the characters. These findings are in close agreement with those of Semin *et al.* (1986), Afiash *et al.* (1999), Sarker (2002) and Mohamadi *et al*. (2005). According to Eberhart and Russell (1996), a stable genotype is characterized by a slope not different from unity (bi =1) and the deviation from regression close to zero (S^2=0).

The linear regression (bi) is considered to be a definite and measurable response to the environment. Genotypes that have relatively the same amount of performance overall wide range of environments would have bi values less than unity and would be least responsive to change in the environments. The standard error of regression coefficients is a measure of 'stability of response' exhibited by each population. Since the linear regression represents very definite and measurable response to the environment, it is no longer profitable to consider this component of genotype environment interaction as a measure of stability in the way proposed by Finiay and Wilkinson (1963).

In the present investigation, the varieties of wheat showed different combination of performances in different characters and therefore, it is difficult to draw conclusion regarding their stability over a wide range of environments. However, Shatabdi with high mean, one with unit regression slope and stability value nearly zero (S^2=0) for plant height, number of grain/spike and 1000-grain weight and grain yield, indicating its stability to varying environments. Shourav and Gaurav gave moderate and Kanchan gave lowest grain yield significantly in all the environments. Nanak Chand *et* a/. (2008) reported similar results for 1000- grain weight, only one genotype RD2634 had average mean associated with bi=1 and s^2 =0, identified for wider adaptation and stability over all sites across environments. These results are in conformity with the findings of Yadav and Rao (1985), Hadjichristodoulon (1992), Shahmohamadi *et al.* (2005), Verma (2007) and Islam *et al. (*2016). A stable variety should be one with high mean performance, one with unit regression slope (bi=1.00) and the deviation from regression as small as possible. Thus for a particular character the genotype with higher mean performance and average regression coefficient together with a considerable low S^2 value will be suitable for favorable environments. However, even if the genotypes though have high deviation around their regression lines yet they deserve inclusion in suitable environments. These varieties are very sensitive to environmental changes and hence as the environment improves their performance will increase at a rate well above the average of the group. Under the most favorable condition they will be able to express themselves as very high yielding varieties suggesting their exploitation in favorable environments. On the other hand, these genotypes with comparatively low bi and s^2 values together with moderate high mean yield are specially adapted to low yielding environments. These varieties are so insensitive that they are unable to exploit in high yielding environments. Lastly, the genotypes that have low bi and S^2 values and also low mean performance indicate that they are consistently lower yielder in all environments.

The overall results of the present investigation revealed that phenotypic regression analysis also showed that Shatabdi had unit regression slope with low stability value for grain yield, number of grains/spike, 1000-grain weight and plant height indicating its stability to varying sowing time and soil moisture treatments.

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