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RECOMMENDATION OF STABLE GENOTYPES BASED ON MULTIPLE TRAITS ACROSS MULTIPLE ENVIRONMENTS IN *BRASSICA RAPA* L.

Debi Rani Datta*, M. Shalimuddin, M.N. Islam, M. Khorshed Alam, M.R. Humauan and M.A. Monim

Oilseed Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur - 1701, Bangladesh.

*Corresponding author E-mail : debi.datta@yahoo.com

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ABSTRACT

Eight lines of *Brassica rapa* L. along with BARI Sarisha-14 as check were evaluated at Gazipur, Jamalpur, Ishurdi and Jashore for days to 50% flowering, days to maturity and seed yield. Maturity duration ranged from 76-99 days. Plant height ranged from 60-120 cm. Seed yield ranged from 800-2156 kg/ha. The additive main effects multiplicative interaction (AMMI) analysis showed that environments (E), genotypes (G) and GE interaction (GGE) effects were significant for days to first flowering, days to maturity and seed yield. Using Multi-trait genotype-ideotype distance index (MGIDI) and stability statistics, which allowed the identification of three main groups based on their stability concepts. The biplot rendered using the weighted average of absolute scores (WAASB) and mean seed yield identified superior genotypes in terms of performance and stability. Hence, these regions are suggested as discriminative sites for the selection of high yielding and stable rapeseed genotypes. The highest seed yield was recorded in BC-100614 (4)-7 all over the location. Considering stability parameters, MGIDI, days to 50% flowering, days to maturity and seed yield, the lines namely BC-100614 (4)-7 was selected for further use in the future breeding programme.

Key words : *Brassica rapa*, Multi-environment, Stability analysis.

Introduction

Brassicaceae oilseeds are key producers of vegetable oil used for cooking and dietary needs on a global scale. The most popular and widely grown Brassica species for oilseed crops are *B. napus*, *B. juncea* and *B. rapa* (Rahman *et al*., 2022). Eventhough, *B. napus*, also known as rapeseed, has taken over as the primary oilseed crop, *B. rapa* cultivars with short duration and dwarf stature are still utilized as the best spring cultivars in late-frost regions like China, Northern Europe, and Canada. In Bangladesh and India, *B. rapa* is commonly grown as an oilseed crop (Rahman *et al*., 2022). Oilseed crops of *B. rapa* are frequently produced in Bangladesh and India. *B. rapa*, which comprises more than 70% of all oil crop acreage in Bangladesh, is the most pervasive and significant oilseed crop there (BBS, 2016). It is the leading producer with a cultivated area of 0.308 million ha, accounting for 70% of the total cultivated area for oilseed crops and produced 351,537 MT of oilseeds in the 2017–2018 fiscal year (BBS, 2019).

According to productivity land coverage of oilseeds, rapeseed and mustard are Bangladesh's top two oil crops (BBS, 2021). In Bangladesh, rapeseed is the primary source of edible oil. Three of the most often grown species are *B. rapa*, *B. napus* and *B. juncea* indigenous to Bangladesh. Rapeseed oil is utilized in both industrial and culinary applications. According to Khaldun *et al*. (2022), the mustard cake contains high protein (37%) rich feed that is very appetizing to animals. There is now an edible oil shortage in Bangladesh. Only 10% of the domestic demand is currently met by the 0.99 million tonnes of oilseed production that is currently being made (BBS, 2021). Every year, a significant quantity of foreign currency is spent to import almost 90% of the world's oil needs (BBS, 2021). According to the Food and Agriculture Organisation of the United Nations (2020), Bangladesh's national grain output of mustard/rapeseed is only about 950 kg/ha, which is extremely low when compared to other developed nations (2400 kg/ha) (Khaldun *et al.*, 2022). However, due to Bangladesh's rice-based cropping strategy, which makes it difficult to increase overall mustard production, less mustard is grown there (Khaldun *et al.*, 2022).

Rapeseed and mustard are very much sensitive to the environment. Breeders frequently use yield and its associated performance, as well as phenotypic expression, for sorting and selecting agricultural cultivars in mega environment tests. Crop enhancement strategies must focus on risk minimization, yield stability, cost savings and income maximization. Pathogenic infections, humidity, soil texture and fertility, precipitation and temperature can all effect yields. This yield instability or fluctuation is known as genotype by environment interaction (GEI) and has been observed in various crops.

As a result, the current study intends to discover superior genotypes with stable yield performance across a wide variety of settings by assessing the efficacy of various stability analysis approaches. Another goal of this study was to examine how GEI influenced yield and yield-related components of *Brassica rapa* genotypes and to discover high-yielding stable genotypes for future breeding schemes.

Materials and Methods

The experiment was undertaken at Gazipur, Jamalpur, Ishurdi and Jashore during *rabi* season 2021-22. It had eight advanced lines of *Brassica rapa* and one check as BARI Sarisha 14. The trial followed a randomised complete block design with three replications. The plot size was 3 m × 1.2 m. The seed was sown on 10 November 2021 at Gazipur, 13 November 2021 at Jamalpur, 11 November 2021 at Ishurdi, and 12 November 2021 at Jashore in continuous sowing and rows were 30 cm apart from each. After a few days of germination, the seedlings were trimmed, spaced 5 cm apart. N, P, K, S, Zn and Boron from Urea, TSP, MOP, Gypsum, Zinc Sulphate and Boric acid, respectively were sprayed at a rate of 120:80:60:40:4:1 kg/ha of fertilisers (FRG, 2018). During the last stages of land preparation, all other fertilizers and half of the urea were applied. At the flower initiation stage, the remaining urea was added. To raise a good seedling, all intercultural activities were completed on schedule time. Ten plants were chosen randomly from all genotypes and in every plot for measurement of data on days to 50% flowering (DF), days to maturity (DM), and seed yield (kg/ha). The data were analyzed statistically. Stability parameters for different studied traits were calculated using regression approach of Eberhart and Russel (1996).

