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MULTI-ENVIRONMENT TRIAL ANALYSIS BY PARAMETRIC AND NON-PARAMETRIC STABILITY PARAMETERS FOR SEED YIELD IN WINTER RAPESEED (*Brassica napus* L.) GENOTYPES

Yasemin ERDOGDU[1], Enver ESENDAL[1]*

[1]Tekirdag Namık Kemal University, Faculty of Agriculture, Department of Field Crops, Tekirdag, TURKEY
**Corresponding author: yerdogdu@nku.edu.tr*

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ABSTRACT

The objective of this study was to determine the stability of 11 different rapeseed genotypes in terms of seed yield, throughout 3 years (2014-2015-2016), 3 locations (Tekirdag, Kırklareli, Edirne), in total 8 environment in Thrace Region. The experiment was designed as a randomized complete block design with four replications. The aim of this study was to determine rapeseed genotypes having a high adaptation for seed yield. Parametric ($W_i^2, b_i, S_{di}^2, B_i, \sigma_i^2,\ r_i^2, S_{xi}^2, CV_i$ and P_i,) and non-parametric ($S_i^{(2)}, S_i^{(3)}, S_i^{(6)}$, RS and TOP) stability statistics were used to determine stability of the genotypes. The analysis of variance for seed yield showed that genotypes, environments and genotype by environment interaction all were significant (P<0,01). According to parametric and non-parametric (except TOP methods) stability analysis, genotype Wosry 142 was determined as a well-adapted genotype; genotype Wosry 144 poorly adapted genotype in across environments. Genotype Wosry 142 may be recommended for cultivation in the different environments tested.

Keywords: Genotype by environment interactions, stability parameters, winter rapeseed, yield

INTRODUCTION

Rapeseed (*Braccica napus* L.) is the second most important oilseed crop cultivated worldwide after soybean with a production of approximately for 2019 is 70.51 million tonnes (FAO, 2021). The widespread use of biodiesel in addition to edible oil has led to an increase in rapeseed production in recent years. In a few decades, rapeseed has become one of the world's most important oilseeds. Rapeseed cultivation also increased rapidly in Turkey and cultivation area, which was 82 hectares in 2000, increased to 52.510 hectares in 2019. The total rapeseed production increased from 187 tonnes to 180.000 tonnes during the 2000-2019 periods in Turkey. In the Thrace region of Turkey, which is one of the most important production area of sunflower and rapeseed, rapeseed has to compete with sunflower. However average rapeseed yield of Turkey is 3427 kg ha^{-1}, the average sunflower yield is 2793 kg ha^{-1} (FAO, 2021), and also winter rapeseed is well adapted for production in Thrace region. Thrace region has provided to 39% of rapeseed production in Turkey (Yılmaz and Avkıran, 2019). For this reason, it is necessary to determine the appropriate rapeseed genotypes for the Thrace region. However, to date, the number of studies on genotype by environment interaction (GEI) of rapeseed in the Thrace region is quite insufficient.

GEI is an extremely important issue in crop breeding and production (Kang and Gauch, 1996) because genotypes and environments interact to produce an array of phenotypes (Kang, 2002). The phenotypic performance of a genotype may not be the same under diverse agro-climatic conditions (Ali et al., 2002). Although genotypic characteristics and agronomical applications can be controlled, it is not possible to control other environmental factors such as precipitation, temperature and proportional humidity. Therefore, genotypes must be stable against change environmental conditions and successful new varieties must show high performance for seed yield (Becker and Leon, 1988; Akcura et al., 2006).

Seed yield is a very complex quantitative trait, which expression is the result of genotype, environment and the GEI (Nowsad et al., 2016). The occurrence of GEI necessitates multi-environment trials and has resulted in the development and use of numerous measures of stability (Yan and Kang, 2002). Comstock and Moll (1963) obtained data by establishing repeated experiments in various years and locations and investigated the existence of the GEI with variance analyses performed on the obtained data. If genotypes have different values in various environments and this difference is significant, the GEI comes into question for these genotypes. When the

GEI is determined to be significant, the stabilities of the genotypes are examined.

