International Journal of Agriculture Innovations and Research
Volume 2, Issue 2, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received : 17/08/2013 | Accepted on : 08/09/2013 | Published : 10/10/2013

Stability Analysis of Rapeseed Genotypes Targeted Across Irrigated Conditions of Pakistan

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***Abstract* – This study was conducted to determine the performance of rapeseed genotypes under irrigated conditions, analyze their stability, and identify superior genotypes that could be valuable for rapeseed improvement or varietal release. Eleven advanced breeding lines/ cultivars including two checks were tested for a period of 2 year (2010-11 and 2011-12) using a randomized complete block design with 4 replications at seven different locations across Pakistan. The genotype x environment was analyzed using linear regression technique. The analysis of variance for seed yield showed that genotypes, locations and their interaction all were highly significant, combined analysis of variance for seed yield stability was estimated by using the Eberhart and Russell method which revealed significant differences for seed yield among genotypes and environments. The regression coefficient (bi) of eleven genotypes ranged from 0.56 to 1.27. Out of 11 genotypes RBN-04722 is categorized as the most stable genotypes over the locations under study because of its above average yield responses and regression coefficient (bi) near to 1.0, non significant S $^2d_{i)}$ and high value of R^2i(81%). The genotypes SPS-N-7/28 and Gold Star having regression coefficient significantly greater than unity (b_i >1.0) indicated that these genotypes are suitable for favorable environments only. In contrast the genotypes AUP-06-10, 04-k12/13-10-1 and AUP-04-10 had regression coefficient significantly less than unity (bi<1.0) indicating that these genotypes are suitable for poor environments.**

***Keywords* – Rapeseed Genotypes, *Brassica Napus*, Stability Analysis, G X E Interaction, Irrigated Areas, Pakistan.**

I. INTRODUCTION

Rapeseed and mustard is the second most important crop of edible oil after sunflower in Pakistan. In domestic production of edible oil rapeseed and mustard contribute 10% and hence are the potential crop which can fulfill some requirements of edible oil in the country. Improved rapeseed (*Brassica napus* L.) cultivars for Irrigated environments in Pakistan are needed to increase rapeseed productivity. The average yield of this crop is around 880kg/ha which has been static for several years. The low yield is a great concern in view of short supply of edible oil in Pakistan. Seed yield of a genotype is an important in determining the superiority of a genotype but this is not same under different agro climatic conditions. Some genotypes can perform well in certain environments but others cannot do so in the same environment. The genotype to environment interaction as described by the Allard and Bradshaw in1964 is extremely important in the development and evaluation of plant cultivars since diverse environments can reduce the genotype stability of the plant varieties (Eberhart and Russell, 1966 and Hebert et. al., 1995). One of the basic components for characterization of the plant genotype is the estimation of the productivity for stability and adaptability (Raj etal. 1997) which is often expressed by realized yield (Stoffella etal, 1984, Becker and Leon, 1988 and Kang, 1998). Only stable genotypes can guarantee a good yield with decreased risk of losing production and allow the researchers to make general recommendations for a range of environments. So the present study was designed to select suitable rapeseed genotype with wide adaptation to the climatic conditions of Pakistan.

II. MATERIAL AND METHODS

Plant material and field conditions

Eleven genotypes of rapeseed (*B. napus)* were analyzed by Randomized complete block design with four replications. The name and sources of these genotypes are listed in Table 1.

Table 1: Genotypes and their source used in seven environments during 2010-11& 2011-212.

