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Multi-Environment Test for Stability and Adaptability Using Line X Tester Crossing Design in Maize

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ABSTRACT

Stability and adaptability are two main Characteristics that affect most field crops' growth and yield. maize is mainly affected and highly sensitive to environmental conditions. Therefore, the present study aimed to evaluate the stability and adaptability of maize crop genotypes for some agronomic traits related to kernel yield under four different environmental conditions. The field experiments consisted of 9 parents and 20 maize hybrids and were evaluated in randomized block design during the autumn and spring seasons at each location of Kalar and Khanaqeen. Genetic analysis of stability and adaptability according to the methodology of Eberhart and Russel regression coefficient (bi) and Elsahookie, and Al-Rawi genotypic resultant (GR) were performed based on the average of all environments. Results indicated that the cross HS x 844 was stable and showed maximum value of genotypic resultant to kernel yield according to ElSahookie and Al-Rawi, while the crosses 4218 x zp-595, zp-430 x zp-595 and HS x sym-5 were adaptable for this trait according to Eberhart and Russell.

Keywords: Maize, Stability and adaptability, Kernel yield, Crop breeding.

1. Introduction

Maize (***Zea mays*** L.) is currently grown worldwide, estimated at 563 of the 717 million metric tons of maize kernel yield annually produced, with the top three producers being the United States, China, and Brazil. It provides about 365 Kcal/100 g of energy with about 72% starch, 10% protein, and 4% fat. Various food and industrial products, such as sweeteners, starches, oils, glue, beverages, fuel ethanol, and industrial alcohol, can be made from maize. For the last decade, maize has increasingly been used as a biofuel, accounting for 40% of the country's maize production. Therefore, there is currently a high demand for corn foods due to the Low cost and richness of micronutrients which make this food ideal and essential[1]. Over time, new definitions and justifications for concepts like "phenotypic stability" and "adaptation" have been proposed[2, 3]. Before the commercial release of superior hybrids, the multi-environment test (MET) is a crucial step in the hybrid selection process. To select stable hybrids for a general environment or adaptive hybrids for a particular environment, MET is used to analyze the interaction of the hybrid x environment (G x E)[4]. In the face of climate change, agricultural adaptation is essential for sustainable farming. Future trends in food production can be predicted by utilizing projected climate data and crop modeling techniques, and more effective adaptation measures can be evaluated[5]. According to Becker and Leon's definition of a static mean of stability, a stable genotype is one that consistently performs regardless of changes in the environmental variables[3]. Environments and seasons are described as a single factor for environmental conditions in the roles of various circumstances[6]. In addition to environmental changes, a variety of genetic factors have a significant impact on yield[7, 8]. The degree of correlation between various stability parameters indicates whether one or more of the parameters should be used to predict cultivar performance[9]. A linear combination of deviation mean squares is called stability variance[10]. A large genotype x environment interaction for a quantitative trait like yield can severely undermine efforts to choose superior genotypes for both new crop production and the creation of enhanced varieties or cultivars[11]. The regression approach, which is frequently used in plant breeding for the

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selection of stable genotypes or of crucial value in creating superior varieties, is one biometrical method for determining the stability concept[12]. The basis of the principle of trait stability is the genotype x environment interaction (GEI) and its impact on the predictability of future genotype performance. The main effect model's ability to predict outcomes is decreased in trials where there are significant GEI effects. The biggest challenge for breeders is demonstrating that any cultivar is superior[13, 14]. The aim of this study was to determine the best genotype with a high performance of stability and adaptability under multi-environment conditions.

2. Materials and Methods

2.1 Experimental design and plant material

In this experiment, nine maize lines (4218, Zp430, HS, Po-5, 844, 3078, SYM-5, ZP-595, and DKcc) were crossed by Line X Tester mating design to produce twenty F1s progenies at Kalar Crop Research Center during the spring season of 2020 (Table 1). The study was carried out at two separate research locations (Kalar and Khanaqeen), which represent various agricultural environments and, respectively, one that depends on groundwater and the other on surface water. The areas are described as having a semi-arid climate and little winter rainfall[15, 16], and a Hyperthermic temperature regime[17]. The experiment was carried out at each site using a randomized complete block design (RCBD) with three replications in the autumn of 2020 and the spring of 2021. Hills were overplanted and thinned after emergence for a final plant density of about 53333.33 plants per hectare. Each genotype was planted in one raw 0.75m inter-row spacing and 0.25m Intra row spacing in all locations and seasons. All agronomic practices were followed according to recommendations for maize cropping at each site and season.

2.2 Plant measurement:

The data was recorded for:

1- Days to 50% tasseling (DTT): the number of days from planting to that time when 50% of plants in a plot had fully emerged tassels that were shedding pollen.
2- Days to 50% silking (DTS): the number of days from planting to that time when 50% of plants in a plot had fully emerged silks.
3- Number of ear per plant (NEPP): number of ear per plant was counted, and the average was recorded
4- Plant height (PH cm): Refers to the tallness of plants, the distance from soil level to the tip of the plant measured from the hard dough stage till physiological maturity; was recorded in centimeters (cm).
5- Ear height (EH cm): the distance from soil level to the insertion of the top ear in centimeters, was recorded.
6- Ear length (EL cm): the average length of an ear, and was recorded in centimeters (cm).
7- Number of kernels per row (NKPR): number of kernels per row are the average number of kernel rows on an ear; was recorded.
8- Number of rows per ear (NRPE); number of rows per ear is the average of kernels in a row on the ear; the average was recorded.
9- Three hundred kernel weight (3HKW g): it was determined by weighing a random sample of 300 kernels, which was recorded in grams (g).
10- Kernel yield ton/hectare (*Mg*): In all experiments, all ears were collected from each plot once they reached physiological maturity. After that, straw and ears were separated from the collected materials. After drying for 48 hours at 73 °C, the ears were threshed, and kernel yield was measured, weighed, and recorded for each plot based on a 15% moisture content.

2.3 Statistical analysis

In this study, analysis of variance for all sites and seasons was performed for all parameters followed by genetic analysis of stability and adaptability according to the methodology of the regression coefficient (bi)[18], genotypic resultant (GR)[19], and using R-Studio software[20]. The polt model of Eberhart and Russel analysis for stability and adaptability is divided into four parts as shown in figures 1, 2, and 3; the top left part denotes high yield and low stability, the top right part denotes high yield and high stability, bottom left part denotes to low yield and low stability, and bottom right part denotes to low yield and high stability.

Table 1: Studied Breeding Materials (Lines X Tester).