The numerous stability statistics are available to explain GEI (Yan and Kang, 2002). There are two major approaches (Huehn, 1996). The first and most common approach is parametric which relies on distributional assumptions about genotypic, environmental, and GEI effects. The second major approach is the non-parametric or analytical clustering approach, which relates environments and phenotypes relative to biotic and abiotic environmental factors without making specific modelling assumptions (Sabaghnia, 2006). Non-parametric stability statistics provide a viable alternative to existing parametric measures based on absolute data (Lu, 1995).

When studies conducted on the GEI for seed yield in the rapeseed are examined, it was seen that in the studies conducted by Shafii et al. (1992); Wright et al. (1995); Ali et al. (2002); Ali et al. (2003); Escobar et al. (2011); Marjonovic-Jeromela et al. (2011); Zhang et al. (2011); Moghaddam and Pourdad (2011); Shojaei et al. (2011); George et al. (2012); Tahira and Amjad (2013); Mashayekh et al. (2014); Mortazavian and Azizi-Nia (2014); Oghan et al. (2016); Sharma and Sardana (2016); Lima et al. (2017), the GEI was determined to be significant and various stability analyses were carried out.

The objectives of this study were to (i) examine the influence of genotype, environment and GEI in terms of seed yield for winter rapeseed; (ii) determine the adaptation and stability performances of promising winter rapeseed genotypes using parametric and non-parametric stability methods; (iii) identify winter rapeseed genotypes that have both high seed yield and stable performance across different environments in Thrace region.

MATERIALS AND METHODS

Eleven rapeseed genotypes were grown 8 environments in the localities of Edirne, Kırklareli, and Tekirdag during the 2014-2016 growing season at the Thrace region in Turkey. The code, name and origin of these genotypes are listed in Table 1. Location, cropping season, temperature, rainfall, relative humidity, longitude, latitude, and height above sea level for across environment given Table 2.

Table 1. The code, genotype name and origin of the genotypes used in the study

Code	Genotype name	Origin
G1	Turan	KWS
G2	Rally	Cimsan
G3	Nk Petrol	Syngenta
G4	Nk Caravel	Syngenta
G5	Suzer	Trace Agricultural Research Institute
G6	PR44W29	Pıoneer
G7	Excalibur	Dekalp
G8	Wosry 141	Euralis
G9	Wosry 142	Euralis
G10	Wosry 143	Euralis
G11	Wosry 144	Euralis

Table 2. Code, location, growing season, temperature, rainfall, relative humidity, longitude (E), latitude (N) and height above sea level for across environment

Code	Location	Growing season	Temperature °C	Rain-fall (mm)	Relative humidity(%)	Longitude (E)	Latitude (N)	Above sea level (m)
E1	Tekirdag	2013-2014	13.7	478.4	79.2	40°99'04"	27°58'07"	10 m
E2	Tekirdag	2014-2015	13.3	519.9	77.6	40°99'04"	27°58'07"	10 m
E3	Tekirdag	2015-2016	14.5	324.5	75.9	40°99'04"	27°58'07"	10 m
E4	Kirklareli	2013-2014	12.7	647.6	73.5	41°70'26"	27°20'86"	232 m
E5	Kirklareli	2014-2015	12.4	628.2	70.2	41°70'26"	27°20'86"	232 m
E6	Kirklareli	2015-2016	13.6	522.8	72.6	41°70'26"	27°20'86"	232 m
E7	Edirne	2013-2014	13.3	521.6	71.3	41°64'68"	29°59'71"	51 m
E8	Edirne	2014-2015	13.8	530.8	71.5	41°64'68"	29°59'71"	51 m

The experimental layout was a randomized complete block design with four replication. Plots were 5 m^2 with six rows, each 5 m long and 20 cm between rows. The harvested plot size was 3 m^2 (there 4 rows at the center of each plot). The seeding density was 175 seed m^2. Fertilizer application was 36 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} at planting, 46 kg N ha^{-1} at the stem elongation stage and 39 kg N ha^{-1} beginning of the flowering stage. Crop fungicide and insecticide were applied to plants recommended rates.