Results and Discussion

The combined ANOVA and mean performance of different lines over location are presented in Tables 1 and 2, respectively. Table 1 displays the findings of the combined analysis of variance for three characters out of nine materials in four contexts. For every character under study, the sum of squares mean of the genotypes was very significant for every trait, indicating the existence of genetic diversity in the material under inquiry. The sum of squares mean for the environment was highly significant for days to 50% flowering (DF), days to maturity (DM) and Seed yield (kg/ha).

High variation in genotypic response across the various contexts is indicated by the very significant impacts of the environment. One important underlying causative reason for the GXE interaction was thought to be the change in soil structure and moisture between the various settings. The environment had a considerably

Table 1 : Combined ANOVA for days to 50% flowering, days to maturity and yield of *B. rapa* L. across environments.

Source of variation	Df	Days to 50% flowering	Days to maturity	Seed yield
Total	35	15.9	89.1	719926
GEN	8	14.6**	24.4**	89197**
ENV + (GEN x ENV)	27	16.3**	108.0**	906809**
ENV (linear)	1	286**	2569.0**	22996740**
GEN x ENV (linear)	8	4.04**	4.7**	66283**
Pooled deviation	18	3.78	11.6	53158
BC-100614 (1)-6	2	1.62	7.2	10054**
BC-100614 (3)-1	2	5.96	5.5	49986**
BC-100614 (4)-7	2	0.896	10.9	54233
BC-100614 (8)-4	2	1.98	9.8	49742
BC-110714 (7)-2	2	7.5	3.5	33968
BC-120114	2	6.05	7.4	26680
BC-15-YF-01	2	3.88	10.1	8426ns
BC-20-GS-1	2	32	99.5	88007
BARI-Sarisa-14	2	1.19	4.3	57323**
Pooled error	64	2.81	3.7	6474
AMMI component 1	10	-0.89	-0.90	0.29
AMMI component 2	8	-0.32	0.07	-0.25
AMMI component 3	6	-0.29	-0.33	-0.61
AMMI component 4	**4**	0.13	0.00	-0.66
CV(%)		4.8	2.4	4.8
Mean		35.53	86.01	1137

**Denotes significance level at $p<0.01$; Df- Degrees of freedom; CV- coefficient of variation; GEN- Genotype; ENV- Environment.

Table 2 : Mean performances of *Brassica rapa* genotypes in Regional Yield Trial during *rabi* 2021-22 over the 4 locations.

S. no.	Lines/varieties	Days to 50% flowering (day)	Days to maturity (day)	Seed yield (kg/ha)
1	BC-100614 (1)-6	36	86	1165
2	BC-100614 (3)-1	36	87	1189
3	BC-100614 (4)-7	36	86	1293
4	BC-100614 (8)-4	36	86	1182
5	BC-110714 (7)-2	35	85	1032
6	BC-120114	34	86	1034
7	BC-15-YF-01	35	86	1174
8	BC-20-GS-1	37	89	1094
9	BARI-Sarisa-14	34	84	1070
	SE	0.5	0.6	26.0
	LSD ($p \geq 0.05$)	1.4	1.7	73.4
	CV (%)	4.8	2.4	7.9

(1966) are discussed character-wise as follows; Stability parameter *i.e.* regression coefficient (Bi) and deviation from regression (S^2di) for yield and yield-related traits are presented in Tables 3, 4 and 5, respectively.

The environment × location interaction analysis related to days to 50% flowering, days to maturity, and seed yield are shown in Tables 3, 4 and 5, respectively.

The trait days to 50% flowering showed highly significant variation in the case of genotypes, environments and genotype-environment interaction. The mean performances over four locations are also varied from 34 days to 37 days. Besides, the environmental mean varied from 33 days to 38 days and the genotypic mean varied from 34 days to 37 days. Five lines showed a positive phenotypic index while the other four lines showed a negative phenotypic index. A positive phenotypic index means these genotypes need more time for flowering. On the other hand, a negative value means needs less time to flower. Positive and negative environmental index (Ij) indicating both favorable and unfavorable conditions for flowering respectively. The lines BC-100614(1)-6, BC-100614(3)-1, BC-100614 (4)-7, BC-100614 (8)-4 and BC-110714 (7)-2 had B_i values ranging from 0.53 to 0.85. If the B_i value is less than unity meaning that these lines had less sensitivity to changes in the environment. Besides, the line BC-100614(1) had the highest mean value

Table 3 : Genotype by environment interaction of days to 50% flowering of *Brassica rapa* lines in Regional Yield Trial over four locations during *rabi* 2021-2022.

S. no.	Line/Variety	Days to 50% flowering (day)				Over all mean	P. Index (Pi)	Bi	S^2di
		Gazipur	Jamalpur	Ishurdi	Jashore				
1	BC-100614 (1)-6	35	37	43	34	37	1.78	0.61	0.66
2	BC-100614 (3)-1	35	34	38	36	36	0.28	0.85	0.57
3	BC-100614 (4)-7	38	34	37	36	36	0.78	0.53	0.13
4	BC-100614 (8)-4	36	35	38	35	36	0.53	0.85	0.73
5	BC-110714 (7)-2	36	34	38	37	36	0.78	0.75	0.50
6	BC-120114	36	30	37	35	35	-0.97	1.41	0.08
7	BC-15-YF-01	36	31	36	35	35	-0.97	1.20	0.12
8	BC-20-GS-1	35	33	39	33	35	-0.47	1.34	0.26
9	BARI-Sarisa-14	34	32	35	34	34	-1.72	1.46	0.00
Mean		**36**	**33**	**38**	**35**	**35**			
E. Index (Ij)		0.19	-2.14	2.42	-0.47				
SE0.9		0.3	1.0	1.3	0.5				
LSD ($p \geq 0.05$)		2.6	1.0	3.1	4.0	1.4			
CV (%)		4.0	2.0	5.0	7.0	4.8			

Note: Bi-Linear regression; S^2di- Deviation from regression; LSD- Least significant difference; SE- Standard error.

greater relative size than the genotypic effect, indicating that environmental factors have a greater influence on each genotype's performance (Table 1). Results of stability and response of the genotypes for yield under different environments according to Eberhart and Russell

Table 4 : Genotype by environment interaction of days to maturity duration of *Brassica rapa* lines in Regional Yield Trial over four locations during *rabi* 2021-2022.