Parent No.	Lines	Sources
1	4218	Salahaddin University
2	ZP-430	Duhok University
3	HS	Duhok University
4	PO-5	Duhok University
	Testers	
5	844	Salahaddin University
6	3078	Salahaddin University
7	SYM-5	Duhok University
8	ZP-595	Duhok University
9	DKcc	Duhok University
Crosses No.	**Crosses**	***Parentage***
1	1 x 5	4218 x 844
2	1 x 6	4218 x 3078
3	1 x 7	4218 x SYM-5
4	1 x 8	4218 x ZP-595
5	1 x 9	4218 x DKcc
6	2 x 5	ZP-430 x 844
7	2 x 6	ZP-430 x 3078
8	2 x 7	ZP-430 x SYM-5
9	2 x 8	ZP-430 x ZP-595
10	2 x 9	ZP-430 x DKcc
11	3 x 5	HS x 844
12	3 x 6	HS x 3078
13	3 x 7	HS x SYM-5
14	3 x 8	HS x ZP-595
15	3 x 9	HS x DKcc
16	4 x 5	PO-5 x 844
17	4 x 6	PO-5 x 3078
18	4 x 7	PO-5 x SYM-5
19	4 x 8	PO-5 x ZP-595
20	4 x 9	PO-5 x DKcc

3. Results and Discussion

Maize has demonstrated a high sensitivity to environmental change[21]. Data in table 2, and figure 1, explain the stability and adaptability in accordance with Eberhart and Russell, in the way line x tester. It was revealed that the genotype possesses a high mean along regression coefficient more than unity (bi>1) and the mean deviates from the regression close to zero (S^2di=0) can be specifically adapted to favorable environments. Furthermore, the genotypes with a high mean, regression coefficient less than unity (bi<1) and deviating from regression close to zero (S^2di=0) can be specifically adapted to poor environmental conditions[18]. Superior hybrids have a high yield of hybrid performance in a given environment by being able to minimize the impact of any negative environmental factors while maximizing the impact of any positive environmental factors[22]. The first form According to to cross 2 x 9 was adaptable for DTT with the mean value of 61.4 days, bi=1.08 and S2di=0.16 with the parent 4 with the mean of 72.5, bi=0.99 and S^2di=-3.47 and the parent 8 with the mean 64.3, bi=0.98 and S^2di=-2.80. Moreover, DTS, cross 3 x 8 with bi=1.09 and S^2di=-5.32, with a mean value of 63.7 days was found to be stable for this trait, the same for cross 3 x 9, recording 61.3 days, with bi=1.03, and S2di=-5.34, and the cross 4 x 9 with the mean 67.3, bi=1.01, and S^2d=-5.45, and the parent 1 was adaptable for DTS with the mean value of 71.4 days, bi=1.19 and S^2di=3.88. although, concerning to the character NEPP crosses 1 x 6 with the mean value of 1.58, bi=2.01 and S^2di=-0.02, and the cross p4p9 with the mean value of 1.36, bi=1.51 and S^2di=-0.00, and parent 2 and 8 with the means value 1.50, 1.32; bi=2.27,1.22; S^2d=0.00, 0.00 respectively were adaptable, but the parents 5 and 6 with the means value of 1.4, 1.0; bi=1.51, 0.0 and S2di= -0.03, 0.03 respectively were stabled. Regarding the character PH, it was found that the crosses 2 x 5, 2 x 8, 2 x 9, 3 x 6, and 4 x 9 were adaptable recording 1563.6, 1.20, and 4.0, and 160.2, 1.4, and -38.4, and 177.2, 1.24 and -9.9, and 161.8, 1.45, and -10.7, and 162.8, 1.45, and 66.1 for their means, bi and S2di respectively. But the crosses 3 x 7 and 3 x 8 with the means value of 158.4, 158.2; bi=0.82, 0.99 and S^2di= -50.8, -48.8 respectively were stabled.

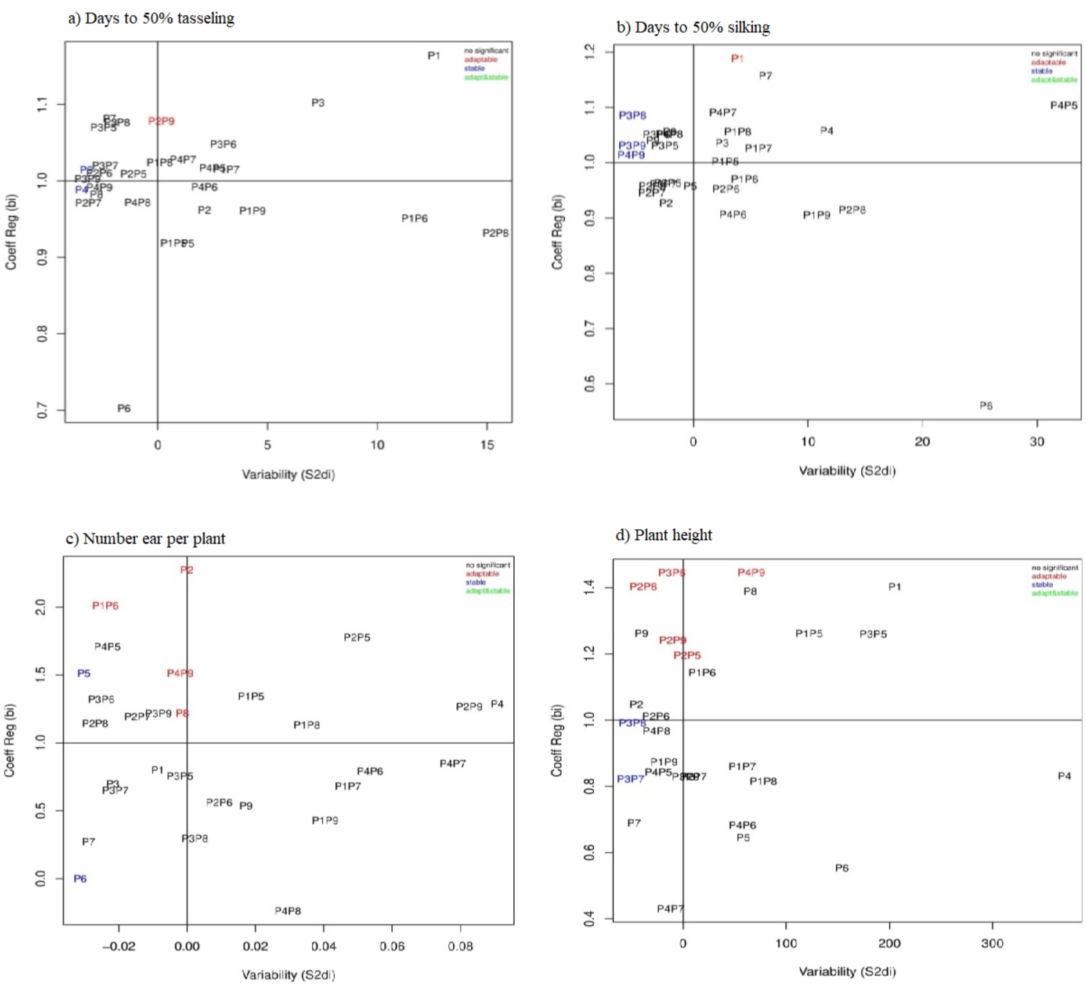

Figure 1: Stability and adaptability analysis based on Eberhart and Russell plot model for 29 genotypes across all sites and seasons.