Statistical Analysis

A combined ANOVA was firs performed for the mean seed yield values of 11 rapeseed genotypes in across 8 environments 2013-2014, 2014-2015, 2015-2016 in Tekirdag, Kırklareli and 2013-2014, 2015-2016 in Edirne ecological conditions. Statistical analyses were carried out using JMP-7. The F-protected least significant difference (LSD) was calculated at the 0.05 probability level according to Steel and Torrie (1986). Then 9 parametric stability parameters were studied in accordance Wrick's (1962) W_i^2=ecovalance; Finlay and Wilkinson's (1963) b_i= regression coefficient; Eberhart and Russel's (1966) b_i= regression coefficient and S_{di}^2= deviations from regression; Perkins and Jinks's (1968) and Baker's (1969) B_i= regression coefficient and S_{di}^2= deviations from regression; Shukla's (1972) σ_i^2= stability variance; Pinthus's (1973) r_i^2= coefficient of determination; Francis and Kannenberg's (1978) S_{xi}^2= environmental variance; CV_i= coefficient of variation; Lin and Binns's (1986) P_i= superiority index. Secondly 5 non-parametric stability parameters were studied in accordance with Nassar and Huehn's (1987) $S_i^{(3)}$= sum of the absolute deviations of the squares of ranks for each genotype; $S_i^{(6)}$= the sum of squares of ranks for each genotype relative to the mean of ranks; Huehn's (1990) $S_i^{(2)}$= genotype between ranks variance over n environments; Kang's (1988) RS= rank sum and Fox et al.'s (1990) TOP= number of sites at which the genotype occurred in the top third of the ranks. In addition, two-way relations between all stability parameters were determined by correlation analysis. All stability statistical analyses were performed using the SAS (Statistical Analyses Systems) program (SAS Institute, 1999).

RESULTS AND DISCUSSION

A combined analysis of variance for seed yield showed that genotype, environment, and GEI were significant at P<0.01 (Table 3). The average seed yield values of the genotype, environment, and GEI of 11 rapeseed genotypes obtained from 8 environments are shown in Table 4.

When the environments were examined, it was seen that seed yield differed between 1189.3-1937.2 kg ha^{-1},that the highest seed yield was obtained in the E7 environment and that the lowest seed yield was obtained in the E2 environment; In the study, the total temperature values of the surroundings during the rapeseed growing season and the average temperature values during the flowering season differed. During the whole growing season, the total temperature values of the environments varied by 2.1 °C degrees. In addition, when the total precipitation regimes are examined, there is a significant difference between the environments. Seed yield differences between environments may be caused by factors such as temperature and precipitation, because rapeseed is sensitive to water stress and high temperature stress during post-anthesis period and strong genotype and environment interactions (Shafii et al., 1992; Gunasekera et al., 2006; Cullis et al., 2010; Zhang et al., 2013).

when the genotypes were examined, the seed yield differed between 1382.5-1605.0 kg ha^{-1}, that the highest seed yield was obtained from the G10 genotype and that the lowest seed yield was obtained from the G6 genotype. These results indicated that rapeseed genotypes had significant differences for seed yield over different environments. In similar studies, it has been revealed that there is a significant difference in seed yield between the environments in rapeseed (Gunasekera, 2006; El-Nakhlawy, 2009; Marjanovic-Jeromela et al., 2011; Nowosad et al., 2016).