S. no.	Line/Variety	Days to Maturity (day)				Over all mean	P. Index (Pi)	Bi	S^2di
		Gazipur	Jamalpur	Ishurdi	Jashore				
1	BC-100614 (1)-6	87	81	100	89	89	3.28	0.79	0.32
2	BC-100614 (3)-1	83	79	89	91	86	-0.47	0.95	0.15
3	BC-100614 (4)-7	86	79	90	92	87	0.78	1.04	0.24
4	BC-100614 (8)-4	82	80	91	91	86	0.03	1.02	0.06
5	BC-110714 (7)-2	82	79	90	92	86	-0.22	1.09	0.08
6	BC-120114	83	77	89	91	85	-0.97	1.12	0.39
7	BC-15-YF-01	86	78	88	90	86	-0.47	0.96	0.15
8	BC-20-GS-1	87	78	89	89	86	-0.22	0.85	0.07
9	BARI-Sarisa-14	84	78	87	88	84	-1.72	1.19	0.00
Mean		84	79	90	90	**86**			
E. Index (Ij)		-1.53	-7.19	4.36	4.36				
SE		1.8	0.4	0.8	0.9	0.6			
LSD ($p \geq 0.05$)		5.5	1.1	2.3	2.8	1.7			
CV (%)		4.0	1.4	1.0	2.0	2.4			

Note: Bi-Linear regression; S^2di- Deviation from regression; LSD- Least significant difference; SE- Standard error.

Table 5 : Genotype by environment interaction of seed yield of *Brassica rapa* lines in Regional Yield Trial over four locations during *rabi* 2021-2022.

S. no.	Line/Variety	Seed yield (kg ha^{-1})				Over all mean	P. Index (Pi)	Bi	S^2di
		Gazipur	Jamalpur	Ishurdi	Jashore				
1	BC-100614 (1)-6	1022	1254	1570	945	1198	-80	0.82	0
2	BC-100614 (3)-1	1141	1608	1780	703	1308	31	1.12	0
3	BC-100614 (4)-7	1074	1581	1919	720	1324	46	1.23	0
4	BC-100614 (8)-4	1484	1443	1997	842	1442	164	1.00	0
5	BC-110714 (7)-2	1380	1281	1813	795	1317	40	0.87	0
6	BC-120114	1001	1163	1587	876	1157	-121	0.85	0.01
7	BC-15-YF-01	1165	1093	1644	817	1180	-98	0.85	0.02
8	BC-20-GS-1	1165	1451	1852	812	1320	43	1.09	0.28
9	BARI-Sarisa-14	1104	1127	1975	798	1251	-26	1.18	0.00
Mean		1171	1333	1793	812	**1277**			
E. Index (Ij)		-107	56	516	-465				
SE		25.1	52.4	63.7	34.7	26.0			
LSD ($p \geq 0.05$)		75.2	157.0	190.9	104.1	73.4			
CV (%)		6.5	7.3	6.0	7.0	7.9			

Note: Bi-Linear regression; S^2di- Deviation from regression; LSD- Least significant difference; SE- Standard error.

indicating that the genotype is better adapted for poor conditions (Sethi *et al*., 2022). The stability metric across environments is S^2d. Fig. 1 displays a biplot demonstrating genotype stability. Stable genotypes (BC-100614(1)-8 and BC-100614(4)-7) cluster around the center, forming a group of genotypes for this trait of days to 50% flowering.

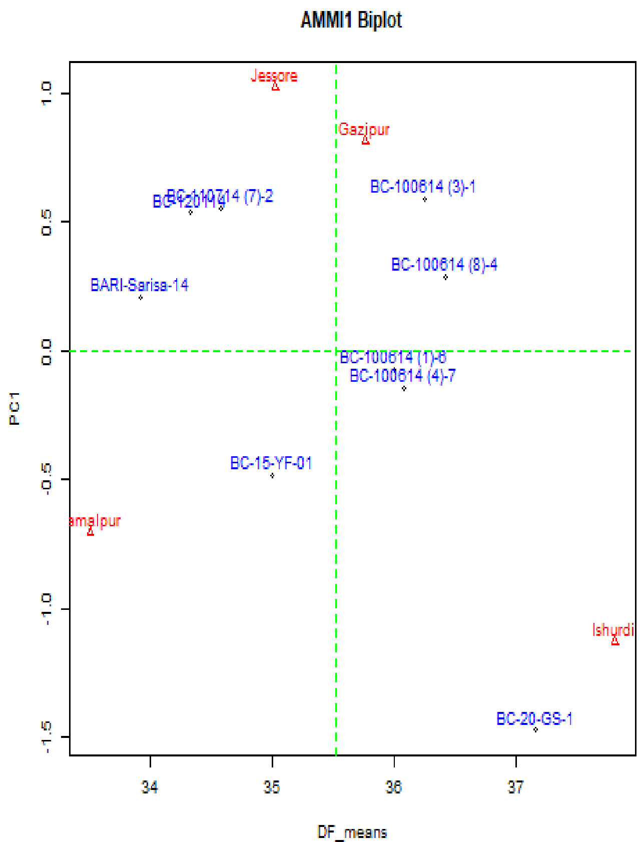

Fig.1a : AMMI1 biplot of days to 50% flowering environmental means vs IPCA1 for 8 *B. rapa* advanced lines and one check in the four environments.

