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Stability Analysis of Maize Genotypes According to Different Methods

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ABSTRACT

This study was carried out to evaluate the stability and adaptability of maize crop genotypes under four different environmental conditions, of eight inbred lines maize, and their crosses of (*Zea mays* L.). Four inbred lines (NADH 905, NADH102, NA106, Sara NA) were designated as lines, and four inbred lines (NA 225, NAHD503, ZM12, NAPI5012) were fixed as testers. The data are combined across sites and seasons to perform a joint analysis in order to obtain information that will help breeders to select the best cultivars for different environments. Beyond this, it is essential to understand the different factors that can hamper the selection. According to (El-sahookie, and Al-Rawi, 2011), maximum percentage of stability for kernel yield was 96.61% recorded by the parentNA106, while for genotypic resultant it was 1.067% recorded by the Crosse NA106× NAPI5012. According to Eberhart and Russell (1966), it was found that the cross NADH 905×NAPI5012 was adaptable for kernel yield. According to (Francis, 1977) it was found that the crosses NADH102×NA225, NADH102×NAPI5012, Sara NA×NAHD503, parents NADH 905, and NA225 were good performance and stable for kernel yield.

تحليل استقرارية بعض التراكيب الوراثية للذرة ألصفراء بطرق مختلفة

لوند فاتح محمد ، شيروان إسماعيل توفيق ، دانا آزاد عبد الخالق
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الخلاصة

أجريت هذه الدراسة لتقييم أستقرارية وتكييف التراكيب الوراثية لمحصول الذرة تحت أربعة ظروف بيئية مختلفة. لثمانية سلالات من الذرة الصفراء، تم تعيين أربعة منها كسلالات (NADH 905، NADH102، NA106، Sara NA) وأربعة منها (NA 225، NAHD503، ZM12، NAPI5012) كفواحص. تم تجميع البيانات عبر المواقع والمواسم لإجراء تحليل مشترك من أجل الحصول على المعلومات التي ستساعد المربين على اختيار أفضل الأصناف للبيئات المختلفة. من

الضروري فهم العوامل المختلفة التي يمكن أن تعرقل الاختيار. وفقًا لـ(2011Al-Rawi Elsahookie) ، كانت النسبة القصوى للاستقرارية لحاصل الحبوب 96.61٪ التي سجلها الأب NA106 ، بينما كانت المحصلة الوراثية 1.067٪ المسجلة بواسطة الهجين NAPI5012 × NA106 وفقًا لـ **(1966 Russell and Eberhart)**، وجد أن الهجين NADH905 × NAPI5012 كانت قابلة للتكيف عبر البيئات المختلفة ضمن الدراسة في حاصل الحبوب. وفقًا لـ (**فرانسيس ، 1977**) وجد أن الهجن NA225 ×NADH102 ، NADH102 × NAPI5012 ، Sara NA × NAHD503 والأباء NADH 905 و NA225 كانت لها أداءجيد ومستقر لحاصل الحبوب.

الكلمات المفتاحية: الذرة الصفراء، التكيف و الاستقرارية،حاصل الحبوب ومكونات حاصل الحبوب

INTRODUCTION

Maize (*Zea mays* L.) is currently grown throughout the world with an approximately of 563 of the 717 million metric tons / year of yield production globally which is mostly produced by the top three countries of United States, China and Brazil (Ranum *et al.*, 2014). It contains about 72% starch, 10% protein and 4% fat to supply about 365 Kcal/100 g of energy. It can be used as food and industrial products in a different of ways including sweeteners, starch, oil, glue, beverages, fuel ethanol, and industrial alcohol. From the last decade, maize has been significantly used as a source of fuel which is estimated by 40% of the maize production in the United States. Therefore, high demand on corn foods due to low cost and richness of micronutrients, make this food ideal and essential (Ranum *et al.*, 2014). Studying adaptability and stability is an important method to identify cultivars which have predictive behavior, and which are responsive to environmental improvements (Cruz *et al.*, 2014).

Different methods have been proposed to study the adaptability and stability of maize cultivars. Among these methods the method proposed by (Eberhart and Russell, 1966) which based on linear regression analysis, which are simple and easy application and interpretation of results. The recommendation of maize cultivars by using this method has been mentioned by several authors. Cargnelutti, (2009) used this method to study the adaptability and stability of 16 maize genotypes in the state of Tocantins, and classify them as to prod. Understanding the relationship among yield testing locations is important of plant breeders to choose target germplasm better adapted to different production environments or regions (Trethowan, *et al.*, 2001). A genotype is considered to be stable if variances among environments are small. This is called stability statistic, or a biological concept of stability. A stable genotype possesses an unchanged or least changed performance regardless of any variation of the environmental conditions. This concept of stability is useful for quality traits, disease resistance and for stress characters like winter hardiness (Baker, and Leon 1988). In breeding for wide adaptation, the aim is to obtain a variety, which performs well in nearly all environments (Cooper and De-Lacy, 1994). In maize breeding programs, the search for genotypes with high grain yield adapted in the most varied environments is one of the most important objectives for breeders. For that, the choice of populations that show good genetic homeostasis is essential for yield increases, (Balestre *et al.*, 2009).