Data in table 2, and figure 2, it is shown illustrates EH, was found that parent 1, 8, 9, and crosses 1 x 9, 2 x 8, 2 x 9, and 3 x 9 were adaptable recording (69.00, 1.22, 0.27), (55.83, 1.51), (-12.93), (55.4, 1.17 and 1.27), (64.56, 1.24, and -2.91), (57.47, 1.38, and 11.11), (65.40, 1.38, and 6.16), (50.79, 1.18), and (-0.94) for their means, bi and S^2di, respectively. Some hybrids were shown to have regression coefficients b2 that were significantly different from zero, suggesting behavior that is better captured by the bit segmented model of[23]. The use of Eberhart and Russell's simple linear regression model would be sufficient for the other hybrids,

Table (2): The method of Eberhart and Russell for Line x Tester.

	Not.		stible			adaptable																								
	DTT			DTS			NEPP			PH			EH			EL			NKPR			NRPE			3HKW			KY		
		E.&R.			E.&R.			E.&R.			E.&R.			E.&R.			E.&R.			E.&R.			E.&R.			E.&R.			E.&R.	
GEN	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
P1	68.2	1.16	12.60	71.4	1.19	3.88	1.49	0.80	-0.01	164.4	1.40	205.5	69.00	1.22	0.27	19.86	1.29	-1.03	38.9	1.32	-7.13	14.22	0.74	0.18	66.26	0.78	-26.11	2.16	0.57	2.96
P1P5	65.7	0.92	0.72	68.0	1.00	2.77	1.36	1.34	0.02	169.9	1.26	122.1	59.76	1.13	-5.50	19.33	1.47	-0.58	40.6	0.70	4.06	15.00	0.36	0.74	64.92	0.80	8.89	4.41	1.62	1.38
P1P6	66.7	0.95	11.69	69.1	0.97	4.47	1.58	2.01	-0.02	167.4	1.14	18.5	68.18	0.96	26.38	21.17	0.71	-0.78	40.9	0.02	-4.79	14.44	0.25	-0.40	80.03	1.01	8.70	3.14	1.18	1.54
P1P7	67.0	1.01	3.12	68.1	1.03	5.68	1.37	0.68	0.05	163.9	0.86	57.3	60.22	0.74	12.52	20.00	0.83	0.58	41.9	-0.49	-3.13	14.78	0.16	1.14	77.89	0.57	62.42	4.13	1.38	2.42
P1P8	64.8	1.02	0.08	66.8	1.06	3.86	1.52	1.13	0.04	165.3	0.82	77.8	63.44	1.00	-7.75	19.06	0.64	-0.23	40.1	-0.44	-1.59	14.00	0.75	4.62	70.87	0.81	-4.45	5.19	1.50	-0.35
P1P9	68.4	0.96	4.31	72.1	0.91	10.76	1.24	0.43	0.04	161.9	0.87	-18.5	64.56	1.24	-2.91	19.06	0.46	0.08	38.6	0.29	-5.92	13.94	0.22	0.47	61.24	-0.09	-46.95	2.24	0.48	1.57
P2	62.4	0.96	2.12	66.0	0.93	-2.41	1.50	2.27	0.00	131.5	1.05	-45.1	47.39	1.02	-9.37	18.78	1.23	-0.74	39.5	1.15	-6.57	14.44	1.74	0.07	68.84	1.09	1.42	3.25	1.10	0.91
P2P5	63.7	1.01	-1.11	66.1	0.96	-2.25	1.42	1.78	0.05	153.6	1.20	4.0	64.86	0.95	49.45	21.14	1.12	4.13	43.7	2.10	-2.51	14.50	1.08	-0.38	78.80	1.02	-30.66	4.65	1.34	-0.53
P2P6	64.5	1.01	-2.67	67.5	0.95	2.83	1.36	0.56	0.01	162.5	1.01	-26.5	67.94	1.14	69.94	21.44	0.86	-0.54	42.2	0.97	-3.47	14.50	0.81	0.42	74.77	1.08	-30.52	3.73	0.80	2.62
P2P7	62.2	0.97	-3.17	65.7	0.95	-3.65	1.66	1.19	-0.01	162.4	0.83	9.9	61.22	0.80	-7.06	20.92	0.30	-1.34	42.8	0.06	-2.95	15.44	0.85	0.64	79.94	1.07	-21.04	5.91	1.29	6.12
P2P8	64.3	0.93	15.39	66.3	0.91	13.87	1.33	1.14	-0.03	160.2	1.40	-38.4	57.47	1.38	11.11	18.94	1.45	0.35	40.1	0.83	26.14	14.45	1.64	-0.41	67.79	1.66	-32.10	4.72	1.91	0.61
P2P9	61.4	1.08	0.16	64.8	0.96	-3.60	1.44	1.27	0.08	177.2	1.24	-9.9	65.40	1.38	6.16	21.81	1.25	0.16	44.7	1.03	2.71	14.17	0.71	-0.41	74.95	0.94	19.25	5.25	1.15	2.02
P3	62.1	1.10	7.30	65.6	1.04	2.50	1.24	0.70	-0.02	129.2	0.83	5.2	38.87	0.72	-15.91	16.06	0.84	0.75	32.2	1.21	27.10	14.44	2.39	-0.12	76.16	2.07	49.39	2.06	0.42	-0.38
P3P5	60.6	1.07	-2.48	62.6	1.03	-2.50	1.32	0.75	0.00	151.5	1.26	184.1	56.85	1.12	27.94	20.36	0.94	-0.92	41.3	0.77	-4.33	15.56	1.01	-0.26	84.78	1.39	96.27	5.59	0.71	1.94
P3P6	64.5	1.05	2.98	67.0	1.05	-3.23	1.41	1.32	-0.03	161.8	1.45	-10.7	58.47	1.32	-13.12	17.83	1.74	1.07	34.8	1.27	3.71	13.83	1.22	0.44	76.05	2.23	128.92	3.76	1.17	2.19
P3P7	61.1	1.02	-2.40	63.6	0.96	-2.64	1.22	0.65	-0.02	158.4	0.82	-50.8	53.88	0.95	-2.60	18.67	0.37	16.17	33.6	0.67	-6.16	15.56	1.30	-0.21	84.57	1.00	46.93	4.84	1.28	-0.04
P3P8	60.9	1.08	-1.86	63.7	1.09	-5.32	1.08	0.30	0.00	158.2	0.99	-48.8	58.86	0.78	47.14	18.61	0.79	-1.06	38.9	0.47	0.86	14.78	1.67	1.15	75.66	1.17	89.46	4.09	0.80	-0.48
P3P9	59.3	1.00	-3.21	61.3	1.03	-5.34	1.33	1.22	-0.01	157.4	0.83	2.4	50.79	1.18	-0.94	20.22	0.85	1.07	40.3	1.70	-5.80	14.39	1.44	-0.03	86.64	1.15	431.00	5.71	1.27	1.30
P4	72.5	0.99	-3.47	78.5	1.06	11.63	1.25	1.29	0.09	136.7	0.83	369.5	46.50	1.13	127.6	17.57	0.73	0.26	37.5	0.49	29.19	15.44	0.40	0.44	43.71	1.37	104.69	1.31	0.70	0.64
P4P5	66.0	1.02	2.48	66.4	1.10	32.33	1.41	1.71	-0.02	155.9	0.84	-23.8	55.44	0.58	12.75	20.97	1.37	-0.46	40.7	1.30	5.18	15.67	1.36	-0.35	77.54	0.79	-11.93	4.69	1.13	5.51
P4P6	65.3	0.99	2.12	68.4	0.91	3.44	1.67	0.79	0.05	158.0	0.68	57.5	51.26	0.56	66.73	20.58	0.94	-0.88	41.5	2.23	-5.04	14.56	0.54	2.62	76.01	0.60	50.78	2.18	0.86	-0.07
P4P7	71.6	1.03	1.14	74.0	1.09	2.56	1.22	0.85	0.08	154.6	0.43	-12.0	45.33	0.43	69.96	18.29	0.68	0.37	34.9	1.72	11.60	14.53	0.76	0.27	67.66	0.24	150.09	2.08	0.54	0.69
P4P8	67.9	0.97	-0.92	70.7	1.05	-2.10	1.40	-0.24	0.03	157.3	0.97	-25.8	50.29	1.08	19.07	18.85	1.11	-0.04	40.0	0.87	8.71	14.95	1.01	1.34	60.92	0.87	-11.76	2.89	1.00	-0.17
P4P9	64.8	0.99	-2.67	67.3	1.01	-5.45	1.36	1.51	0.00	162.8	1.45	66.1	51.21	0.86	16.95	19.36	0.89	3.12	39.8	1.54	1.45	14.78	0.60	-0.32	66.64	1.01	-27.62	3.69	1.18	0.16
P5	67.0	0.92	1.37	70.2	0.96	-0.29	1.40	1.51	-0.03	131.3	0.64	58.2	56.86	0.72	39.56	18.00	1.41	18.40	37.1	3.08	36.28	15.44	1.09	-0.30	55.61	0.97	-45.82	2.02	0.66	-0.58
P6	73.5	0.70	-1.54	78.3	0.56	25.53	1.00	0.00	-0.03	125.7	0.55	154.1	52.38	1.03	50.83	14.37	0.98	2.61	32.5	1.84	9.99	13.14	1.11	-0.25	35.22	-1.50	66.61	0.31	-0.03	-0.44
P7	70.3	1.08	-2.20	73.7	1.16	6.29	1.22	0.27	-0.03	142.7	0.69	-47.4	54.47	0.90	29.64	14.21	1.20	-0.33	28.0	0.20	-6.82	13.56	0.88	-0.09	66.17	1.61	-44.65	2.11	1.09	0.78
P8	64.3	0.98	-2.80	66.8	1.06	-2.08	1.32	1.22	0.00	147.6	1.39	64.9	55.83	1.51	-12.93	15.97	0.93	-1.28	32.0	0.70	-5.48	13.89	2.01	-0.20	60.70	1.77	21.90	2.85	0.67	-0.43
P9	66.7	1.01	-3.26	68.3	1.04	-3.56	1.32	0.54	0.02	157.9	1.26	-40.5	55.40	1.17	1.27	17.31	1.61	-0.61	35.9	1.41	9.31	14.89	0.90	-0.13	62.85	1.53	-46.63	2.97	1.25	-0.43