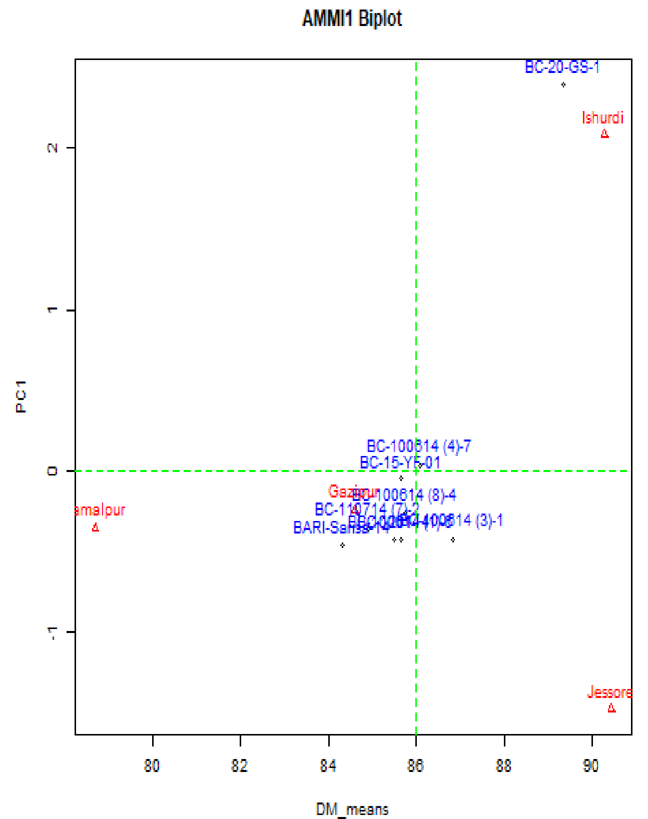

Fig.1b : AMMI1 biplot of days to 80% maturity environmental means vs IPCA1 for 8 *B. rapa* advanced lines and one check in the four environments.

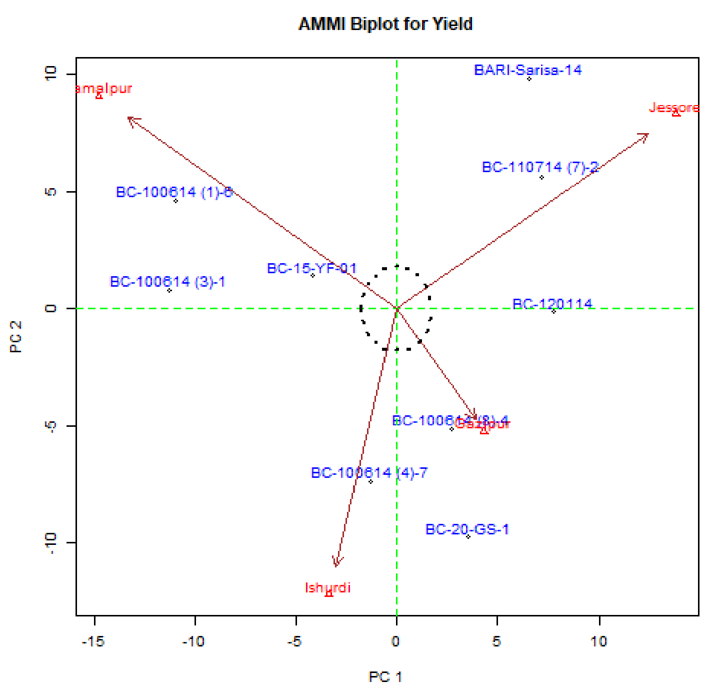

Fig. 1c : AMMI1 biplot of seed yield (kg ha^{-1}) environmental means vs IPCA1 for 8 *B. rapa* advanced lines and one check in the four environments.

A similar finding was also found from the researcher Jeromela *et al*. (2008).

The trait days to maturity exhibited significant variation among the locations. Location Ishurdi and Jashore required a little longer days than the other two locations to get maturity (Table 4). Besides, the mean performance over four locations is shown in Table 2. Here, all the entries take time to mature from 84 to 89 days. Yield performance over the tested locations also shows a significant variation among the entries. The highest mean yield was recorded in BC-100614 (4)-7 (1293 kg/ha) and the lowest was found in BC-110714 (7)-2 (1032 kg/ha). The seed yield was very low due to waterlogged stress at the seedling stage for cyclonic storm Jawad was bringing heavy rainfall. The yield of some promising entries is shown quite higher than the check variety which is desired for further steps of the variety development process.

The seed yield along with the value of phenotypic index (Pi), environmental index (Ei) regression coefficient (Bi) and stability (S^2di) are presented in Table 5. The environmental mean and genotypic mean ranged from 812 kg/ha to 1793 kg/ha and 1157 kg/ha to 1442 kg/ha, respectively. Five lines showed positive phenotypic index while the other genotypes had negative phenotypic index for yield. Thus, the positive phenotypic index represents

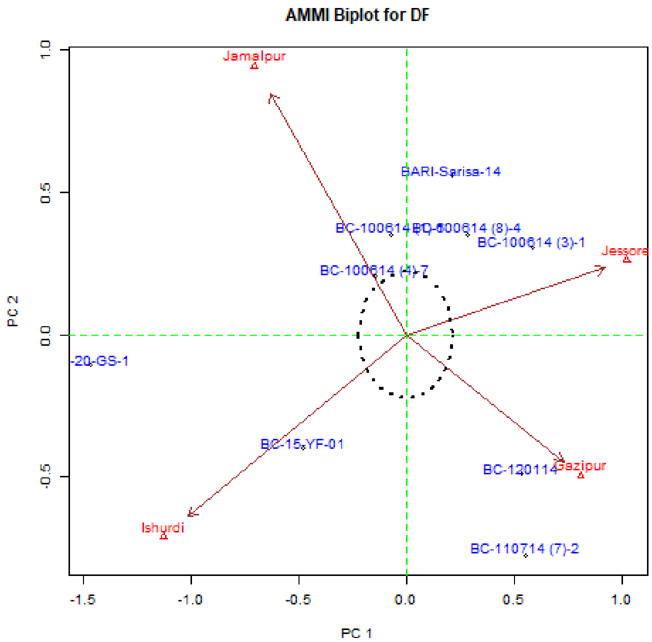

Fig. 2a : AMMI1 and AMMI2 biplots indicating GE interaction for days 50% flower of 9 *B. rapa* lines across 4 environments of Bangladesh.