According to Cruz and Carneiro, (2003) some points are indispensable for the choice of genitors such as performance per se of the genitor, high combining ability, low inbreeding depression if the objective is produced inbred line and genotypes with broad adaptability. When imprecise analysis of the genotype x environment interaction (GE) is performed, several problems arise, mainly the reduction in the accuracy of genotype selection (Lavoranti, 2003). The adaptability and stability of different types of corn hybrids and found that the homogeneity and/or heterogeneity of hybrids do not provide more or less stability and that stable hybrids may be selected in any population (Machado *et al.*, 2008). The adaptability and stability of hybrids are useful parameters for recommending cultivars for known cropping conditions (Scapim *et al.*, 2000). It was revealed that the genotype possesses high mean along with regression coefficient more than unity (b_i>1) and mean deviates from the regression close to zero ($S_{d_i}^2 = 0$), can be specifically adapted to favorable environments. Furthermore, the genotypes with high mean, regression coefficient less than unity (b_i>1) and deviates from regression close to zero ($S^2_{d_i} = 0$) can be specifically adapted to poor environments (Eberhart and Russell, 1966).

Therefore, the main objective of this study was the interactions between genotypes and environments, stability of kernel yield, and its components of maize hybrid under different environmental conditions, using different methods in Sulaimani Governorate-Iraq.

MATERIALS AND METHODS

This study was carried out at two different locations, and two seasons in Kurdistan Region-Iraq. The combinations of environments result from two locations by two seasons. The first was Dukan Township (Lat. 35° 11′; N, Long. 45° 08′; E, 690 MASL) 60 Km Northwest of Sulaimani City, and the second was Qlyasan Agricultural Research Station, College of Agricultural Engineering Sciences, University of Sulaimani (Lat. 35° 34′; N, Long. 45° 21′; E, 765 MASL) 2 Km Northwest of Sulaimani City, during 2020-2022.
Eight inbred lines maize *Zea mays* L. (Table 1), four of them *viz.* (**NADH 905, NADH102, NA106, Sara NA**) were used as females, hereafter designated as lines, and the other four *viz.* (**NA 225, NAHD503, ZM12, NAPI5012**) were used as males, fixed as testers. All possible crosses were perfected from April 16 2020 to generate 16 F_{1s} crosses at Qlyasan location, according to the line × tester mating design developed by (Kempthorne, 1957). F_1 seeds were sown during April 3 2021 at Dukan location and on April 7 2021 at Qlyasan location, along with their parents, and repeated at two seasons in Randomized Complete Block Design (RCBD) with three replicates. Each plot comprised one row of 3 m long with space of 75 cm between rows and seeds were placed 25 cm apart.

Statistical analysis:
In this study, analysis of variance for all sites and seasons were performed for all parameters followed by genetic analysis of stability according to the methodology of El-Sahooki and Al-Rawi, (2011) Eberhart and Russel regression coefficient (b_i), (Eberhart and Russell, 1966), Francis and Kannenberg coefficient of variability (CV) (Francis and Kannenberg, 1978) using R-Studio software (Team, 2020). The regression analysis for correlations between parameters and graphs were performed by GraphPad Prsim software, (GraphPad, 2019).

Stability Analysis: Elsahookie, (1995), El-Sahooki and Al-Rawi, (2011).

$$Stability\ (H)\% = \frac{1-S}{\bar{X}_i} \times 100$$

Where,

$$S = \sqrt{S^2} = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$$

$_i$: The value of the genotype.
$\bar{X}_i$: The average of the character value crossing studied environments.

Genotypic Resultant:

$$Genotypic\ Resultant\ (GR) = (1 - \frac{S}{\bar{X}_i}) \times (\frac{\bar{X}_i}{\bar{X}_{..}})$$

$\bar{X}_i$: The average of the character value crossing studied environments.
$\bar{X}_{..}$ = the general mean of a particular character for all environment

Table1. Studied breeding materials

No.	Crosses and Parental No.	Parentages
1	1 × 5	NADH 905× NA225
2	1 × 6	NADH 905× NAHD503
3	1 × 7	NADH 905× ZM12
4	1 × 8	NADH 905× NAPI5012
5	2 ×5	NADH102× NA225
6	2 ×6	NADH102× NAHD503
7	2 × 7	NADH102× ZM12
8	2 ×8	NADH102 × NAPI5012
9	3 × 5	NA106× NA225
10	3 × 6	NA106× NAHD503
11	3 × 7	NA106× ZM12
12	3 × 8	NA106× NAPI5012
13	4 × 5	Sara NA × NA225
14	4× 6	Sara NA × NAHD503
15	4 × 7	Sara NA × ZM12
16	4 × 8	Sara NA × NAPI5012
17	Line 1	NADH 905
18	Line 2	NADH102
19	Line 3	NA106
20	Line 4	Sara NA
21	Tester 1	NA225
22	Tester 2	NAHD503
23	Tester 3	ZM12
24	Tester 4	NAPI5012

