Pak. J. Agri. Sci., Vol. 57(3), 701-706 ; 2020
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/20.8261
http://www.pakjas.com.pk

INVESTIGATING ADAPTABILITY AND STABILITY OF RAPESEED CULTIVARS VIA YIELD STABILITY STATISTICS

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Seven rapeseed genotypes were studied at nine different locations across Pakistan during two growing seasons 2015-16 and 2016-17 for the stability of seed yield. Experiments were conducted in randomized complete block design at each location. The analysis of variance showed significant differences among genotypes at each location in both years. The genotypes Hyola-401 and RBN-13018 produced significantly higher average seed yield than other genotypes tested at different locations and during both years. The combine analysis of variance indicated that seed yield was highly affected by the change in environmental conditions. Stability parameters estimated were linear regression coefficient (b_i) of a genotype seed yield mean over locations and deviation from regression (s^2d). The high yielding genotype RBN-13018 having regression coefficient higher than unity (b_i>1.0) indicated that this genotype performed better under productive environments only. However, high yielding genotype Hyola-401 had regression coefficient (b_i) close to unity (b_i =1.0) and low deviation from regression line (s^2d). It indicated that seed yield of this genotype had non-significant influence of variation in environmental conditions and is more stable.

Keywords: Adaptability, G×E interaction, Pakistan, rapeseed, seed yield, stability statistics.

INTRODUCTION

According to FAOSTAT (2015) rapeseed and mustard is the third most important source of vegetable oils in the world. It was grown on an area of 36 million hectare worldwide in 2013.Popović *et al*. (2010) reported that the importance of brassica crops has increased significantly in the world mainly due to the various use possibilities of their products. The production of rapeseed and mustard grain in the world jumped from just over 8 million tons in the 1970s to over 60 million tons in the early decade of 2010 (FAOSTAT, 2013; USDA, 2014).

Although rapeseed and mustard are the traditional oilseed crops of Pakistan yet only 285.0 thousand tons of rapeseed and mustard was produced from an area of 201 thousand hectares during the cropping season 2015-16 (Economic Survey of Pakistan, 2016-17). There is chronic deficiency of edible oil in Pakistan and about 80% of the domestic requirement of edible oil is fulfilled through imports, spending huge amount of foreign exchange (Abro *et al*., 2016). Since early 1970s the import of edible oil has been increased at the rate of 12.5% annually which now reached up to 1.98 million tons worth of Rs.152.514 billion during 2016-17. This trend will further not only continue but becoming worse with the increase in population. There has been a trend of decrease in total production, and planting area of rapeseed and mustard in Pakistan for the last twelve years (Fig. 1). However, efforts have been made to enhance the local production of edible oil. Rapeseed and mustard crops have potential to increase the indigenous edible oil production. But slow increase in total production, planting area, and yield of rapeseed in Pakistan is mainly due to the non-availability of high yielding adapted cultivars of rapeseed and lack of mechanized farming in the country.

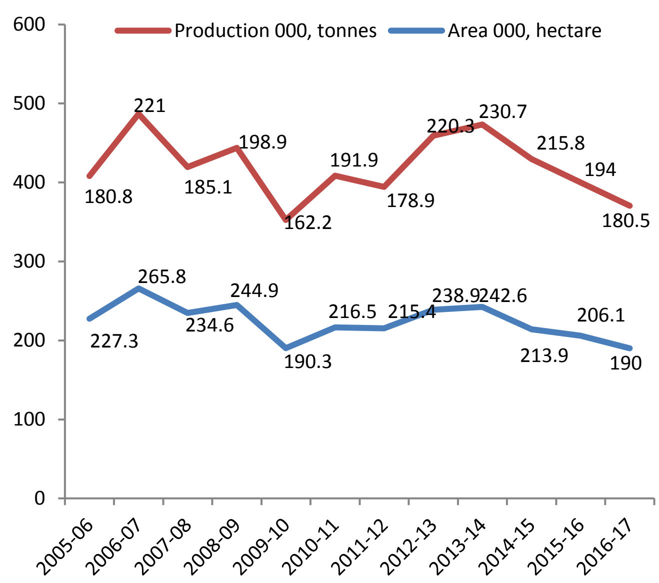

Figure 1. Rapeseed and mustard production in Pakistan over the last twelve years. Data from Agriculture Statistics of Pakistan,2016-17.