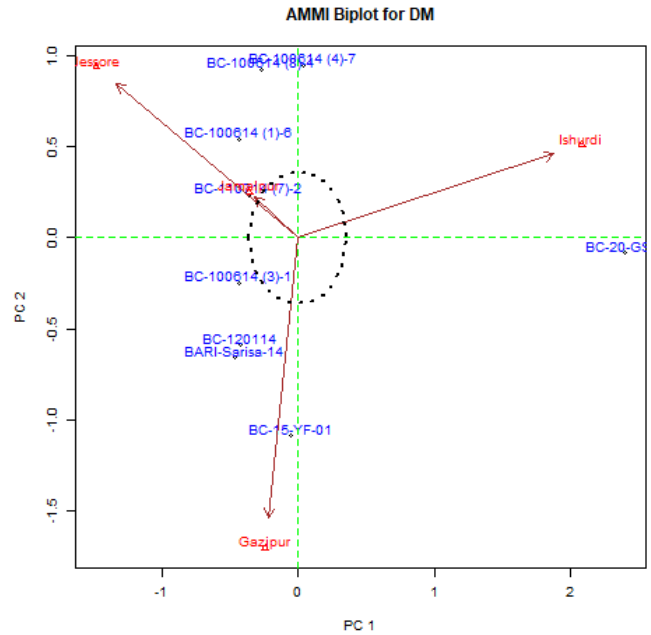

Fig. 2b : AMMI1 and AMMI2 biplots indicating GE interaction for days to maturity of 9 *B. rapa* lines across 4 environments of Bangladesh.

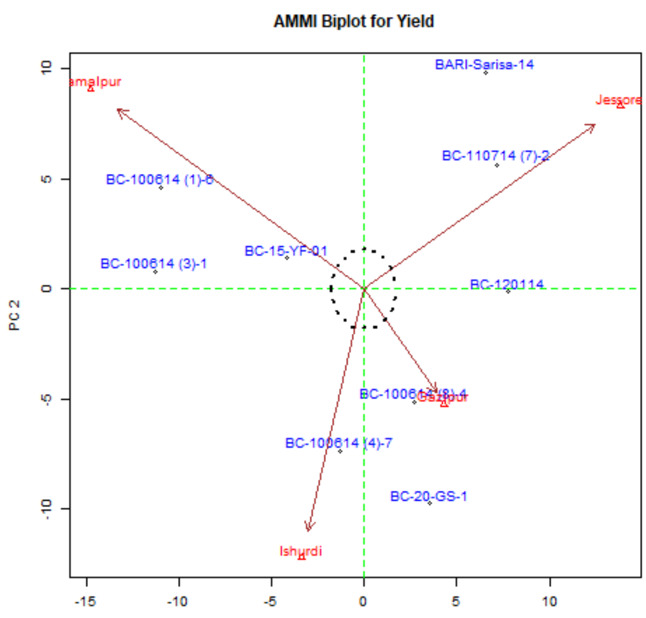

Fig. 2c : AMMI1 and AMMI2 biplots indicating GE interaction for seed yield (kg ha^{-1}) of 9 *B. rapa* lines across 4 environments of Bangladesh.

the higher yield and the negative represents the lower yield among the genotypes. Again, the positive and negative environmental index (Ij) reflects the rich or favourable and poor or unfavourable environments for this character, respectively (Table 5). The environmental index (Ij) directly reflects the poor or rich environment in terms of negative and positive Ij, respectively. Thus, the environment Gazipur and Jashore were poor environments on the other hand Jamalpur and Ishurdi were rich environments for rape seed production Table 5.

The regression coefficient (Bi) values for yield of these genotypes ranged from 0.82 to 1.23 (Table 5). These differences in Bi values indicated that all the genotypes responded differently to different environments. Considering the mean, Bi and S^2di three parameters, it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Among the advanced lines BC-100614 (8)-4, BC-20-GS-1, BC-100614 (3)-1, BARI-Sarisa-14 and BC-100614 (4)-7 exhibited the higher value of seed yield and bi~1. The lines BC-100614 (1)-6, BC-120114, BC-15-YF-01 and BC-110714 (7)-2 had Bi value significantly different from the unity with non-significant S^2di value indicating high responsiveness of the lines but suitable for favourable environments.

The AMMI biplot provides a visual expression of the relationship between the first interaction principal component axis (AMMI component 1) and mean of genotypes and environment (Fig. 3) with the biplot according for up to 78.6% of the treatment sum of squares. The first interaction principal component axis (AMMI component 1) was highly significant and explained the interaction pattern better than the other interaction axis. The AMMI model uses the x-axis to interpret genotypes and the y-axis to reflect genotype-environment interactions (Qasemi *et al.*, 2022). The interaction effects between genotypes and environment were highly diverse. According to Kendal *et al.* (2016),

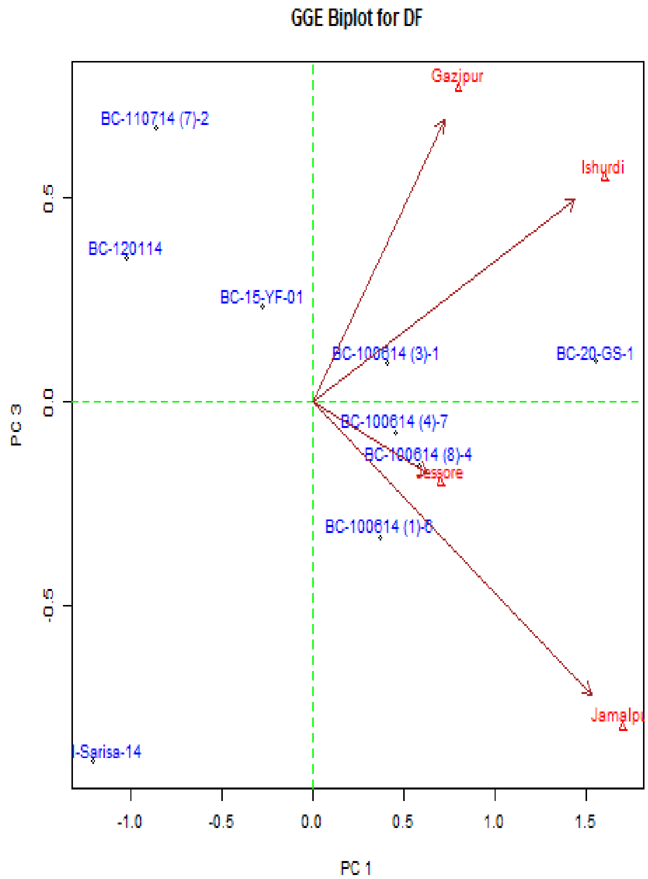

Fig. 3a : GGE biplot showing of the test environments for days to 50% flowering.