Table 2. Analysis of variance for interaction among environment × genotypes Eberhart and Russel (1966)

Source of Variance	d.f.	S.S.	M.S.
Varieties	v-1	$\frac{1}{n}\sum_{i} Y_{i.}^2 - C.F.$	MS_1
Environments (Env.) V × Env.	$\left.\begin{matrix} n-1 \\ (v-1)(n-1 \end{matrix}\right\} v(n-1)$	$\sum_i \sum_j Y_{ij}^2 - \sum Y_{i.}^2/n$	
Env. (Linear)	1	$\frac{1}{v}(\sum_j Y_{.j} I_j)^2/\sum_j I_j^2$	
V × Env. (Linear)	v-1	$\sum_i \left[(\sum_j Y_{ij} I_j)^2 / \sum_j I_j^2 \right] - \text{Env. (Linear)S.S.}$	MS_2
Pooled Deviations	v(n-2)	$\sum_I \sum_J \sigma^2 ij$	MS_3
Variety 1	n-2	$\left[\sum_j Y_{ij}^2 - \frac{(Y_{i.})^2}{n} \right] - (\sum_j Y_{ij} I_j)^2 / \sum_j I_j^2$	
.	.	.	
.	.	.	
.	.	.	
Variety v	n-2	$\left[\sum_j Y_{vj}^2 - \frac{Y_{v.}^2}{n} \right] - (\sum_j Y_{vj} I_j)^2 / \sum_j I_j^2 - \sum_j \sigma_{vj}^2$	
Pooled Error	n(r-1)(v-1)		
Total	nv-1	$\sum_i \sum_j Y_{ij}^2 - C.F.$	

RESULT AND DISCUSSION

Data in Table 3 a and b, illustrate the estimates of stability and genotypic resultant of genotypes across four different environments according to El-Sahooki and Al-Rawi, (1966). Parent 8 showed the highest value of stability for number of ears plant^{-1} and biological yield reached 100.00 and 98.17% respectively. The cross 1×8 gave the maximum stability for ear width reached 97.12%. The cross 3×6 exhibited the highest percentage of stability for ear length and weight of kernels ear^{-1} reached 95.70 and 97.06% respectively. The highest, percentage of stability for number of rows ear^{-1} and harvest index recorded by the cross 1×7 reached 97.64, and 94.53% respectively. The cross 4×7 produced the highest percentage, of stability for number of kernel's row^{-1}, 300 Kernels weight reached 97.96 and 97.27% respectively. The maximum Percentage of stability due to kernel yield was 96.61% recorded by parent 3. Regarding genotypic resultant present in the same table, Parent 5 showed the maximum value of a genotypic resultant due to number of ears plant^{-1} reached 1.079. The highest value for genotypic resultant due to ear width was 1.097 showed by the cross 2×5, while for ear length it was 1.111 obtained from the cross 1×8. Parent 4 gave the best value for this parameter due to number of rows ear^{-1} and harvest index reached 1.167 and 1093 respectively. Parent 2 gave the maximum value of genotypic resultant for number of kernels row^{-1} with 1.233, while for weight of kernels ear $^{-1}$it was 1.087 showed by the cross 1×6. The cross 4×5 gave the maximum value for 300 kernel weight reached 1.063. The best value for genotypic resultant due to biological and kerned yield, recorded by the cross 3×8, recording 1.264 and 1.067 respectively. Statistically concept according to estimates of (H%) and (GR) according to (El Sahookie, 1990), who mentioned if the value of homeostasis is less than 85%, it means that the cultivar was unstable across environments, and if the value of genetic resultant was high and close to unity, it means that the cultivar has a good performance under varying environments.