for which this hypothesis was not disproved, to explain how the hybrids behaved in the various environments[24]. Concentrating to the character EL cross 2 x 8 with the mean value of 18.94, bi=1.45 and S^2di=0.35,and the cross 2 x 9 with the mean value of 21.81, bi=1.25, and S2di=-0.16, and cross 3 x 6 with the mean 17.83,bi=1.74, and S^2di=1.07, and parent 9 with the mean value 17.31, bi=1.61, and S^2d=-0.61 were adaptable, but the cross 2 x 7 with the means value of 20.92,bi=0.30, and S^2di= -1.34 was stable. As is revealed by NKPR that crosses 2 x 5 and 4 x 6 were adaptable for NKPR recording the means value of 43.7, 41.5; bi=2.10, 2.23, and S^2di= -2.51,-5.04 respectively, but parents 1 and 7 with the means value of 38.9, 28.0, bi=1.32, 0.20, and S^2di= -7.13, -6.82 were respectively stable. NRPE explains the stability and adaptability of NRPE for parents 2, 3, and 8 were found to be adaptable, recording mean value of 14.44, 14.44 and 13.89 rows with bi= 1.74, 2.39, 2.01, and S^2di=-0,07, -0.12, -0.20 respectively, the same for the cross 3 x 9 with mean value of 14.39, bi= 1.44 and S^2di= -0.03, moreover crosses 1 x 6, 2 x 8, and 2 x 9 with the means value of 14.44, 14.45, and 14.17; bi=0.25, 1.64, and 0.71, and S^2di= -0.40, -0.41, and -0.41 respectively were stable.