The market demand of edible oil can be met by increasing the planting area of rapeseed, adopting mechanized farming and by boosting up the rapeseed yield per unit area. Developing high yielding and stable cultivar is one of the most important solutions of the problem.

Consistency in yield had invariably been a problem due to strong influence of environmental effects (Mirza *et al*., 2013; Sozen and Karadavut, 2019). According to Yan (2001) when field trials are carried out in different agroecological conditions, usually 80% of yield variation is caused by environment, while genotype and genotype by environment interaction cause 10% of variation each. Marjanović-Jeromela *et al.* (2011) reported that environmental factors and genotype by environment interaction had the highest influence on the formation of seed yield per plant in rapeseed. The study of environmental and physiological factors which caused genotype × environment (G×E) interaction assisted breeders to make use of specific adaptation in the development of stable genotypes (Sah *et al.*, 2015; Kir and Yavuz. 2019). Similarly, G×E interaction is the reaction of each genotype to variations in the environment and it had been one of the most important subjects of study in plant breeding, for genetic enhancement and proposal of stable genotypes (Rodriguez *et al*., 2002; Nowosad *et al*., 2016; Karadavut and Sozen, 2019). There are many methods by which incidence of G×E interaction for seed yield performance can be used to identify genotypes with stable performance across environments. Many researchers like Lin *et al.* (1986), Engqvist and Becker (1993); Flores *et al*. (1998); Mohammadi *et al*. (2012) and Puhl *et al.* (2019) reviewed these statistics along with their advantages and disadvantages and the relationships between them.

The study of G×E interaction for rapeseed is important for Pakistani agriculture because Pakistan has diverse environmental conditions. Thus, the present investigation was carried out to identify high yielding genotype of rapeseed with consistence yield performance under wide range of environment.

MATERIALS AND METHODS

Plant material for field trials was consisted of seven rapeseed genotypes. The genotypes were selected from six different research institutes/stations for evaluation. The trials were conducted in two growing seasons during 2015-16 and 2016-17. The names and source of these genotypes along with oil contents (%)are listed in Table 1.

The trial was conducted at nine different locations. The name of the locations and their abbreviation (that will further utilize in the description of the results) and sowing dates are mentioned in Table 2.

Variation in latitude, longitude and weather elements like maximum temperature, minimum temperature and rainfall of the locations where trials were sown is obvious from the data presented in Table 3.

The trial was conducted in randomized complete block design with 4 replications at each location. Plot size was standardized to 4 rows of 5-meter length with 30-cm row spacing. Trials were sown at best possible sowing time (1^{st} to 25 October) at each site with recommended seed rate. Fertilizers were applied @ 90N:60P_2O_5 kg ha^{-1} at the time of seedbed

Table 1. Name and source of rapeseed genotypes along with oil contents (%)

Entry #	Name of Entry	Oil contents (%)	Source
1	CRH-119	42.9	Oilseeds Research Program, NARC, Islamabad
2	AZRI Rapeseed	41.5	Arid Zone Research Centre, Dera Ismail Khan
3	Faisal Canola	41.6	Oilseed Research Institute, Faisalabad
4	RBN-13018	41.0	Oilseed Research Institute, Faisalabad
5	KN-265	41.6	Oilseeds Research Station, Khanpur
6	Hyola-401	42.3	ICI Pakistan Seeds Limited, Lahore
7	11CBN-006	42.4	Barani Agricultural Research Institute, Chakwal

Table 2. Research institutes/stations where trials were conducted.