Code	Cultivar/line	Source
1	AUP-04-10	Department of PBG, KPK Agric. University, Peshawar
2	Punjab Sarson	Oilseeds Research Institute, Faisalabad
3	RBN-04722	Oilseeds Research Institute, Faisalabad
4	AUP-06-10	Department of PBG, KPK Agric. University, Peshawar
5	Hyola-401(Check)	ICI Pakistan Seeds Limited, Lahore
6	04K12/13-10-1	Nuclear Institute for Food and Agriculture, Tarnab, Peshawar
7	KN-120-33	Agricultural Research Station Khanpur (Rahim Yar Khan)
8	Kn-120-34	Agricultural Research Station Khanpur (Rahim Yar Khan)
9	Gold Star	KANZO Quality Seeds, Lahore
10	SPS-N7/28	Oilseeds Research Program, NARC, Islamabad
11	CRH-40/10	Oilseeds Research Program, NARC, Islamabad

The experiment was performed under irrigated conditions for two years i.e. 2010-11 and 2011-12 growing seasons at seven different locations across Pakistan (Table 2). The seeds were sown using drill in 1.2m x 5m plot consisting of 4 rows with a 30 cm row space. The plots were fertilized with 90 kg N ha^{-1} and 60 kg $P_2 O_5$ ha^{-1} at the time of seed bed preparation. Irrigation, weed and pest control measure were applied whenever required. Seed yield per plot was estimated by harvesting and threshing the 2-4 rows from each plot and converted into kg/ha.

Table 2: Site description and sowing and harvesting dates during Rabi 2010-11 and 2011-12

Code	Growing Season	Environments	Abbreviation	Sowing date
E1	2010-11	Oilseeds Research Program, NARC, Islamabad	NARC	20-10-2010
	2011-12	Oilseeds Research Program, NARC, Islamabad	NARC	14-10-2011
E2	2010-11	Oilseeds Research Institute, Faisalabad	FSD	19-10-2010
	2011-12	Oilseeds Research Institute, Faisalabad	FSD	20-10-2011
E3	2010-11	Regional Agric. Res. Institute, Bahawalpur	B/pur	14-10-2010
	2011-12	Regional Agric. Res. Institute, Bahawalpur	B/pur	15-10-2011
E4	2010-11	Agric. Res. Station Khanpur (Rahim Yar Khan)	K/pur	19-10-2010
	2011-12	Agric. Res. Station Khanpur (Rahim Yar Khan)	K/pur	20-10-2011
E5	2010-11	Pioneer Pak Seed, Ltd., Lhr. (Sahiwal farms)	Pioneer	31-10-2010
	2011-12	Pioneer Pak Seed, Ltd., Lhr. (Sahiwal farms)	Pioneer	04-11-2011
E6	2010-11	KANZO quality seeds. Ltd. (Sheikhupura farms)	KANZO	21-10-2010
	2011-12	KANZO quality seeds. Ltd. (Sheikhupura farms)	KANZO	17-10-2011
E7	2010-11	Nuclear Inst. Food and Agriculture, Tarnab, Peshawar	NIFA	14-10-2010
	2011-12	Nuclear Inst.Food and Agriculture, Tarnab, Peshawar	NIFA	04-10-2011

Statistical Analyses

The combined analysis of variance over location was computed by assuming replications and locations effects as random and genotypes as fixed variable (Steel and Torrie, 1980). For evaluating the yield stability over environments, the following stability parameters were calculated:

1. *Regression coefficient (bi)* is a regression performance of each genotype in different locations calculating means over all the genotypes and estimated by following Singh and Chaudhary, 1979.
2. *Mean square deviation from regression (S2di)* was calculated for each genotype following Eberhart and Russell Model (1966).

Results and Discussion:

Data for seed yield kg/ha of eleven entries for the two year at seven different location is summarized in Table 3 which revealed that mean seed yield varied among environments and ranged from 2.045 t ha^{-1} to 2.958 t ha^{-1} for environments ORI, Faisalabad and RARI, Bahawalpur, respectively during the growing season 2010-11 and 1.038 t ha^{-1} to 3.333 t ha^{-1} for environments Pioneer, Sahiwal and NARC, Islamabad, respectively during the growing season 2011-12.