When the GEI was examined, the seed yield ranged between 1057.5-2127.5 kg ha^{-1} and that the highest seed yield was obtained from the G11 genotype in the E7 environment, and that the lowest seed yield was obtained again from the G11 genotype in the E2 environment (Table 4). Seed yield in rapeseed vary with genotype, environment and GEI (Shafii et al., 1992; Si et al., 2003; Si and Walton, 2004; Gunasekera et al., 2006; Moghaddam and Pourdad, 2011; Zhang et al., 2013; Nowosad et al., 2016). The fact that the GEI was determined to be significant shows that the stability conditions of genotypes are different in terms of seed yield.

Table 3. Analysis of variance for winter rapeseed seed yield in 8 envirnment

Source of variation	d.f	Sum of square	Mean square	F
Environment (E)	7	15151397	2164485.28	193.49**
Error 1 (R/E)	24	403611	16817.12	1.50^{ns}
Genotype (G)	10	1538152	153815.20	13.75**
G ×E	70	8793593	125621.9	11.22**
Error 2	240	2684764		
Total	351	28571518		
CV $_{(\%)}$ = 1.40				

** P<0.01 at significance; ns: not significant

Table 4. Mean seed yield of winter rapeseed genotypes tested across 8 environments (kg ha^{-1})

Genotype	E1	E2	E3	E4	E5	E6	E7	E8	Mean*
G1	1410.0	1322.5	1397.5	1362.5	1432.5	1305.0	2022.5	1180.0	1429.0 de
G2	1407.5	1107.5	1617.5	1485.0	1412.5	1455.0	1605.0	1482.5	1446.5 cd
G3	1977.5	1227.5	1187.5	1597.5	1582.5	1530.0	1615.0	1457.5	1521.8 b
G4	1635.0	1105.0	1287.5	1777.5	1587.5	1197.5	1915.0	1277.5	1472.8 bcd
G5	1195.0	1347.5	1627.5	1715.0	1257.5	1442.5	2065.0	1272.5	1490.3 bc
G6	1175.0	1275.0	1482.5	1225.0	1257.5	1320.0	2020.0	1305.0	1382.5 e
G7	1397.5	1117.5	1602.5	1517.5	1560.0	1225.0	1927.5	1252.5	1450.0 cd
G8	1130.0	1130.0	1437.5	1537.5	1277.5	1585.0	2035.0	1305.0	1429.6 de
G9	1392.5	1155.0	1600.0	1727.5	1485.0	1470.0	1947.5	1385.0	1520.3 bc
G10	1380.0	1237.5	2015.0	1690.0	1712.5	1485.0	2030.0	1290.0	1605.0 a
G11	1470.0	1057.5	1330.0	1975.0	1925.0	1602.5	2127.5	1250.0	1592.1 a
Mean*	1415.4 d	1189.3 f	1507.7 c	1600.9 b	1499.0 c	1419.7 d	1937.2 a	1314.3 e	

* LSD% :Genotype=40.7 Environment=44.4 Genotype × Environment=147.3

Parametric methods

The results of 9 parametric stability parameters and mean seed yields for 11 rapeseed genotypes at the 8 environments are presented in Table 5. According to Wricke (1962), if the W_i^2 of a genotype is low, the stability of that genotype is high. The highest W_i^2 was calculated in the G3 genotype, followed by the genotypes G11 and G10. The lowest W_i^2 was calculated in the G9 genotype, followed by the genotypes G7, G1 and G2. With the stability analysis, it was found that the most stable genotypes with W_i^2 values near 0 were G9, G7 and G1 respectively (Table 5).

Genotypes G10 and G11 had higher seed yields and b_i values above 1.0 these genotypes are sensitive to environmental variations and would be suggested for cultivation under favorable environments (Table 5). Genotypes G9 and G5 had higher seed yields and b_i values near 1.0 these genotypes are stable to environmental variations and would be suggested for cultivation across environments. Genotypes G4 and G6 had lowest avarage yield and and b_i values near 1.0 these genotypes are stable. Genotypes G7 and G8 had lowest avarage yield and b_i values above 1.0 these genotypes poorly adapted across environments. Genotype G3 with b_i<1 and higher average yields was adapted across unfavorable environments. Genotype G2 with b_i<1 and lowest average yield was adapted across unfavorable environments. Genotype G1 had lowest avarage yield and and b_i values near 1.0 these genotype poorly adapted across environments (Finlay and Wilkinson, 1963)