Sr.	Name of Institutes/Stations	Abbreviation	Sowing Dates	
			2015-16	2016-17
1	National Agricultural Research Centre, Islamabad	NARC, ISD	16-10-15	14-10-16
2	Oilseed Research Institute, AARI, Faisalabad	ORI, FSD	22-10-15	14-10-16
3	Regional Agriculture Research Institute, Bahawalpur	RARI, B-pur	15-10-15	17-10-16
4	Oilseed Research Station, Khanpur	ORS, K-pur	06-10-15	10-10-16
5	Pioneer Research Farm, Sahiwal	Pioneer, Sahiwal	22-10-15	19-10-16
6	Barani Agricultural Research Station, Jarma, Kohat	BARS, Kohat	20-10-15	18-10-16
7	Arid Zone Research Center, Dera Ismail Khan	AZRC, DIK	18-10-15	07-10-16
8	Nuclear Institute for Food & Agriculture, Peshawar	NIFA, Peshawar	15-10-15	17-10-16
9	Agriculture Research Institute, Tandojam	ARI, T-Jam	14-10-15	20-10-16

Table 3. Weather elements (maximum temperature, minimum temperature and rain fall) of locations where rapeseed material tested.

Sr.	Location	Latitude	Longitude	Av. Max. Temperature(°C)	Av. Min.Temperature (°C)	Av. Rain fall (mm)
1	Islamabad	33.68	73.05	29	14	1142.0
2	Faisalabad	31.26	73.08	32	17	346.0
3	Bahawalpur	29.20	71.47	23	13	3.3
4	Khanpur	28.26	70.19	36	24	1.5
5	Sahiwal	30.39	73.10	34	22	4.5
6	Kohat	33.50	71.40	30	21	4.3
7	D.I.Khan	31.49	70.56	34	24	5.1
8	Peshawar	34.02	71.56	29	16	403.9
9	Tandojam	25.40	68.43	36	25	2.5

Source: wikipedia

preparation. Irrigation, weed and pest control measures were applied whenever required. Seed yield in grams was recorded from each plot in all replications and then converted into kilogram per hectare by multiplying by ten and dividing by plot size as shown in the following formula.

$$\text{Seed Yield (kg ha}^{-1}) = \frac{\text{Seed Yield (g plot}^{-1}) \times 10}{\text{Plot size (m}^{2})}$$

Analysis of variances of seed yield from each genotypes and location pooled analysis of variance over locations for genotype × environment interaction was computed with MSTATC Statistical Software (version 1.3). The analysis of phenotypic stability of the entries was performed according to the method given by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

Data for seed yield kg/ha of seven genotypes for the two years at nine different locations is presented in Table 4. The yield data recorded revealed that mean seed yield varied among environments. The average seed yield of seven rapeseed genotypes from nine locations during 2015-16 ranged from 1507 to 1834 kg ha^{-1}. The genotype RBN-13018 produced highest seed yield of 11834 kg ha^{-1} followed by Hyola-401 with seed yield of 1830 kg ha^{-1}. The genotype 11CBN-006 produced lowest seed yield of 1507 kgha^{-1}. The yield potential of rapeseed genotypes was fully exploited at AZRI, DI Khan where an average seed yield of 2604 kg ha^{-1} was recorded. The yield performance of genotypes was quite poor at ARI, Tandojam where 1095 kg ha^{-1} was produced.

During 2016-17, the average seed yield of seven rapeseed genotypes from nine locations ranged from 1571 to 2010 kg

Table 4. Seed yield (kg/ha) of rapeseed genotypes in 9 environments during 2015-16 and 2016-17.

Locations	Growing Season	CRH-119	AZRI Rapeseed	Faisal Canola	RBN-13018	KN-265	Hyola-401	11CBN-006	MEAN
NARC, Islamabad	2015-16	1923	1138	1469	2713	1486	2168	1510	1772
	2016-17	2108	2506	2155	2765	2195	2312	2152	2313
ORI, Faisalabad	2015-16	1219	935	1254	1515	1163	1363	1320	1253
	2016-17	1569	778	2044	2006	1544	1964	1500	1629
RARI, Bahawalpur	2015-16	825	1183	1131	1444	942	1575	1092	1170
	2016-17	1800	1750	1871	1488	1908	1842	1779	1777
ORS, Khanpur	2015-16	1792	1750	1750	1729	1896	1625	1917	1780
	2016-17	1167	625	833	1146	979	938	979	952
Pioneer, Sahiwal	2015-16	1429	2021	1652	1196	1675	1452	1486	1559
	2016-17	1638	1063	1217	1058	1754	1763	1663	1451
BARS, Kohat	2015-16	1800	1425	1492	2008	1833	2083	1767	1773
	2016-17	1782	1665	1652	1382	1998	1988	2192	1808
AZRIC, DI Khan	2015-16	2438	3071	2509	2770	2494	2817	2127	2604
	2016-17	2463	3418	2718	3288	3142	2973	2324	2904
NIFA, Peshawar	2015-16	2306	1906	1556	2206	1944	2400	1300	1945
	2016-17	2333	1100	1633	2417	1333	2767	1667	1893
ARI, Tandojam	2015-16	1048	1216	1113	923	1333	983	1048	1095
	2016-17	1996	1238	1695	1646	1642	1547	1409	1596
Average	2015-16	1642	1627	1547	1834	1641	1830	1507	
	2016-17	1873	1571	1758	1911	1833	2010	1741	