Data in table 4 and b explain the adaptability and stability of genotypes across environments according to Eberhart and Russell, (1966). The crosses 1×6 and 1×8 with the means 1.44 and 1.35 was found to be stable, while the crosses 1×7, 2×6, 2×7 and 4×7 with the means 1.42 for both 1×7 and 2×6 and 1.11 and 1.44 for 2×7 and 4×7 respectively for number of ears plants^{-1}, was adaptable (Figure 1). Concerning to ear width, it was observed that the cross 4×6 with the mean 4.13 cm was stable, while the crosses 1×6, 1×7, 1×8, 3×7, 3×8, and parent 3 and parent 8 was adaptable recording 3.97, 4.27, 4.31,3.56,3.89, 3.37, and 3.22 cm respectively (Figure 2). The cross 2×7 with 17.58 cm was stable due to ear length in, while the crosses 1×6, 1×8 and 3×8 with 14.83 13.50 and 15.33cm, was adaptable for this trait (Figure 3). In Parent 3 with 18.67 Number of rows ear^{-1} was adaptable due to the character number of rows ear $^{-1}$ (Figure 4). Regarding number of kernels row^{-1}, it was indicated that the crosses 1×8, 2×8, 3×7 and parent 4 with 32.25, 25.17, stable 33.83 and 36.25 kernels row^{-1} respectively was stable, while the crosses 2×7, 4×7 parents 1,5 and 7 with 33.42, 35.00, 31.83, 34.00 and 28.83 respectively number of kernels row^{-1} was adaptable (Figure 5). Regarding weight of kernels ear^{-1}, it was noticed that the cross 2×7 with 89.23 was stable and adaptable, while the crosses 1×6, 1×7 1×8, 2×5, 2×8, 3×6, 3×7, 3×8 ,4×5, and the parents 2, 6, 7 and 8 with the means. 74.43, 108.85, 73.74, 89.29, 84.92,82.33, 74.52, 79.75, 81.58, 69.54, 46.42, 59.14 and 41.63 g was found to be stable but the crosses 2×6, 4×7, 4×8, with 104.69 ,120.18 and 121.83 g was adaptable (Figure 6). Concerning 300 kernel weight it was confirmed that the crosses 3×8 and 4×6 with 55.07 and 64.42 g respectively was stable and adaptable, while the crosses 2×5 and 3×5 with 49.04 and 49.20 respectively was stable, but the crosses 1×7, 2×6, 2×8, 4×5, 4×7 and 4×8 with 59.94, 61.29, 61.45, 53.48, 63.92 and 69.32g was adaptable (Figure 7). Parent 5 with 0.40 was found to be adaptable for harvest index (Figure4.8). Concerning biological yield, the crosses cross 3×7 and parents 7 and 8 with 10.75, 10.06 and 9.02ton ha^{-1} was stable, while the crosses 2×6, 2×7, 3×6, 3×8, parent of 5 with 13.43, 12.76, 13.05, 13.16 and 12.24 tons' ha-1 was adaptable (Figure 9). From the same table it was revealed that the crosses 1×6 and 1×8 with 4.06 and 4.00tons ha^{-1} was stable, but the crosses 1×7, 2×6, 2×7 and 4×7 with 5.67, 5.73 4.78 and 6.64tons ha^{-1} respectively was adaptable (Figure 10). According to the Eberhart and Russell method (1966), two environments were classified as unfavorable - Coimbra and São Miguel do Anta. These environments showed negative values for I j, which are usually associated with areas of adverse weather or soil conditions, or areas with low levels of technology and little input. The environments at Viçosa1, Viçosa2 and Sete Lagoas were classified as favorable, and were where the hybrids had the highest grain yields. This indicates that the respective in breeds have different performance of these traits in different locations and the overlap between (location × inbreeds) is highly significant for all traits, different in their origin and them inbreeds are also the case for the various sites of the environment and therefore the genotype or in breed shows the maximum genetic ability to express the grade (Badu *et.al* 2003).

Table 3 a. Estimation of stability and genotypic resultant according to El-Sahooki and Al-Rawi (2011) for Line× Tester Experiment

Characters	Number of ears plant^{-1}		Ear width (mm)		Ear length (cm)		Number of rows ear^{-1}		Number of kernels row^{-1}	
Genotypes	H%	GR	H%	GR	H%	GR	H%	GR	H%	GR
1	73.884	0.964	87.018	0.772	90.986	0.861	94.262	0.878	91.441	0.857
1×5	81.381	0.931	86.264	0.883	81.606	0.712	93.995	0.837	91.206	0.843
1×6	84.630	0.955	86.630	0.953	86.547	0.946	95.272	0.799	96.274	1.231
1×7	61.942	0.667	84.881	0.942	79.802	0.868	97.643	0.990	97.416	0.982
1×8	93.928	0.789	97.125	0.971	92.917	1.111	96.282	1.026	92.643	0.948
2	72.139	0.814	90.115	1.045	89.909	1.071	90.247	1.083	94.531	1.233
2×5	97.281	0.861	96.867	1.097	92.516	0.957	92.930	0.943	84.603	0.883
2×6	84.949	0.784	90.684	0.953	93.766	0.993	91.994	0.981	97.243	0.765
2×7	87.400	0.837	96.490	1.000	94.392	0.986	92.493	0.871	84.375	0.877
2×8	86.901	0.779	92.233	0.945	93.454	0.870	97.184	0.825	91.945	0.900
3	75.963	0.914	78.910	0.723	84.895	0.807	97.543	0.949	95.275	1.007
3×5	92.361	0.892	84.508	0.846	69.410	0.626	97.543	0.949	95.921	0.959
3×6	77.604	0.802	92.329	0.974	95.703	1.070	95.792	0.902	91.275	0.772
3×7	86.064	0.949	91.935	0.978	88.990	0.960	86.309	0.938	83.580	0.860
3×8	77.349	0.884	92.030	1.074	82.663	1.025	88.778	1.103	78.619	0.860
4	73.461	0.812	91.032	1.051	90.461	1.078	93.185	1.167	86.224	0.889
4×5	84.502	0.729	82.084	0.704	92.140	1.034	89.870	0.874	83.835	0.834
4×6	94.458	0.773	95.997	0.799	92.186	0.908	91.963	0.809	89.089	0.710
4×7	83.052	0.722	74.530	0.647	91.955	1.041	84.570	0.980	93.392	0.919
4×8	93.335	0.777	94.811	0.954	94.196	1.071	96.052	0.964	97.961	1.110
5	93.712	1.079	88.375	0.830	94.982	1.096	95.745	0.931	87.886	0.934
6	93.130	0.886	91.985	0.785	89.916	0.923	94.469	0.890	79.780	0.791
7	89.548	0.803	93.607	0.874	92.529	0.855	96.450	0.918	87.040	0.784
8	100.00	0.796	84.250	0.698	91.398	0.874	95.272	0.799	69.168	0.522