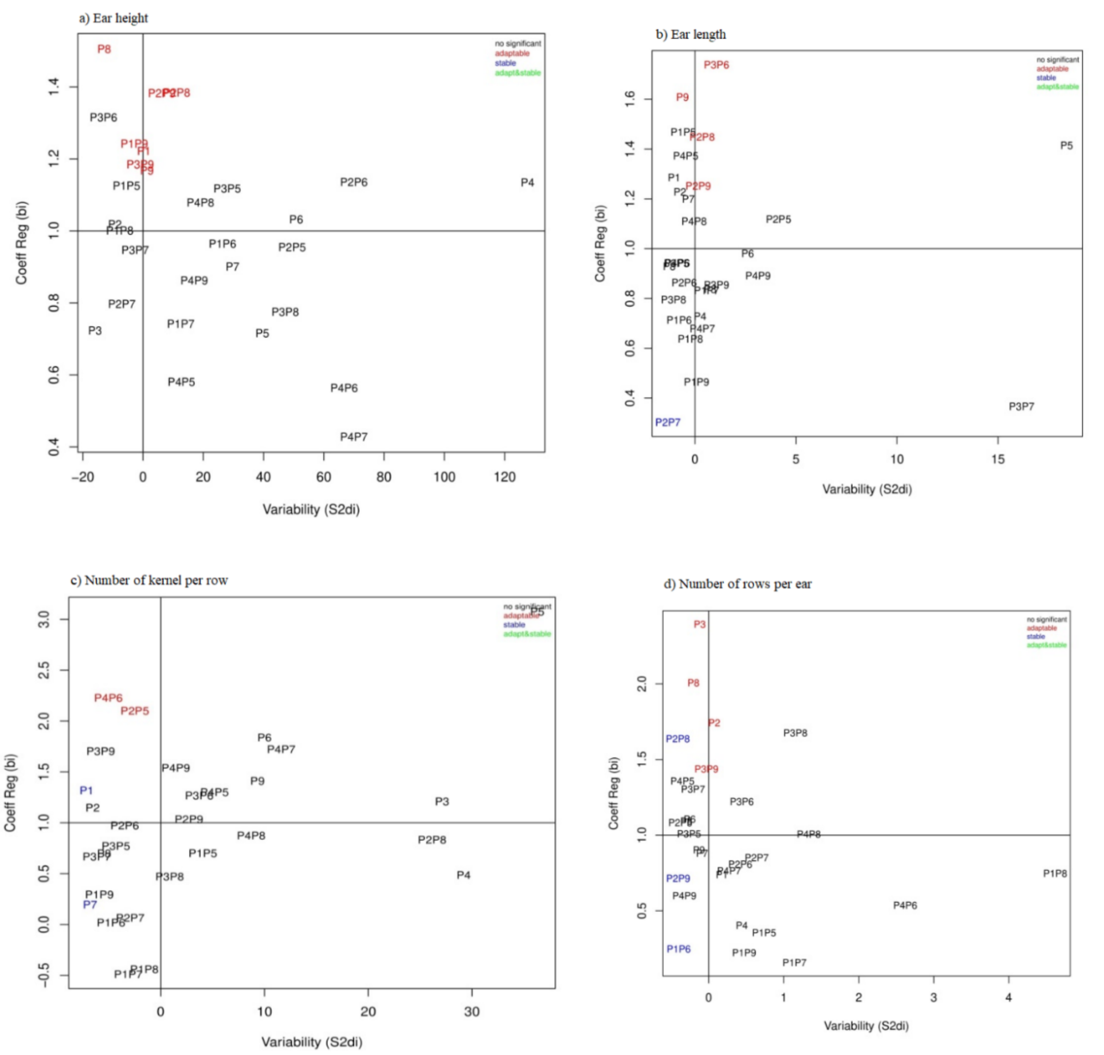

Figure 2: Stability and adaptability analysis based on Eberhart and Russell plot model for 29 genotypes across all sites and seasons.

According to[16], each variety has a unique resistance, so some plants can adapt to their environment quickly while others take a long time. Each variety possesses a unique genetic potential for reacting to its environment. The various characteristics that a plant exhibits can also result from the environment. Although a variety is capable of producing high yields, it will not reach its full potential if the environmental conditions are unfavorable. The yield factors, particularly the number of seeds per cob and the weight of 1000 grains, have a greater impact on the weight of dry grain yield per unit area of corn[25]. The stability of genotypes in table 2, and figure3, due to 3HKW present in the cross 1 x 9, and parents 5, 7, 9 were stable, showing the means value of 61.25, 55.61, 66.17, and 62.85g, with bi=-0.09, 0.97, 1.61, and 1.53, and S^2di= -46.95, -45.82, -44.65, and -46.63 respectively, but the cross 2 x 8, and parents 3, 8 were adaptable, showing the means value of 67.79, 76.16, and 60.70g, with bi=1.66, 2.07 and 1.77, and S2di= --32.10, 49.39, and 21.90 respectively. All hybrids studied in each year and station had significantly different grain yields, according to genotype data on grain yield. Additionally, the combined analysis's findings indicated a sizable impact on the environment[26]. The performance of KY. genotypes across different environment due to kernel yield for adaptability and stability present the parent 5 was found to be stable, recording the mean value 2.02 t/h with bi= 0.66, and S2di= -0.58, while the crosses 1 x 4, 2 x 8, and 3 x 7 was found to be adaptable, recording the mean value 5.16 t/h bi= 1.50, S^2di=-0.35, 4.72 t/h bi= 1.91, S^2di=0.61, and 4.84 t/h, bi=1.28, S^2di=-0.04 respectively. Several previous studies reported significant differences among genotypes for grain yield, and yield-related traits in different sets of maize genotypes[9, 27-29]. Indicative of whether one or more estimates should be obtained for accurate predictions of cultivar behavior is the degree of association among adaptability or stability estimates of various models. This association also aids the breeder in selecting the best-adjusted and most informative stability parameter(s) to fit his concept of stability[9]. They revealed that some maize genotypes had variable yields in addition to the emergence of some relatively stable genotypes. As a result, the environment will always have an impact on maize yields[28]. Data in table (3) explain the stability and adaptability as stated by Elsahookie and Al-Rawi. One of the most crucial aspects of researching genotypes grown in various environments is yield and other quantitative traits of crop plants. It is crucial to distinguish the genotype with the best performance and environmental stability[19]. In the way line X Tester. According to the DTT parent, 6 was found to be stable and showed maximum value for stability and genotypic resultant recording 86.812 and 0.975 respectively. Furthermore, DTS parent 6 exhibited maximum value for stability (H), and genotypic resultant reached (88.429 and 1.016) respectively. While NEPP parent 6 and, cross 4 x 6 give maximum values for stability and genotypic resultant reached 100.0% and 1.001 respectively. While according to PH the cross 4 x 7 and, cross 2 x 9 give maximum values for stability and genotypic resultant reached 92.337% and 0.943 respectively. Likewise EH the cross 4 x 5 recorded the best value for stability and cross 1 x 6 recorded the best value for genotypic resultant reaching 84.906% and 0.976 respectively. Consequently, the EL, cross 2 x 7 produced maximum values for stability reached 96.861% and the genotypic resultant reached 1.071. The NKPR parent 7 gave the highest values for stability, and cross 2 x 9 gave the highest values for genotypic resultant reaching 97.501% and 1.07 respectively. In the same way, the NRPE revealed that cross 1 x 6 possesses the highest values for stability and cross 3 x 5 possesses the highest values for genotypic resultant reaching 98.224% and 1.002 respectively. In addition, the 3HKW highest values for stability and genotypic results according to the crosses 1 x 9 and, 3 x 7 reached 97.895% and 1.014 respectively. In terms of grain yield, hybrids were found to be significant (P<0.01). Significant (P<0.01) interactions between genotype and environment (G x E) effects on grain yield were also discovered[30]. Similarly, the KY cross 3 x 5 produced the highest stability, and genotypic resultant reached 64.957% and 1.033 respectively. Adaptability to a poor environment due to high mean performance and the value of regression coefficient has been reported in the literature. Several previous studies reported significant differences among genotypes for grain yield, and yield-related traits in different sets of maize genotypes [31-33].