ha^{-1} (Table 4). The genotype Hyola-401 produced highest seed yield of 2010 kg ha^{-1} followed by genotype RBN-13018 with seed yield of 1911 kg ha^{-1}. The genotype AZRI Rapeseed produced lowest seed yield of 1571 kg ha^{-1}. The yield potential of rapeseed genotypes was fully exploited at AZRI, DI Khan where an average seed yield of 2904 kg ha^{-1} was recorded. The yield performance of genotypes was quite poor at ORS, Khanpur where 952 kgha^{-1}was recorded.

Combine analysis of variance indicated significant differences among genotypes and locations. This point out the presence of variability among the genotypes and environment(Table 5). The interactions; genotype × location, year × location, and genotype × location × year were highly significant. The presence of genotype x location interaction showed that seed yield of particular genotype tended to rank differently at different locations. Similarly, significant genotype x year interaction indicated a significant effect of the year on relative productivity. Meaning thereby that each location in each year should be treated as a separate environment as earlier reported in brown Sarson by Gazal *et al.* (2016).

***Stability Statistics*:** The analysis of phenotypic stability of the entries included in the trial was performed according to the method given by Eberhaet and Russel (1996)using mean, Sd, b_i, S^2d_i, R^2 and b_i, and CV%, respectively The stability parameters were obtained as linear regression coefficient (b_i) of an entry seed yield mean on the average of all entries and deviation from regression (s^2d) then stability was tested with the hypotheses of regression coefficient of unity (b = 1.0) and a minimum deviation from regression line (s^2d = 0).The results obtained are described as under.

***Stability Statistics 2015-16*:** The regression coefficient (b_i) of rapeseed entries ranged from 0.66 to 1.19 (Table 6). The entry AZRI Rapeseed had highest regression coefficient (b_i=1.19) followed by the entry RBN-13018 (b_i=1.14). Thus, the entries having b_i significantly greater than unity indicated that these entries showed below average stability to changes in environments. Even a small change in environment may result a large increase in response and hence these entries are suitable for high yielding environments only. In contrast, entries 11CBN-006 (b_i=0.66), and Faisal Canola (b_i=0.85 had regression coefficient significantly less than unity and indicated above average stability to changes in environments. Even large changes in environments produced only a small increase in response and so these entries are suitable for low yielding environments. The entries CHR-119 (b_i=1.11), Hyola-401 (b_i=1.13) and KN-265 (b_i=0.94) had regression coefficient close to unity (b_i=1) and are suitable for both high and low yielding environments. But the entry Hyola-401 had high average seed yield (1830 kgha^{-1}) and regression coefficient close to unity (b_i=1.0) with significantly less standard error and mean square of regression. Thus, Hyola-401 is considered as the most stable entry among the entries studied at nine locations.

***Stability Statistics 2016-17*:** During the year 2016-17, the regression coefficient (b_i) of rapeseed entries ranged from 0.63 to 1.52 (Table 7). The entry AZRI Rapeseed had highest regression coefficient (b_i=1.52) followed by the entry RBN-13018 (b_i=1.25).Thus, the genotypes having b_i greater than

Table 5. Analysis of variance for seed yield among 7 rapeseed genotypes.