Table 3 b. Estimation of stability and genotypic resultant according to El-Sahooki and Al-Rawi (2011) for Line× Tester Experiment

Characters	Weight of kernels ear^{-1} (g)		300-kernel yield (g)		Harvest index		Bio. yield (tons ha^{-1})		Kernel yield (tons ha^{-1})	
Genotypes	H%	GR	H%	GR	H%	GR	H%	GR	H%	GR
1	96.282	0.957	87.920	0.801	90.686	1.009	84.891	0.724	92.949	0.880
1×5	94.406	0.843	83.825	0.697	85.376	0.772	96.226	0.936	92.172	0.829
1×6	83.196	1.087	70.507	0.710	77.395	0.881	86.571	0.955	74.431	0.934
1×7	80.153	0.709	87.448	0.847	94.525	0.928	80.747	0.720	76.949	0.681
1×8	88.664	0.950	93.863	0.773	91.705	0.946	95.820	0.952	88.861	0.925
2	53.140	0.664	65.436	0.674	75.866	0.807	75.344	0.870	58.378	0.740
2×5	62.941	0.674	96.279	0.940	82.123	0.777	78.022	0.856	61.026	0.646
2×6	85.280	0.869	83.939	0.867	93.399	1.070	91.088	0.797	85.534	0.863
2×7	70.352	0.580	81.109	0.671	69.313	0.663	83.788	0.812	78.368	0.696
2×8	93.410	0.923	85.212	0.799	70.801	0.639	75.011	0.841	93.510	0.899
3	95.211	0.852	81.547	0.703	88.343	0.857	88.335	0.817	96.614	0.854
3×5	95.412	0.913	75.035	0.694	62.922	0.559	60.585	0.685	92.791	0.845
3×6	97.055	0.950	76.242	0.685	90.834	0.862	94.454	0.934	92.982	0.880
3×7	88.898	1.021	78.183	0.846	83.092	0.789	89.339	1.053	85.502	0.946
3×8	67.866	0.979	79.675	0.923	79.191	0.820	91.477	1.264	72.525	1.067
4	60.794	0.889	76.265	0.888	93.790	1.093	78.060	0.960	71.360	1.032
4×5	83.156	0.913	88.640	1.063	90.462	0.952	80.153	0.804	86.941	0.928
4×6	82.096	0.685	89.535	1.006	79.950	0.844	84.552	0.699	84.583	0.726
4×7	63.649	0.720	91.504	1.029	77.478	1.056	90.331	0.771	69.907	0.837
4×8	92.272	0.840	97.265	1.024	85.720	0.724	88.508	0.885	87.723	0.738
5	90.894	0.967	94.794	1.032	84.008	0.853	70.356	0.740	82.992	0.856
6	90.069	0.511	89.016	1.036	72.469	0.644	84.881	0.644	82.937	0.556
7	67.476	0.479	80.911	0.712	90.543	0.812	85.834	0.743	81.710	0.626
8	75.986	0.380	91.228	0.851	69.163	0.527	98.167	0.761	70.091	0.413

Table 4 a. Estimation of stability according to Eberhart and Russell for Line × Tester Experiment