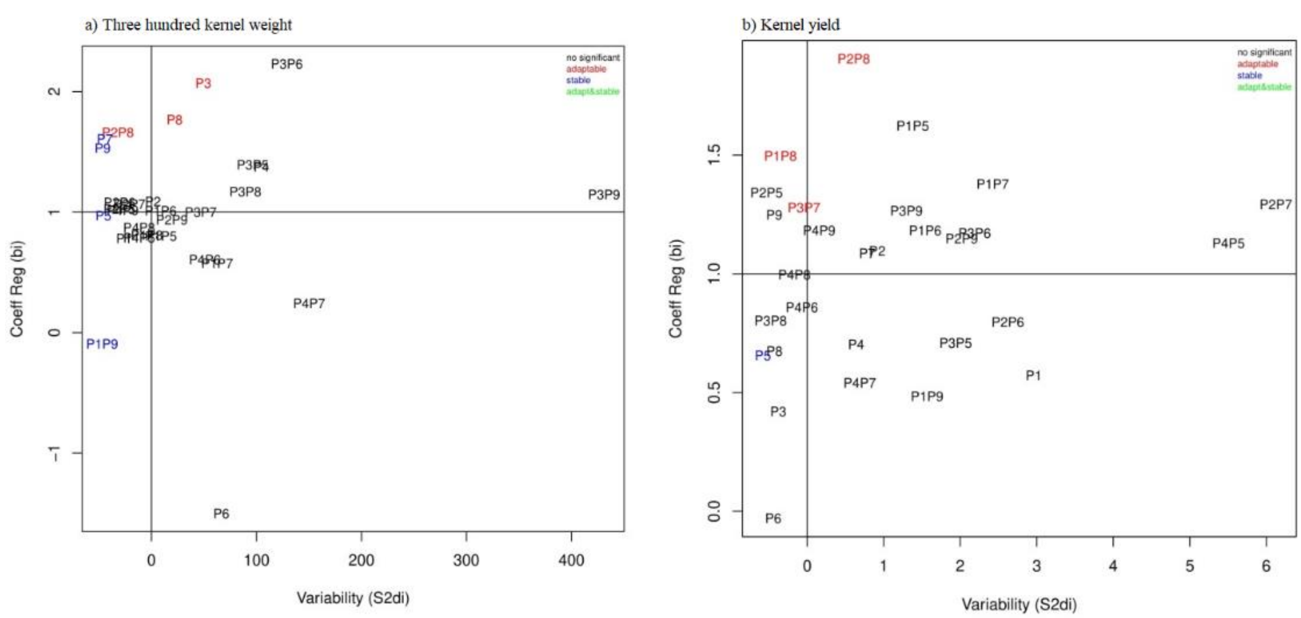

Figure 3: Stability and adaptability analysis based on Eberhart and Russell plot model for 29 genotypes across all sites and seasons. (**Not: Top-lift** quarter= high yield, and low stability.

Table (3): The method of ElSahookie and Al-Rawi (2011) for Line x Tester.