Source of variation	Degree of freedom	Sum of squares	Mean Squares	F ratio	Probability
Replication	3	950833	316944*	3.04	0.029
Year (Y)	1	2933233	2933233**	28.14	0.000
Location (L)	8	93238473	11654809**	111.82	0.000
Genotype (G)	6	6559066	1093178**	10.49	0.000
Y x L	8	22878656	2859832**	27.44	0.000
Y x G	6	1215391	202565^{NS}	1.94	0.073
L x G	48	25306041	527209**	5.06	0.000
Y x L x G	48	12485940	260124**	2.50	0.000
Error	375	39084900	104226		
Total	503	204652534			

Table 6. Stability Statistics for 7 genotypes during the year 2015-16.

Sr.#	Genotypes	Mean S.Y*	Sd	CV%	b_i	S^2d_i	R^2	r_i^2	W_i
1	CRH-119	1642	552.9	33.7	1.11	23581	0.879	39061	316763
2	AZRI Rapeseed	1627	657.5	40.4	1.19	124648	0.710	169715	1063363
3	Faisal Canola	1547	423.5	27.4	0.85	7712	0.871	23233	226320
4	RBN-13018	1834	644.1	35.1	1.14	129787	0.687	171697	1074688
5	KN-265	1640	468.9	28.6	0.94	14293	0.869	25312	238203
6	Hyola-401	1830	576.9	31.5	1.13	44993	0.833	66514	473644
7	11CBN-006	1507	367.5	24.4	0.66	28382	0.695	77530	536589

Grand mean= 1661.1, CV= 22.97%, S.Y= Seed Yield kg/ha

Table7. Stability Statistics for 7 genotypes during the year 2016-17.

Sr.#	Genotypes	Mean	Sd	CV%	b_i	S^2d_i	R^2	r_i^2	W_i
1	CRH-119	1873	401.6	21.4	0.63	33754	0.749	89737	644158
2	AZRI Rapeseed	1571	897.3	57.1	1.52	113100	0.864	245465	1534034
3	Faisal Canola	1758	542.2	30.9	0.91	39455	0.845	4438	383021
4	RBN-13018	1911	769.1	40.3	1.25	129707	0.790	176986	1142724
5	KN-265	1833	610.4	33.3	1.01	64029	0.820	70790	535888
6	Hyola-401	2010	617.3	30.7	1.00	83073	0.781	94090	669033
7	11CBN-006	1740	429.2	24.7	0.68	39409	0.753	83577	608960

Grand mean= 1813.7 CV= 13.18%

unity indicated below average stability to changes in environments. Even a small change in environment may result a large increase in response and hence these entries are suitable for high yielding environments only. In contrast, entries CRH-119 (b_i=0.63), 11CBN-006 (b_i=0.68), and Faisal Canola (b_i=0.91), had regression coefficient less than unity and indicated above average stability to changes in environments. Even large changes in environments produced only a small increase in response and so these entries are suitable for low yielding environments. The entries KN-265 (b_i=1.01), and Hyola-401 (b_i=1.00) had regression coefficient close to unity (b_i=1) and are suitable for both high and low yielding environments. But the entry Hyola-401 had high average seed yield (2010 kgha^{-1}) and regression coefficient close to unity (b_i=1.0) with significantly less standard error and mean square of regression. So, Hyola-401 is the most stable entry among the entries studied at nine locations. Hammed (2005); Escobar *et al*. (2011) and Tahira *et al.* (2013) used the same criteria in rapeseed to identify the stable and adaptive genotypes for seed yield over the environments.

***Conclusion*:** The results of this study indicated that seed yield is significantly influenced by changes in environmental conditions as there were significant variations in seed yields of the genotypes tested in response to the environment in two years. Out of the 7 genotypes tested for adaptability and stability, genotypeHyola-401 represented stability trends for seed yield. Other genotypes did not appear to be stable in seed yield because of below average seed yield.

***Acknowledgments*:** Sincere gratitude goes to Mr. Asif Ghumman and Mr. Saleem Abid, Statistics and Computing Program, AERI, NARC for providing assistance in data analysis and interpretation.

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[Received 14 Nov 2018: Accepted 12 Feb 2020: Published (online) 08 June 2020]