Characters	Genotypes	1	1×5	1×6	1×7	1×8	2	2×5	2×6	2×7	2×8	3	3×5
Number of ears plant^{-1}	*Mean*	1.08	1.64	1.44	1.42	1.35	1.03	1.06	1.42	1.11	1.16	1.09	1.20
	b_i	2.20	5.99	3.02	1.55	3.50	-0.02	0.92	6.22	-0.25	-1.66	2.42	-2.33
	$S^2_{d_i}$	0.00	0.10	0.05	0.04	0.33	-0.01	-0.01	0.05	-0.02	0.02	0.01	-0.01
Ear width (mm)	*Mean*	3.33	3.44	3.97	4.27	4.31	3.23	3.88	4.51	4.40	4.08	3.37	4.02
	b_i	1.72	-1.61	2.02	2.15	2.45	0.21	-0.19	0.98	0.13	1.43	3.20	0.33
	$S^2_{d_i}$	0.18	-0.02	-0.02	-0.03	-0.02	-0.03	-0.04	0.15	-0.03	-0.04	0.02	-0.04
Ear length (cm)	*Mean*	19.08	16.08	14.83	18.58	18.50	16.75	20.33	20.25	17.58	18.00	19.25	17.75
	b_i	-1.01	0.87	2.21	2.06	3.10	-0.87	1.07	0.99	1.08	0.68	0.03	0.06
	$S^2_{d_i}$	-0.15	0.19	-0.69	-1.10	-1.18	-0.37	-0.67	2.81	-1.24	-0.42	2.28	0.16
Number of rows ear^{-1}	*Mean*	15.67	15.00	14.33	13.50	16.33	14.17	17.17	19.33	16.33	17.17	18.67	15.17
	b_i	3.93	0.06	3.46	-1.26	-1.35	-1.14	-1.32	1.41	-1.93	1.38	10.78	-3.55
	$S^2_{d_i}$	1.63	0.18	-0.76	-0.44	-0.85	0.91	-0.45	4.25	0.78	1.76	2.33	0.02
Number of kernels row^{-1}	*Mean*	31.83	30.00	29.58	40.92	32.25	25.50	32.75	41.75	33.42	25.17	31.50	33.25
	b_i	4.08	1.69	-1.70	0.13	0.36	-0.80	1.84	0.93	3.61	-0.45	0.79	-2.59
	$S^2_{d_i}$	-3.31	-7.54	-7.34	-8.67	-11.33	-1.72	-9.73	-5.93	3.35	-11.79	-6.78	15.89
Weight of kernels ear^{-1} (g)	*Mean*	91.45	82.83	74.43	108.85	73.74	69.54	89.29	104.09	89.23	84.92	94.23	68.68
	b_i	1.43	-0.16	0.39	1.75	1.40	-1.19	0.97	4.66	3.16	1.19	3.26	-1.93
	$S^2_{d_i}$	-62.19	-74.23	-83.65	-83.21	-83.26	-83.74	-83.52	-61.73	-81.55	-80.94	-57.76	-70.68
300-kernel yield (g)	*Mean*	71.37	54.24	49.46	59.94	57.64	66.87	49.04	61.29	58.11	61.45	66.90	49.20
	b_i	0.99	0.81	1.00	2.20	0.89	0.86	0.38	2.64	0.23	1.16	-0.43	1.17
	$S^2_{d_i}$	-12.78	-17.13	-16.60	-8.70	-15.53	-14.66	-18.58	-2.55	-16.87	-0.18	12.02	-17.99
Harvest index	*Mean*	0.42	0.44	0.36	0.45	0.39	0.42	0.41	0.42	0.37	0.45	0.54	0.38
	b_i	1.61	0.65	0.35	2.09	0.19	2.02	-0.05	1.43	0.46	0.43	-0.08	1.77
	$S^2_{d_i}$	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.02
Bio. yield (tons ha^{-1})	*Mean*	11.66	9.91	11.31	12.83	10.36	9.62	11.56	13.43	12.76	10.18	9.92	11.27
	b_i	1.37	0.82	-0.19	0.92	1.13	0.86	0.23	1.95	1.64	0.52	0.35	1.08
	$S^2_{d_i}$	-0.50	-0.40	-0.99	-0.04	-0.20	-0.74	-0.98	0.29	0.06	-0.95	-0.24	-0.74
Kernel yield (tons ha^{-1})	*Mean*	4.82	4.27	4.06	5.67	4.00	3.88	4.70	5.73	4.78	4.56	5.40	4.01
	b_i	0.99	0.00	0.53	2.33	1.57	-0.08	0.85	3.99	3.14	1.10	2.51	-1.01
	$S^2_{d_i}$	-0.08	-0.04	-0.17	0.16	-0.17	0.36	-0.13	0.12	-0.06	-0.15	0.53	0.42

Table 4 b. Estimation of stability and adaptability according to Eberhart and Russell