Eberhart and Russel (1966) reported that in order to determine the adaptation and stability conditions of genotypes, the S_{di}^2 should be used in addition to the b_i, that the b_i value of a stable genotype should be near 1, that the genotype average should be higher than the overall average and that the S_{di}^2 value should be near 0. As a result of the study b_i, it was found that the genotypes that were near 1 were G1, G6, G9 and G7; that the genotypes with averages higher than the overall average were G10, G11, G3 and G9; and that the genotypes with the S_{di}^2 values near 0 were G9, G7, G2 and G1 (Table 5). In accordance with these results, the G9 genotype was determined to be the most suitable genotype for the environments where the experiment was conducted.

Perkins and Jinks (1968) and Baker (1969), used the B_i value as stability criteria. When the B_i values of seed yield obtained in the study were examined, it was found that the genotypes that were the nearest to 0 were G1, G6 and G9 respectively. Considering the fact that the S_{di}^2 should be low, it was found that the lowest genotypes were G9, G7 ve G2 and respectively (Table 5). In accordance with these results, the G9 genotype was determined to be the most suitable genotype for the environments where the experiment was conducted.

Shukla (1972) developed an unbiased estimate using σ_i^2 of genotypes. The highest σ_i^2 that was obtained in the study was acquired from G3, G11 and G10 and the lowest σ_i^2 was obtained from the genotypes G9, G7 and G1 (Table 5). In accordance with these values, the genotypes G9, G7 and G1, which are the nearest to 0, were found to be the most stable genotypes. Also, there is a linear relationship between the σ_i^2 and the W_i^2. The stability conditions of the genotypes were found to be the same according to both stability analysis.

Pinthus (1973) used the r_i^2 as a stability parameter and reported that the genotypes with r_i^2 near 1 were stable. As a result of the analysis the genotypes that were the nearest to the r_i^2 1 were G9, G7, G1 and G10 respectively. The genotypes with r_i^2 near 0 which had the lowest stabilities were G3, G2, G4 and G5 (Table 5). In accordance with these results, the G9 genotype was determined to be the most suitable genotype for the environments where the experiment was conducted.

Francis and Kennenberg (1978) used the S_{xi}^2 of each genotype and the CV_i as the stability criterion. According to this stability analysis, the S_{xi}^2 and CV_i values of a stable genotype should be near 0 and its genotype average should be higher than the overall average. The genotypes that were the nearest to the S_{xi}^2 0 were G2, G9 and G3; and the genotypes that were the furthest from 0 were G11, G10 and G8. When the CV_i of the genotypes were considered, the genotypes that were the nearest to the CV_i 0 were G2, G9 and G3; and the genotypes that were the furthest to 0 were G11, G8 and G4 (Table 5). In accordance with these results, the G2 and G9 genotypes were determined to be the most suitable genotypes for the environments where the experiment was conducted.

Lin and Binns (1986) used the concept of P_i to determine the stabilities of genotypes. And if the P_i value of a genotype is near 0, the stability of that genotype is high. The genotypes that were the nearest to the P_i 0 were G10, G11 and G9 respectively; and the genotypes that were the furthest from it were G6, G8 and G1 (Table 5). In accordance with these results, the G10, G11 and G9 genotypes were determined to be the most suitable genotype.