Table 3: Seed yield (t ha^{-1}) of rapeseed genotypes in 7 environments during 2010-11 and 2011-12

Locations	Growing Season	AUP 04-10	Punjab Sarson	RBN 04722	AUP 06-10	Hyola 401	04k12/ 13-10-1	KN 120-33	KN 120-34	Gold Star	SPS N7/28	CRH 40/10	MEAN
NARC Islamabad	2010-11	1.929	1.829	2.456	2.197	2.212	2.032	2.395	2.934	2.293	3.007	2.533	**2.347**
	2011-12	3.529	3.391	3.804	2.749	1.925	3.048	3.483	3.850	3.781	3.048	4.056	3.333
ORI Faisalabad	2010-11	2.183	2.150	2.375	1.858	1.925	2.650	2.550	2.300	1.309	1.425	1.766	**2.045**
	2011-12	1.851	2.055	2.222	1.548	1.870	1.999	1.888	2.036	1.340	1.425	1.518	1.796
RARI Bahawalpur	2010-11	2.722	3.111	3.389	2.486	3.028	2.833	3.598	2.695	2.889	2.625	3.166	**2.958**
	2011-12	2.683	3.479	3.521	3.054	3.433	1.641	3.271	2.716	3.562	2.583	1.446	2.854
ARS Khanpur	2010-11	1.896	2.646	2.541	2.073	2.875	2.427	2.656	2.656	2.125	2.084	2.000	**2.362**
	2011-12	1.542	1.854	2.322	1.833	1.708	1.312	1.415	1.635	1.093	0.979	1.208	1.536
Pioneer Sahiwal	2010-11	1.891	2.286	1.984	2.110	1.785	2.333	2.350	2.198	1.922	2.254	1.818	**2.085**
	2011-12	1.343	1.075	1.030	1.184	0.719	1.175	1.415	1.124	1.137	0.637	0.580	1.038
KANZO Sheikhupura	2010-11	3.414	1.120	1.902	1.848	1.344	1.894	1.686	3.319	1.950	3.092	2.193	**2.160**
	2011-12	2.309	2.205	4.336	2.830	1.753	3.344	2.873	3.466	2.708	2.702	3.183	2.883
NIFA Peshawar	2010-11	2.361	2.972	3.194	2.500	3.056	2.778	2.972	3.111	3.944	2.389	2.583	**2.896**
	2011-12	2.222	2.833	2.750	2.916	3.388	3.000	3.222	3.777	5.639	4.055	2.750	3.323
	MEAN	2.277	2.358	2.702	2.228	2.216	2.319	2.555	2.701	2.549	2.308	2.200	

International Journal of Agriculture Innovations and Research
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The analysis of variance for seed yield showed that genotypes, locations and their interaction namely genotype x location, genotype x year, years x location and genotype x year x location all were highly significant ($P < 0.01$). However, the effect of year was non-significant for seed yield. The presence of genotype x location interactions showed that particular genotype tended to rank differently in seed yield at different locations. Similarly significant genotype x year interaction indicates a significant effect of the year on relative productivity (Table 4). It also showed that each location in each year should be treated as a same environment because the second order interactions i.e. genotype x location x year were smaller than the first order interactions. However the contradictory results were reported by Mevlüt et al (2005). They reported greater genotype x location x year interaction than the variety x year interaction and variety x location interaction and treated each location in each year as a separate environment.

Table 4: Analysis of variance for seed yield among 11 rapeseed genotypes

Source of variation	df	Sum of Square	Mean Square
Replication (L x Y)	42	24.638	0.587**
Genotype (G)	10	21.722	2.172**
Years (Y)	1	0.124	0.124^{NS}
Locations (L)	6	192.382	32.064**
G x Y	10	7.350	0.735**
G x L	60	85.314	1.422**
Y x L	6	83.141	11.877**
G x Y x L	60	43.828	0.730**
Error	420	61.432	0.146
Total	615	517.983	

The results of the combined analysis of stability are presented in Table 5. An analysis of variance for stability revealed significant differences for seed yield among genotypes (except AUP-06-10) and environments indicating variability among environments as well as among the genotypes. The significant mean square for Genotype x Environment (Linear) for seed yield were obtained which reveals differences among the regression coefficients also. The similar results were also reported by Ali et. al, 2002.