	DTT		DTS		NEPP		PH		EH		EL		NKPR		NRPE		3HKW		KY	
G.	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**	**H%**	**GR**
1 X 5	80.662	0.810	79.095	0.789	71.891	0.717	80.506	0.884	76.612	0.809	83.956	0.858	92.111	0.972	93.773	0.964	83.100	0.773	19.634	0.246
1 X 6	79.880	0.814	79.999	0.810	67.886	0.786	82.557	0.893	81.052	0.976	92.448	1.034	96.886	1.032	98.224	0.972	83.740	0.961	13.282	0.119
1 X 7	79.006	0.809	78.538	0.784	79.299	0.802	85.979	0.911	83.276	0.886	89.706	0.948	95.191	1.037	93.000	0.942	86.179	0.962	22.998	0.270
1 X 8	78.198	0.774	77.582	0.760	76.849	0.859	86.526	0.924	80.396	0.901	91.720	0.924	94.501	0.985	86.102	0.826	85.005	0.864	39.854	0.588
1 X 9	80.469	0.841	81.848	0.865	80.417	0.734	86.297	0.903	76.104	0.868	92.772	0.934	96.986	0.974	94.273	0.901	97.895	0.859	30.089	0.192
2 X 5	78.190	0.761	79.488	0.770	64.706	0.674	80.271	0.797	79.350	0.909	85.848	0.959	87.934	0.999	93.334	0.928	84.625	0.956	40.229	0.532
2 X 6	78.507	0.774	79.951	0.791	84.065	0.838	84.345	0.886	76.776	0.921	91.016	1.032	93.389	1.025	92.880	0.923	83.003	0.890	40.891	0.434
2 X 7	78.577	0.747	79.784	0.768	80.954	0.987	86.719	0.910	83.586	0.904	96.861	1.071	96.039	1.069	92.710	0.981	83.960	0.962	42.353	0.712
2 X 8	79.372	0.779	79.962	0.778	78.162	0.763	78.182	0.810	69.740	0.708	83.311	0.834	87.260	0.911	90.030	0.891	71.766	0.697	14.407	0.193
2 X 9	75.811	0.712	79.262	0.753	70.822	0.748	82.359	0.943	73.582	0.850	87.330	1.006	92.062	1.070	95.494	0.927	83.260	0.895	48.217	0.720
3 X 5	75.764	0.702	76.839	0.705	82.293	0.800	77.751	0.761	74.198	0.745	90.113	0.970	94.446	1.014	93.939	1.002	78.072	0.949	64.957	1.033
3 X 6	77.503	0.764	77.978	0.766	76.214	0.789	77.578	0.811	72.488	0.749	78.746	0.742	88.411	0.800	90.508	0.858	63.787	0.695	26.077	0.279
3 X 7	77.079	0.720	78.738	0.734	85.059	0.761	87.108	0.892	77.833	0.741	81.227	0.801	94.692	0.829	92.263	0.984	83.624	1.014	43.949	0.605
3 X 8	75.724	0.705	76.137	0.711	84.615	0.674	84.412	0.863	80.482	0.837	90.874	0.894	93.388	0.945	87.876	0.890	78.379	0.850	58.897	0.686
3 X 9	76.832	0.697	76.448	0.686	75.443	0.739	86.379	0.878	70.881	0.636	89.261	0.954	89.724	0.940	90.532	0.893	74.489	0.925	50.112	0.813
4 X 5	78.672	0.794	75.552	0.736	69.460	0.722	86.304	0.870	84.906	0.831	86.054	0.954	89.662	0.949	92.274	0.991	86.884	0.966	34.256	0.457
4 X 6	78.984	0.789	81.129	0.814	81.528	1.001	88.005	0.899	80.183	0.726	90.180	0.981	86.988	0.938	89.683	0.895	86.030	0.937	14.250	0.088
4 X 7	80.169	0.877	79.139	0.859	71.980	0.647	92.337	0.923	79.607	0.637	90.343	0.873	84.543	0.768	93.410	0.930	82.547	0.801	30.288	0.180
4 X 8	80.301	0.834	79.071	0.819	85.050	0.877	84.517	0.859	72.122	0.641	86.903	0.866	90.359	0.941	90.645	0.928	81.893	0.715	26.486	0.218
4 X 9	78.986	0.782	78.907	0.778	70.428	0.703	77.285	0.813	77.476	0.701	86.977	0.890	89.052	0.922	96.021	0.973	81.856	0.782	31.061	0.326
1	76.116	0.793	76.457	0.801	84.302	0.926	77.365	0.822	77.887	0.949	86.485	0.908	91.976	0.932	93.621	0.913	85.431	0.811	9.986	0.061
2	78.654	0.750	80.232	0.776	61.038	0.673	80.157	0.681	73.397	0.614	86.123	0.855	92.936	0.956	88.695	0.878	80.227	0.792	23.665	0.219
3	75.289	0.714	77.631	0.746	84.639	0.774	83.380	0.696	77.212	0.530	86.961	0.738	82.695	0.693	85.137	0.843	67.403	0.736	53.830	0.316
4	81.318	0.901	80.663	0.928	65.669	0.604	80.555	0.712	63.551	0.522	89.601	0.832	86.493	0.843	94.553	1.001	57.493	0.360	-30.45	-0.11
5	81.029	0.830	80.724	0.830	73.066	0.754	86.182	0.732	81.234	0.816	74.167	0.706	75.649	0.731	93.512	0.990	80.090	0.638	32.731	0.188
6	86.812	0.975	88.429	1.016	100.0	0.735	85.644	0.696	72.786	0.673	81.965	0.623	83.035	0.701	92.177	0.830	45.583	0.230	-7.517	-0.007
7	78.860	0.847	77.695	0.839	93.572	0.841	87.944	0.811	77.409	0.745	81.692	0.613	97.501	0.709	93.307	0.867	72.345	0.686	-15.53	-0.09
8	79.051	0.777	77.752	0.761	74.649	0.724	75.887	0.724	67.058	0.661	87.933	0.742	93.833	0.780	87.034	0.829	65.104	0.566	49.723	0.404
9	79.139	0.806	78.640	0.788	83.027	0.806	80.085	0.817	73.581	0.720	80.481	0.736	86.897	0.811	93.907	0.958	72.329	0.652	12.391	0.105

Conclusion

The aim of the study was to identify the stable and adaptable genotypes for assessed traits' importance and effect on yield and yield contributing characters. The genetic variation in the materials at hand is critical to the success of any breeding enterprise. The larger the genetic variety, the higher heritability and as a result, the higher chances of success through selection. Within the materials chosen there was a great deal of variation. The cross 3 x 5 is promising for a breeding program, which showed greater adaptability and stability in all environments.

Conflict of interests

None

References

[1] P. Ranum, J. P. Peña-Rosas, and M. N. Garcia-Casal, "Global maize production, utilization, and consumption," *Ann. N. Y. Acad. Sci.*, vol. 1312, no. 1, pp. 105–112, 2014, doi: 10.1111/nyas.12396.

[2] C. S. Lin, M. R. Binns, and L. P. Lefkovitch, " Stability Analysis: Where Do We Stand? 1 ," *Crop Sci.*, vol. 26, no. 5, pp. 894–900, 1986, doi: 10.2135/cropsci1986.0011183x002600050012x.

[3] H. C. Becker and J. Leon, "Stability analysis in plant breeding," *Plant Breed.*, vol. 101, no. 1, pp. 1–23, 1988.

[4] M. Balestre, J. C. de Souza, R. G. Von Pinho, R. L. de Oliveira, and J. M. V. Paes, "Yield stability and adaptability of maize hybrids based on GGE biplot analysis characteristics.," *Crop Breed. Appl. Biotechnol.*, vol. 9, no. 3, 2009.

[5] Q. Saddique, H. Cai, J. Xu, A, Ajaz, J. H. Yu, Y. Wang, H. Chen, M. I. Khan, D. L. Liu,and L. He, "Analyzing adaptation strategies for maize production under future climate change in Guanzhong Plain, China," Mitig. Adapt. Strateg. Glob. Chang., vol. 25, no. 8, pp. 1523–1543, 2020.

[6] P. Fasahat, A. Rajabi, S. B. Mahmoudi, M. A. Noghabi, and J. M. Rad, "An overview on the use of stability parameters in plant breeding," *Biometrics Biostat. Int. J.*, vol. 2, no. 5, p. 43, 2015.

[7] Y. A. Mahmood, "Drought effects on leaf canopy temperature and leaf senescence in barley," *Iraqi J. Agric. Sci.*, vol. 51, no. 6, pp. 1684–1693, 2020.