Non-parametric methods

The results of 5 non-parametric stability parameters and mean seed yields for 11 rapeseed genotypes at the 8 environments are presented in Table 6. According to Huehn (1979) and Nassar and Huehn (1987) the $S_i^{(2)}$, $S_i^{(3)}$ and $S_i^{(6)}$ reported that these obtained values needed to be near "0" for a genotype to be stable; and that zero variance showed high determination. In the light of these findings, the most stable genotypes according to the $S_i^{(2)}$analysis result were G9, G7 and G10 respectively; the most stable genotypes, according to the $S_i^{(3)}$ analysis result were again G9, G7 and G10 respectively and the most stable genotypes according to the $S_i^{(6)}$ analysis result were G7, G9 and G6 respectively. The genotypes with the lowest stabilities were G11, G3 and G4 respectively according to the $S_i^{(2)}$analysis result, G11, G3 and G5 according to the $S_i^{(3)}$ analysis result, and G11, G5 and G3 according to the $S_i^{(6)}$ analysis result (Table 6). In accordance with these results, the G9 and G7genotypes were determined to be the most suitable genotype.

Table 6. Mean seed yield values (kg ha^{-1}) and non-parametric stability parameters of 11 winter rapeseed genotypes across 8 environment

	Non-parametric Methods					
Genotypes	$\bar{X}$	$S_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$	**RS**	**TOP**
G1	1429.0	11.55	9.71	2.85	13	12.5
G2	1446.5	11.12	12.30	3.38	13	25.0
G3	1521.8	14.26	17.42	4.28	14	37.5
G4	1472.8	14.12	15.33	3.92	13	37.5
G5	1490.3	10.28	17.05	4.68	11	37.5
G6	1382.5	12.78	8.32	2.71	19	12.5
G7	1450.0	5.71	4.06	1.86	9	0.0
G8	1429.6	12.55	10.05	2.99	13	25.0
G9	1520.3	2.28	3.33	1.90	5	25.0
G10	1605.0	9.71	7.88	2.94	10	25.0
G11	1592.1	18.98	31.10	6.97	12	62.5

KEY: $\bar{X}$= seed yield (kg ha^{-1}); $S_i^{(2)}$= genotype between ranks variance over n environments (Huehn, 1990); $S_i^{(3)}$= sum of the absolute deviations of the squares of ranks for each genotype (Nassar and Huehn, 1987); $S_i^{(6)}$= the sum of squares of ranks for each genotype relative to the mean of ranks (Nassar and Huehn, 1987); RS= rank sum (Kang, 1988); TOP= number of sites at which the genotype occurred in the top third of the ranks (Fox et al., 1990)

According to Kang (1988) if the RS of a genotype is low, the stability of that genotype is high. The genotypes with low RS values were G9, G7 and G10 respectively, while the genotypes with high RS values were G6 and G3 (Table 5).In accordance with these values, the genotypes G9 and G7 were found to be the most stable genotypes.

To reveal the stabilities of genotypes, Fox et al. (1990) suggested the TOP stability analysis, which is a non-parametric stability analysis obtained with the rate of inclusion in the top three ranks in each environment according to the performance rankings (from the highest) of the genotypes that were tried in various environments. The genotypes with TOP values near 100 are the genotypes with the highest stabilities. While the genotypes with the highest TOP values were G11; the genotypes with the lowest TOP values were G7 genotype (Table 6). In accordance with these values, the genotype G11was found to be the most stable genotypes.

Relationship between parametric and non-parametric methods conclusions

The rank correlations between seed yield and stability methods are given in Table 7. Seed yield is significantly correlated with TOP (P<0.05) and showed a negative and significant correlation with P_i (P<0.01). W_i^2 is significantly correlated with S_{di}^2, σ_i^2 (P<0.01) and with the methods of $S_i^{(2)}$,$S_i^{(3)}$, $S_i^{(6)}$, TOP (P<0.05). and showed a negative and significant correlation with r_i^2 (P<0.01). The b_i is significantly correlated with B_i, r_i^2, S_{xi}^2, CV_i, (P<0.01). S_{di}^2 is significantly correlated with σ_i^2, $S_i^{(2)}$ (P<0.01) and with the methods of $S_i^{(3)}$, $S_i^{(6)}$, (P<0.05) and showed a negative and significant correlation with r_i^2 (P<0.01). The B_i is significantly correlated with r_i^2, S_{xi}^2, CV_i (P<0.01). σ_i^2 is significantly correlated with $S_i^{(2)}$,$S_i^{(3)}$, $S_i^{(6)}$,TOP, (P<0.05), and showed a negative and significant correlation with r_i^2 (P<0.01). S_{xi}^2 is significantly correlated with CV_i (P<0.01) and with the methods of $S_i^{(3)}$, $S_i^{(6)}$, TOP, (P<0.05). P_i is significantly correlated with RS, (P<0.05). $S_i^{(2)}$ is significantly correlated with $S_i^{(3)}$, $S_i^{(6)}$, (P<0.01) and with the methods of RS and TOP (P<0.05). $S_i^{(3)}$ is significantly correlated with, $S_i^{(6)}$ and TOP (P<0.01). $S_i^{(6)}$ is significantly correlated with TOP (P<0.01).