Table 5: Combined analysis of variance for stability for seed yield of 11 genotypes

Source of variation	Degree of freedom	Sum of squares	Mean Squares
Genotypes (G)	10	2.548	0.255*
Environment + (G x E)	66	34.034	
Environment (Linear)	1	23.154	23.154
Genotypes x Environment (Linear)	10	2.764	0.276*
Pooled Deviation	55	8.116	0.123**
AUP-04-10	5	0.577	0.115**
Punjab Sarson	5	1.001	0.200**
RBN-04722	5	0.507	0.101**
AUP-06-10	5	0.070	0.014^{NS}
Hyola-401(Check)	5	1.629	0.326**
04K12/13-10-1	5	0.341	0.068**
KN-120-33	5	0.366	0.073**
Kn-120-34	5	0.677	0.135**
Gold Star	5	1.639	0.328**
SPS-N7/28	5	0.492	0.098**
CRH-40/10	5	0.817	0.163**
Pooled error	231	21.443	0.093

** significant at P< 0.01

The mean seed yield of 11 rapeseed genotypes ranged from 2.20 t ha^{-1} to 2.702 t ha^{-1}. The highest seed yield 2.702 t ha^{-1} was produced by the genotypes RBN-04722 followed by KN-120-34, KN-120-33 and Gold Star with mean seed yield of 2.701 t ha^{-1}, 2.555 t ha^{-1} and 2.549 t ha^{-1}, respectively (Table 6). This table also showed that out of the seven environments NIFA site was the best with 3.110 t ha^{-1} location mean which is closely followed by B/pur and NARC with 2.906 t ha^{-1} and 2.840 t ha^{-1} location mean respectively. Pioneer site proved to be the low yielding site for these genotypes with 1.561t ha^{-1} location mean. Genotype RBN-04722 produced highest seed yield at two sites; B/pur and K/pur with 3.455 and 2.432 t ha^{-1}, respectively. Whereas KN-120-34 produced highest seed yield at NARC (3.392 t ha^{-1}) and KANZO (3.393 t ha^{-1}). The genotypes 04K12/13-10-1, KN-120-33 and Gold Star performed best at Faisalabad, Pioneer and NIFA, respectively.

Table 6: Pooled seed yield (t ha^{-1}) of rapeseed genotypes at seven locations.

Genotype	NARC	FSD	B/PUR	K/PUR	Pioneer	KANZO	NIFA	Mean
AUP-04-10	2.729	2.017	2.703	1.719	1.617	2.862	2.292	2.277
Punjab Sarson	2.610	2.103	3.295	2.250	1.681	1.663	2.903	2.358
RBN-04722	3.130	2.299	**3.455**	**2.432**	1.507	3.119	2.972	2.702
AUP-06-10	2.473	1.703	2.770	1.953	1.647	2.339	2.708	2.228
Hyola-401(C)	2.069	1.898	3.231	2.292	1.252	1.549	3.222	2.216
04K12/13-10-1	2.540	**2.325**	2.237	1.870	1.754	2.619	2.889	2.319
KN-120-33	2.939	2.219	3.435	2.036	**1.883**	2.280	3.097	2.555
KN-120-34	**3.392**	2.168	2.706	2.146	1.661	**3.393**	3.444	2.701

Gold Star	3.037	1.325	3.226	1.609	1.530	2.329	**4.792**	2.549
SPS-N7/28	3.028	1.425	2.604	1.532	1.446	2.897	3.222	2.308
CRH-40/10	3.295	1.642	2.306	1.604	1.199	2.688	2.667	2.200
Location Mean	2.840	1.920	2.906	1.949	1.561	2.521	3.110	