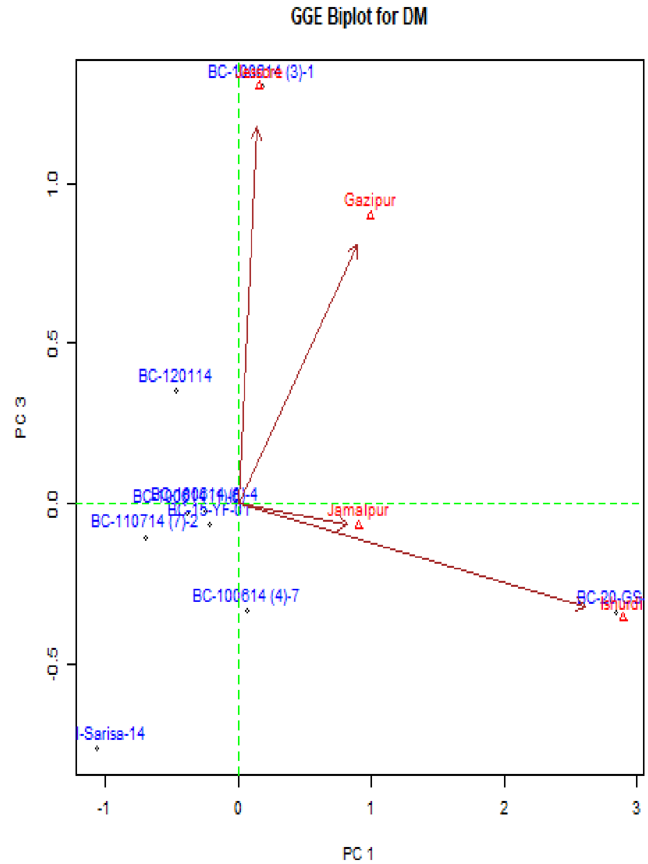

Fig. 3b : GGE biplot showing of the test environments for days to 80% maturity.

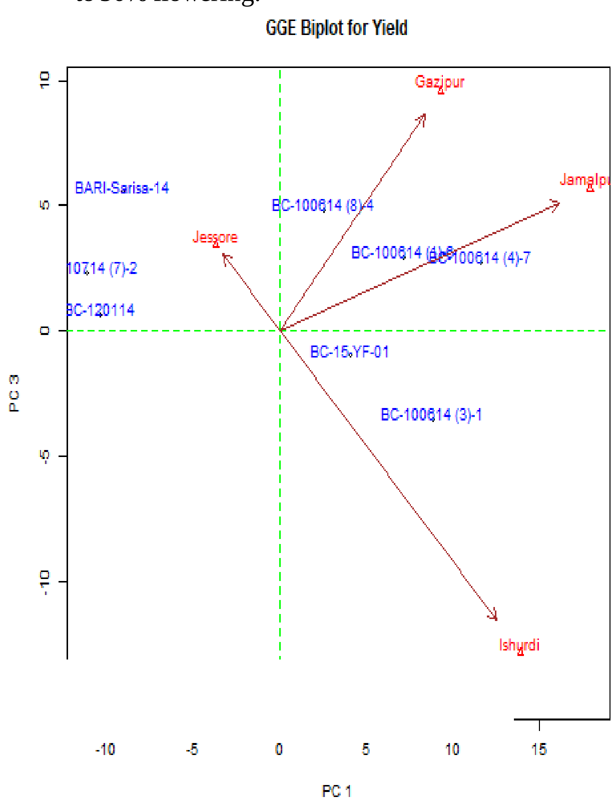

Fig. 3c : GGE biplot showing of the test environments for seed yield (kg ha^{-1}).

environments above the y-axis are attractive and high-performing, whereas those below it are undesirable and inefficient.

AMMI1 biplot analysis

When it comes to comprehending the impact of main effects and interaction effects on yield and yield-associated variables, AMMI biplots are a very useful interpretive tool (Fig. 1a-1c). The primary effects (mean of the genotype and mean of the environment) are plotted against IPCA1 scores for both genotypes and environments in the AMMI1 biplot. The study suggests that differences in the primary (additive) effects are shown by genotype displacement along the abscissa, while differences in the interaction effects are indicated by genotype displacement along the ordinate. Similar environments have a similar effect on genotypes, and similar genotypes have similar adaptations (Kempton, 1984). Higher yields are found for genotypes and habitats on the right side of this axis' midpoint than for those on the left, and for genotypes and environments on the same parallel line. The analysis showed that genotype BC-100614 (8)-4 lying on the right side of the perpendicular is less influenced by the G×E interaction for seed yield

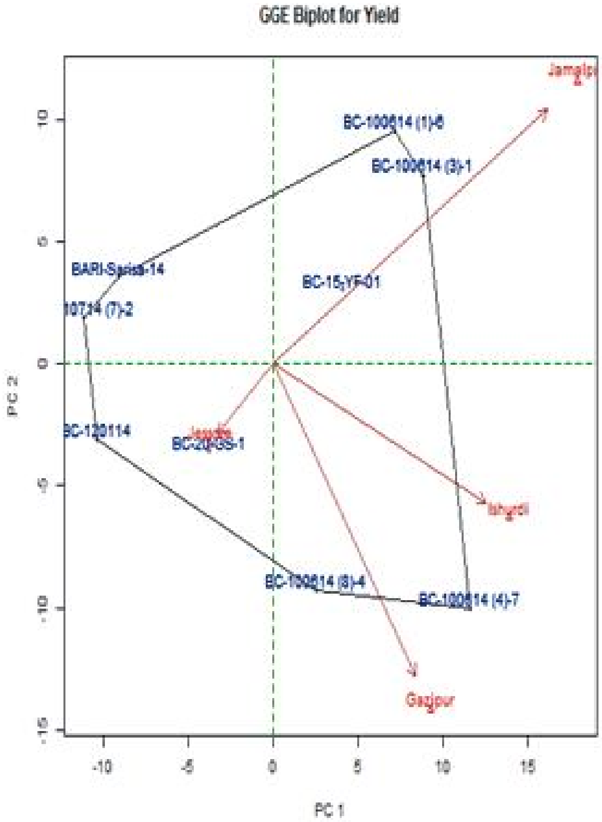

Fig. 4a : The GGE biplot polygon view is based on symmetrical scaling for the which-won-where pattern for days to 50% flowering in rapeseed lines and environments.