Characters	Genotypes	1	1×5	1×6	1×7	1×8	2	2×5	2×6	2×7	2×8	3	3×5
Number of ears plant^{-1}	*Mean*	1.13	1.51	1.21	1.05	1.30	1.39	1.44	1.39	1.45	1.19	1.13	1.00
	b_i	-1.89	-2.65	-1.64	0.21	3.69	2.68	1.42	3.06	-0.72	-0.97	-0.75	0.00
	$S^2_{d_i}$	0.00	0.15	-0.02	-0.01	0.05	0.01	0.13	0.15	-0.01	-0.01	0.00	-0.02
Ear width (mm)	*Mean*	3.98	3.56	3.89	3.91	4.10	4.13	4.53	4.48	3.65	3.32	3.63	3.22
	b_i	1.14	2.84	2.26	0.39	1.01	1.28	0.75	0.79	-1.40	0.98	-0.75	1.88
	$S^2_{d_i}$	-0.04	-0.02	-0.02	-0.01	-0.01	-0.05	0.08	0.13	0.02	-0.04	-0.03	-0.03
Ear length (cm)	*Mean*	15.83	16.17	15.33	19.33	19.00	18.33	21.08	20.25	19.63	17.46	15.71	16.25
	b_i	0.14	2.00	3.83	0.15	-0.62	1.42	2.16	1.01	0.69	1.23	0.72	1.00
	$S^2_{d_i}$	0.25	-1.07	-0.17	0.52	-1.14	0.42	8.65	2.08	-0.90	0.05	-0.37	-0.53
Number of rows ear^{-1}	*Mean*	13.67	15.67	15.67	16.17	15.17	17.50	20.00	20.17	15.67	15.17	15.33	13.50
	b_i	-0.64	1.35	-1.35	-1.26	1.96	6.48	7.27	3.31	-1.23	-2.61	0.12	0.15
	$S^2_{d_i}$	-0.74	-0.85	-0.85	-0.44	-0.62	4.37	2.46	1.04	-0.38	-0.41	-0.48	-0.32
Number of kernels row^{-1}	*Mean*	31.33	33.83	32.00	36.25	27.08	32.92	35.00	33.00	34.00	31.75	28.83	24.17
	b_i	-0.86	-1.32	0.84	0.12	1.98	3.33	5.53	3.66	2.83	2.05	2.17	-4.22
	$S^2_{d_i}$	-3.94	-11.54	-10.87	-11.34	-11.05	11.15	14.99	-6.05	-1.53	41.88	0.11	38.12
Weight of kernels ear^{-1} (g)	*Mean*	82.33	74.52	79.75	75.88	81.58	95.71	120.18	121.83	88.68	46.42	59.14	41.63
	b_i	-0.51	-0.34	-0.31	-0.49	0.20	1.01	3.69	4.56	0.72	-0.35	1.84	-0.96
	$S^2_{d_i}$	-81.72	-83.66	-80.14	-71.21	-81.87	-81.56	-77.33	-61.25	-72.10	-81.58	-82.79	-84.05
300-kernel yield (g)	*Mean*	55.78	51.27	55.07	62.65	53.48	64.42	68.92	69.32	64.76	69.29	52.34	55.54
	b_i	1.01	1.17	1.73	0.11	1.58	1.77	1.70	2.03	-0.12	0.94	0.78	-0.59
	$S^2_{d_i}$	-13.42	-14.625	-18.47	-15.59	-11.29	-18.72	2.63	-0.13	-3.31	-14.52	73.51	-16.09
Harvest index	*Mean*	0.36	0.38	0.35	0.33	0.37	0.37	0.41	0.46	0.40	0.35	0.36	0.30
	b_i	1.23	0.83	1.30	1.79	0.63	1.31	0.46	-0.34	2.35	1.68	0.20	1.70
	$S^2_{d_i}$	0.01	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01
Bio. yield (tons ha^{-1})	*Mean*	13.05	10.75	13.16	11.63	11.50	13.71	16.07	14.30	12.24	8.82	10.06	9.02
	b_i	1.99	0.76	3.16	0.77	0.31	0.35	0.67	1.62	2.20	0.54	0.87	0.09
	$S^2_{d_i}$	-0.84	-1.08	-0.43	-0.77	-0.89	1.59	-0.07	3.29	-0.57	0.37	-1.09	-1.11
Kernel yield (tons ha^{-1})	*Mean*	4.34	3.99	4.11	3.80	4.27	4.99	6.64	6.53	4.66	3.03	3.46	2.66
	b_i	-0.07	-0.10	-0.35	0.47	0.36	1.15	3.03	2.76	1.20	-0.37	0.92	-0.92
	$S^2_{d_i}$	-0.06	-0.15	-0.10	0.04	-0.11	-0.08	0.09	1.13	0.02	0.15	-0.01	0.34