[8] M. H. R. Anowara Akter, M Jamil Hasan , M U Kulsum and and S. A. A K Paul, L F Lipi, "Genotype× environment interaction and yield stability analysis in hybrid rice (Oryza sativa L.) by AMMI biplot," *Bangladesh Rice J.*, vol. 19, no. 2, pp. 83–90, 2015.

[9] J. B. Duarte and M. J. de O. Zimmermann, "Correlation among yield stability parameters in common bean," *Crop Sci.*, vol. 35, no. 3, pp. 905–912, 1995.

[10] G. K. Shukla, "Some statistical aspects of partitioning genotype-environmental components of variability," *Heredity (Edinb).*, vol. 29, no. 2, pp. 237–245, 1972.

[11] N. Kumar, S. B. S. Tikka, M. C. Dagla, B. Ram, and H. P. Meena, "Genotypic adaptability for seed yield and physiological traits in sesame (Sesamum indicum L.)," *The Bioscan*, vol. 8, no. 4, pp. 1503–1909, 2013.

[12] D. M. Reddy and V. P. Ahuja, "Phenotypic stability in recycled inbreds of maize," *Natl. J. Plant Improv*, vol. 6, no. 1, pp. 29–30, 2004.

[13] Y. Mahmood, H. N. Hassan, and M. S. Mohammed, "Yield Performance of Barley Hybrids (Hordeum vulgare L.) under Drought stress and non-stressed Conditions," *Passer J. Basic Appl. Sci.*, vol. 3, no. 1, pp. 107–113, 2021.

[14] R. E. Comstock and R. H. Moll, "Genotype environment interactions. Statistical genetics and plant breeding.," 1963.

[15] H. N. Hassan, M. S. Mohammed, and Y. A. Mahmood, "Association between some grain related traits of barley under drought and irrigated conditions," *J. Univ. Garmian*, vol. 6, pp. 76–83, 2019.

[16] A. Marliah, T. Hidayat, and N. Husna, "Pengaruh varietas dan jarak tanam terhadap pertumbuhan kedelai [Glycine Max (L.) Merrill]," *J. Agrista*, vol. 16, no. 1, pp. 22–28, 2012.

[17] S. A. Awtaq, A. S. Azeez, Y. A. Mahmood, N. R. Abdulkareem, and K. M. Jamal, "Kalar1 and Kalar2, newly released wheat varieties for cultivation under rain-fed conditions," *Kurdistan J. Appl. Res.*, pp. 35–43, 2021.

[18] S. A. t Eberhart and W. A. Russell, "Stability parameters for comparing varieties 1," *Crop Sci.*, vol. 6, no. 1, pp. 36–40, 1966.

[19] H. H. Elsahookie and O. H. Alrawi, "Efficiency of some equations to analyze genotype X environment interactions," *Iraqi J. Agric. Sci*, vol. 42, no. 6, pp. 1–18, 2011.

[20] Rs. Team, "RStudio: integrated development for R. RStudio, PBC, Boston, MA. 2020." 2021.

[21] S. Admassu, M. Nigussie, and H. Zelleke, "Correlation Among Some Statistical Measures of Phenotypic Stability in Maize (Zea mays L.)," *Int. J. Appl.*, vol. 5, no. 4, pp. 549–559, 2010.

[22] D. Ruswandi, Y. Yuwariah, M. Ariyanti, M. Syafii, and A. Nuraini, "Stability and adaptability of yield among earliness sweet corn hybrids in West Java, Indonesia," *Int. J. Agron.*, 2020.

[23] C. D. Cruz, R. A. de Torres, and R. Vencovsky, "An alternative approach to the stability analysis proposed by Silva and Barreto," *Rev. Bras. Genética*, vol. 12, no. 3, pp. 567–580, 1989.

[24] A. L. L Santos, Diego Coelho dos, Carlos Henrique Pereira, José Airton Rodrigues Nunes, "Adaptability and stability of maize hybrids in unreplicated multienvironment trials," *Rev. Cienc. Agron.*, vol. 50, no. 1, pp. 83–89, 2019, doi: 10.5935/1806-6690.20190010.

[25] T. Fahmi and E. Sujitno, "Keragaan produktivitas varietas jagung pada musim hujan di lahan kering dataran tinggi Kabupaten Bandung, Jawa Barat," *Pros. Sem. Masy. Biodiv. Indon*, vol. 1, no. 7, pp. 1674–1677, 2015.

[26] S. H.Shojaei, K. Mostafavi, A. Lak, A. Omrani, S. Omrani, S. M. N.Mousavi, Á. Illés, C. Bojtor, and J Nagy, "Evaluation of stability in maize hybrids using univariate parametric methods," *J. Crop Sci. Biotechnol.*, vol. 25, no. 3, pp. 269–276, 2022.

[27] C. Busanello, V. Q. de Souza, A. C. de Oliveira, M. Nardino, D. Beretta, B.O. Caron, D. Schmidt, V. F. de Oliveira, and V. A. Konflaz, "Adaptability and stability of corn hybrids in southern Brazilian environments," Int. J. Biol., vol. 7, no. 9, p. 228, 2015.

[28] B. Waluyo, "Stability and Adaptability of Nine Open Pollinated Varieties of UB Maize," *AGRIVITA, J. Agric. Sci.*, vol. 32, no. 3, pp. 293–301, 2010.

[29] T. R. Francis and L. W. Kannenberg, "Yield stability studies in short-season maize. I. A descriptive method for grouping genotypes," *Can. J. plant Sci.*, vol. 58, no. 4, pp. 1029–1034, 1978.

[30] J. Shrestha, S. Subedi, R. Acharya, S. Sharma, and M. Subedi, "Grain Yield Stability of Maize (Zea mays L.) Hybrids using Ammi Model and GGE Biplot Analysis," *SAARC J. Agric.*, vol. 19, no. 2, pp. 107–121, 2021.

[31] A. Kumar and N. N. Singh, "Stability studies of inbred and single crosses in maize," *Ann. Agric. Res*, vol. 25, pp. 142–148, 2004.

[32] U. Karadavut and A. Akilli, "Genotype-environment interaction and phenotypic stability analysis for yield of corn cultivar," *Greener J. Agric. Sci.*, vol. 2, no. 9, pp. 220–223, 2012.

[33] C. H. Sneller, L. Kilgore-Norquest, and D. Dombek, "Repeatability of yield stability statistics in soybean," *Crop Sci.*, vol. 37, no. 2, pp. 383–390, 1997.