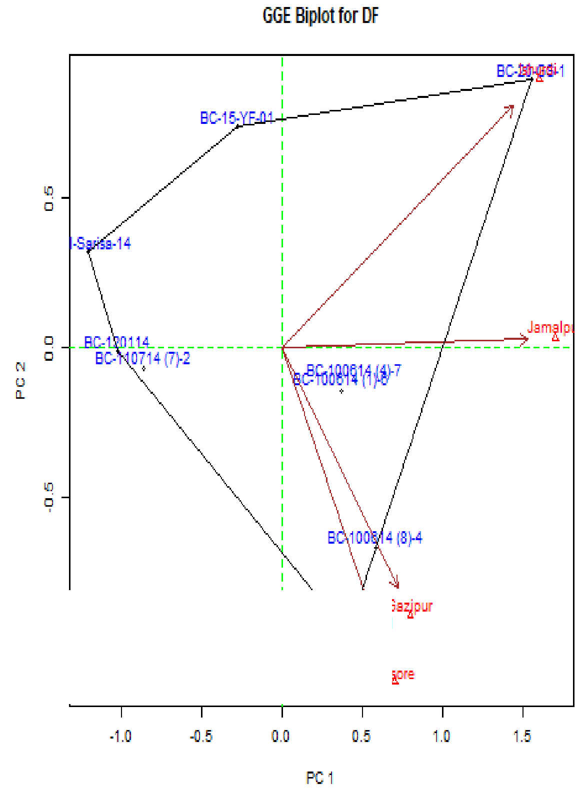

Fig. 4b : The GGE biplot polygon view is based on symmetrical scaling for the which-won-where pattern for days to maturity in rapeseed lines and environments.

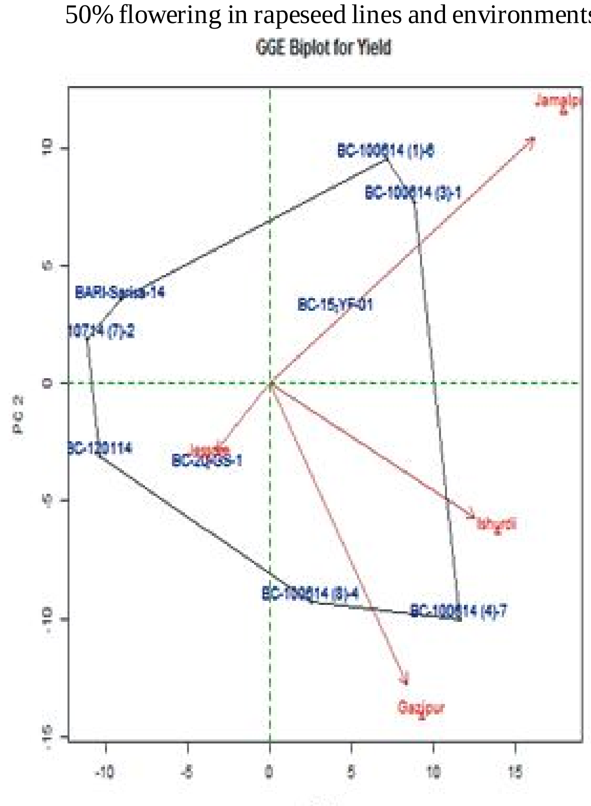

Fig. 4c : The GGE biplot polygon view is based on symmetrical scaling for the which-won-where pattern for seed yield in rapeseed lines and environments.

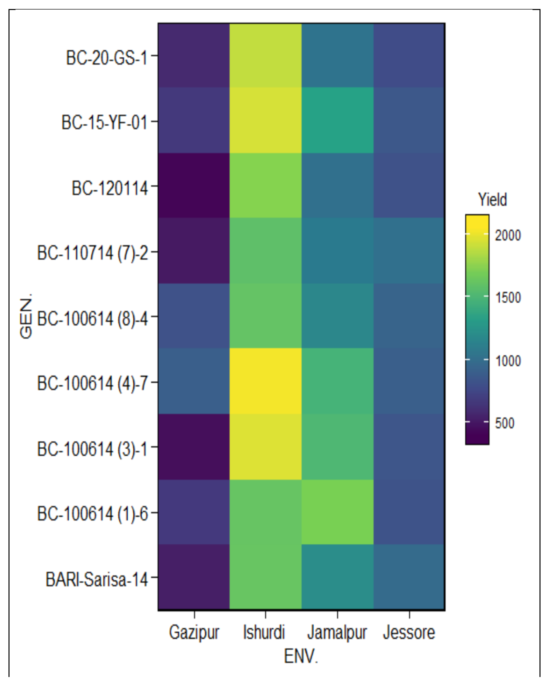

Fig. 5 : Heatmap displaying genotype performance and stability across all environments, with a ranking of nine lines based on different weightings of stability and seed yield performance in individual environments. The x-axis depicts the environment, while the y-axis depicts the genotypes and the corresponding mean seed yield (kg ha^{-1}) recorded.