Table 7. Spearman's (1910) rank correlation coefficients between the different parametric and nonparametric stability parameters for seed yield of 11 winter rapeseed genotypes

	$\bar{X}$	W_i^2	b_i	S_{di}^2	B_i	σ_i^2	r_i^2	S_{xi}^2	CV_i	P_i	$S_i^{(2)}$	$S_i^{(3)}$	$S_i^{(6)}$	RS
W_i^2	0.38													
b_i	0.24	-0.38												
S_{di}^2	0.38	0.96**	-0.22											
B_i	0.24	-0.38	1.00**	-0.22										
σ_i^2	0.38	1.00**	-0.38	0.96**	-0.38									
r_i^2	-0.09	-0.86**	0.76**	-0.76**	0.76**	-0.86**								
S_{xi}^2	0.52	0.28	0.77**	0.42	0.77**	0.28	0.19							
CV_i	0.25	0.16	0.78**	0.36	0.78**	0.16	0.25	0.93**						
P_i	-0.88**	-0.07	-0.21	-0.04	-0.21	-0.07	-0.08	-0.27	-0.02					
$S_i^{(2)}$	0.11	0.70*	0.05	0.74**	0.05	0.70*	-0.45	0.54	0.48	0.18				
$S_i^{(3)}$	0.42	0.67*	0.16	0.66*	0.16	0.67*	-0.40	0.63*	0.46	-0.14	0.83**			
$S_i^{(6)}$	0.48	0.65*	0.21	0.65*	0.21	0.65*	-0.36	0.67*	0.49	-0.19	0.80**	0.99**		
RS	-0.49	0.42	-0.25	0.48	-0.25	0.42	-0.40	0.02	0.15	0.72*	0.68*	0.26	0.22	
TOP	0.62*	0.60*	0.19	0.60	0.19	0.60*	-0.35	0.61*	0.41	-0.36	0.63*	0.89**	0.90**	0.00

*: P<0.05 at significance; **: P<0.01 at significance

CONCLUSION

This study has provided the evaluation of the GEI in terms of seed yield of different winter rapeseed genotypes under the ecological conditions of the Thrace region. For this, stability of genotypes was examined using different 9 parametric and 5 non-parametric stability analysis methods. Genotip, environment and GEI played a significant role in terms of seed yield in this study. When considering the mean seed yields of the genotypes over the environments, it was determined that genotypes G10, G11, G3, G9 and G5 had the highest seed yield whereas the lowest seed yield was obtained from G6, G1 and G8 genotypes. According to parametric stability measures (W_i^2, b_i, S_{di}^2, B_i, σ_i^2, r_i^2, S_{xi}^2, CV_i, and P_i) G9, G6 and G1 genotypes were determined to be stable genotypes. According to non-parametric stability measures ($S_i^{(2)}$, $S_i^{(3)}$, $S_i^{(6)}$, RS and TOP) G9, G6 and G11 genotypes were determined to be stable genotypes. Genotype G9 was demonstrated superior adaptability with high yield performance in many environments. G9 genotype would be suggested for cultivation under changing environmental conditions.

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