According to Eberhart and Russell Model (1966) both linear (b_i) and non-linear (S^2d_i) components of genotype x environment interaction are required for estimating the stability of a genotype and a high performing genotype with regression coefficient (b_i) approximately 1 and S^2d_i equal to zero is considered as stable genotype over different environments. The genotypes possessing regression values above 1.0 will be described as having below average stability and such genotypes will be highly sensitive to environmental changes and suitable only for high yielding environments. A regression coefficient below 1.0 will categorized the genotypes as above average stability and such genotypes will show resistance to environmental changes and suitable for growing in low yielding environments.

The stability parameters presented indicated that the regression coefficient (bi) of eleven genotypes ranged from 0.56 for 04k 12/13-10-1 to 1.27 for SPS N-7/28 (Table 6). The genotype SPS N-7/28 and Gold Star having regression coefficient 1.27 and 1.89 respectively significantly greater than unity (b_i >1.0) indicated that these genotypes are suitable for favorable environments only. In contrast the genotypes Punjab Sarson (bi = 0.77), AUP-06-10 (bi = 0.76), AUP-04-10 (bi = 0.68) and 04-k12/13-10-1 (bi = 0.56) had regression coefficient significantly less than unity (bi<1.0) indicating that these genotypes are suitable for poor environments. Out of 11 genotypes RBN-04722 is categorized as the most stable genotypes over the locations under study because it showed above average yield responses and regression coefficient near to unity and non-significant deviation from regression (S^2d_i). Its R^2_i value was also high (81%) confirming its stability. Pinthus, 1973 suggested using R^2_i value to select stable genotypes for seed yield. Shafii *et.al*, 1992; Hammed, 2005 and Escobar *et. al*., 2011 used this method of stability analysis in rapeseed to identify stable and adaptive genotypes for seed yield over the environments. Raj *et. al,* 1997 and Rashid, *et. al*, 2002 used the same criteria in mustard crop to select the stable genotypes for seed yield.

Table 7: Stability parameters for 11 rapeseed genotypes

Genotypes	**Mean seed yield (t ha^{-1})**	**b_i**	**S^2d**	**R^2_i**
AUP-04-10	2.277	0.68**	0.075*	62.6
Punjab Sarson	2.358	0.77**	0.160**	55.7
RBN-04722	**2.702**	**1.01^{NS}**	**0.061^{NS}**	**81.0**
AUP-06-10	2.228	0.76**	0.012^{NS}	94.5
Hyola-401(Check)	2.216	0.95^{NS}	0.286**	54.1
04K12/13-10-1	2.319	0.56**	0.028^{NS}	65.6
KN-120-33	2.555	0.91^{NS}	0.033^{NS}	82.8
Kn-120-34	2.701	1.09^{NS}	0.096*	78.7
Gold Star	2.549	1.89**	0.288**	82.2
SPS-N7/28	2.308	1.27**	0.059*	87.4
CRH-40/10	2.200	1.09^{NS}	0.124**	75.5

III. Conclusion

From this study it is concluded that out of the eleven evaluated genotypes RBN-04722 is the most stable genotypes over the locations under study because it showed above average yield responses and regression coefficient near to unity and non-significant deviation from regression (S^2d_i). Its R^2i value is also high. The genotypes SPS-N7/28 and Gold Star are suitable for favorable environments due to its above mean seed yield and regression coefficient greater than unity (b_i >1.0).The genotypes AUP-06-10, 04-k12/13-10-1 and AUP-04-10 are suitable for poor environments because their seed yield are around the grand mean and their regression coefficients are significantly less than unity (bi<1.0).

The results of this investigation also demonstrated that regression coefficient and other stability parameters are suitable means of selecting stable, high yielding and responsive cultivars and can be applied for the selection of rapeseed cultivars either adapted to wide range of environments or adapted to restricted environment.

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