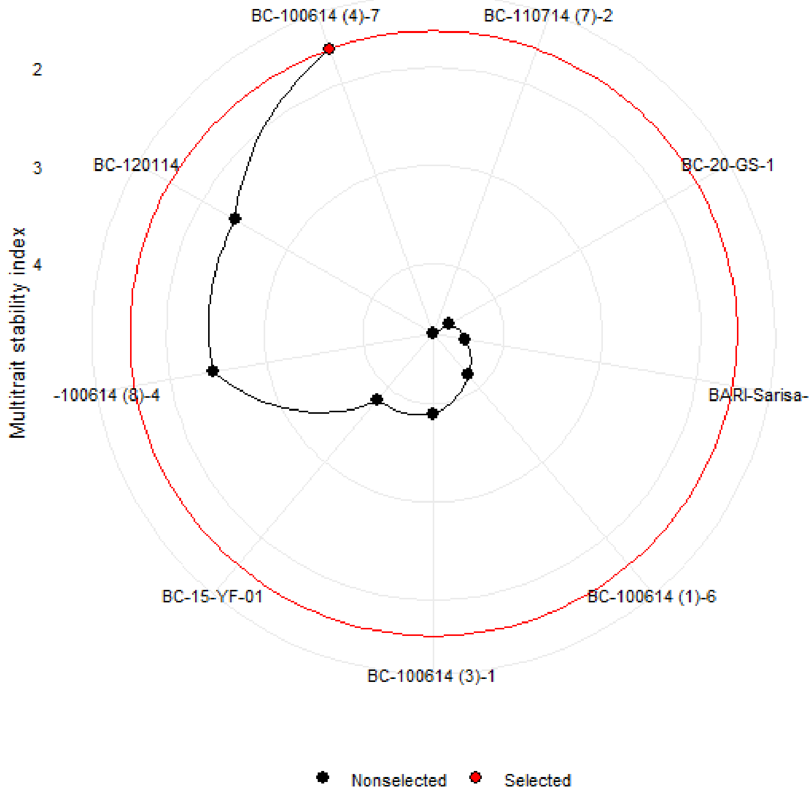

Fig. 6 : Genotype ranking based on the MTSI considering a selection intensity of 5% (red circle). Selected genotypes are highlighted in red.

(Fig. 4h). Genotypes *viz*., BC-15-YF-01, BC-20-GS-1 and BC-100614 (4)-7 were found stable across the locations for seed yield as they lie closer to the center point in the biplot. A previous combined analysis of variance by a number of researchers (Gajghate *et al.*, 2021) indicated that the environmental effect and GEI were the next most common sources of variation, after the genotypic effect. The impacts of GEI on grain yield were examined using AMMI and biplot analysis. The genotypes that are highly adaptable, stable and high yielding were selected by computing the yield stability index and AMMI stability value.

AMMI2 biplot analysis

Based on an IPCA1 vs. IPCA2 plot, this illustrates how much each genotype interacts with the environment (Fig. 2a-2c). On the plot, genotypes that are closely clustered together will provide similar results at every site, whereas genotypes that are farther apart will yield diverse results or respond to surroundings in various ways. According to Osiru *et al*. (2009), genotypes and environments that belong to the same sector interact both favorably and unfavorably depending on which sector they are in. Genotypes *viz*., BARI-Sarisa-14, BC-110714 (7)-2 and BC-120114 occurring close together on the biplot have similar yields across the three locations and G16, G17 and G29 showed differences in mean yield across the locations (Fig. 2c). Genotypes close to the origin are suggestive of consistent performance across all places. BC-15-YF-01, BC-120114 and BC-100614(8)-4 were found stable and showed less interaction with the environmental-interactive forces. The fact that the genomes BARI-Sarisa-14 and BC-20-GS-1 were far from the origin suggests that they are sensitive to various environmental conditions that affect seed production.

GGE biplot analysis

A data visualization tool called GGE biplot shows a two-way G×E interaction graphically Table 3 (a-c) (Yan and Fregeau, 2008). It is a useful instrument for studying mega-environments (e.g. “which-won-where” pattern), whereby specific genotypes can be recommended to specific mega-environments (Yan *et al*., 2007). With this approach, genotypes are assessed for mean performance, stability, and environmental assessment, or the ability to distinguish between genotypes in target environments. The polygon view of a GGE-biplot based on symmetric scaling unambiguously displays the which-won-where pattern providing a comprehensible summary of the GEI pattern of a multi-environmental trial (MET) data set (Fig. 4a to 4c). The polygon is formed by connecting vertex genotypes (BC-100614 (1)-6, BC-120114, BC-110714 (7)-2, BC-100614 (8)-4, BC-100614 (3)-1, BARI-Sarisa-14 and BC-100614 (4)-7) for seed yield (Fig. 4c). These genotypes have the largest vectors in their respective directions; the vector length and direction represent the extent of the response of the genotypes to the tested environments. All other genotypes are contained within the polygon and have smaller vectors, *i.e.*, they are less responsive in relation to the interaction with the environments within that location. A set of lines drawn from the biplot origin and intersecting the sides of the polygon at right angles. Thus, the lines divide the biplot into four sectors and thereby the biplot subdivides the target environment into subregions (mega-environments). Mega-environments are those sectors that comprise one or more environments. This way the environment markers were grouped into two sectors (*i.e.* two mega-environments) where sector 1 contained environments Jamalpur and sector 4 had two environments Gazipur and Ishurdi (Fig. 4c). In agreement with the results reported by Yan (2002), the genotype(s) vertex in these sectors may have higher or the highest yield compared to other parts in all environments. Besides, the heat map displays genotypic performance and stability across all environments and all genotypes (Fig. 5).

Multi-trait stability index and genotype selection

Based on mean performance and stability, the multi-trait stability index (Olivoto *et al.*, 2021) has shown to be effective in genotype selection for many traits. Zuffo *et al.* (2020) also found stable genotypes of soybean for stress circumstances. Using the Multi-Trait Stability Index (MTSI) and Multi-Trait Genotype-Ideotype Distance Index (MGIDI), Benakanahalli *et al.* (2021) developed an appropriate genotypic selection to discover stable guar genotypes with productive attributes under varied environmental conditions. As shown by the red line in Fig. 6, which represents the number of genotypes selected based on selection pressure, the genotypes selected by the MGIDI index in the current investigation were BC-100614 (4)-7. Desired selection differential is shown for all three of the examined traits. The percentage of selection differential varies from 0.09% (days to maturity) to 13.74%.

Conclusion

All stability statistics together identify one line BC-100614 (4)-7, for further breeding programs of rapeseed considering earliness and seed yield.

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