Depending on the average performance of genotypes on the as well as the values of their coefficient of variation C.V, Francis, (1977) developed his method for determining the good performance and stable genotypes. According to Francis method the Cross 4×6 was good performance and stable genotype, which recorded 1.386 ears plan^{-1} with C.V%. 14.02% also parent 5 determined as a good performance and Stable for number of ears plant^{-1}, which gave 1.446 ears plant^{-1} and with "C. V% 6.31% (Figure 11). Concerning to the character ear width it was revealed that the crosses 2×6 2 2×7, 2×8, 3×5, 3×6, 4×5, 4×6, 4×7, 4×8 and parent 4. were good performance and stable and depending and CV%. their means which were 4.505, 4.396 4.083, 4.023 3.977, 4.0989 4.132, 4.532, 4.883 and 3.908 cm respectively, while their CV% were 9.89, 3.13, 9.32, 3.51, 7.77, 7.67, 8.06, 7.97, 8.98 and 5.19% respectively (Figure 12). Regarding ear length, the crosses 2×5, 2×6, 2×8, 4×5, 4×8, parents 1, 3, 4 and 5 were good performance and stable for this trait, they recorded 20.333, 20.250, 18.00, 19.00, 20.250, 19.083, 19.250, 19.333 and 19.625 cm respectively and their CV% were 7.08, 20.099 6.23 94.29, 9.54 7.86 8.04, 5.80 and 5.02%, respectively **(**Figure 13). The Crosses 1×8 and 2×5, and parent 4 were found to be good performance and Stable for the character number of rows ear^{-1}, they recorded 16.33, 17.16, and 16.16rows ear^{-1} respectively, and their CV. values were 2.35, 3.71, and 3.94% respectively (Figure 14). The genotypes 1×7, 1×8, 2×5, 2×6, 3×7 and parent 4 were determined as good performance and stable for number of kernels row^{-1}. They recorded 40.916, 32.250, 32.750, 41.750, 33.833, and 36.250 kernels row^{-1} respectively, with their CV% 3.72, 2.58, 7.35, 5.46 4.72, and 2.03% respectively **(**Figure 15). Regarding the character weight of Kernels ear, it was indicated that the crosses 1×7, 2×5, 2×8, 4×6 and parents 1and 5 were good performance and stable, recording 108.85, 89.291, 84.918, 95.708, 91.45 and 88.675 g respectively.

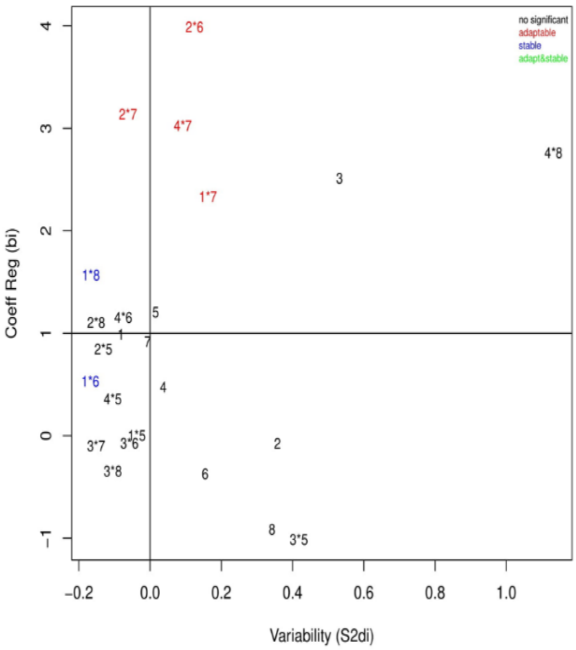

Figure 1. Stability and adaptability analysis for Number of ears plant-1

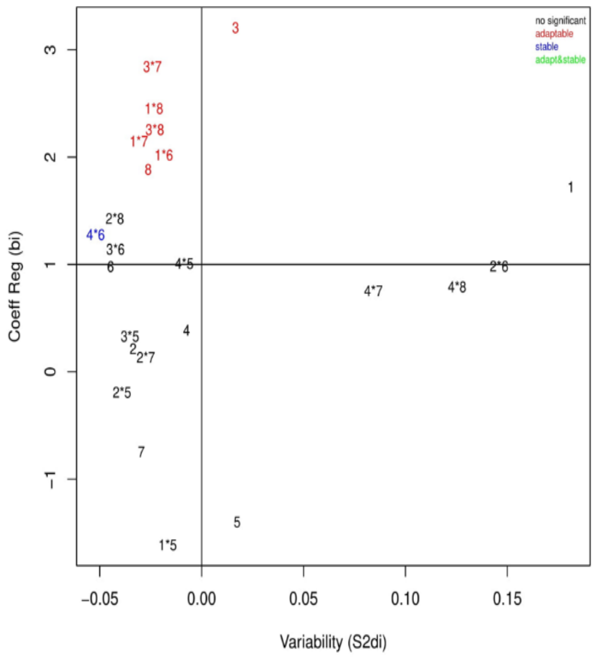

Figure 2. Stability and adaptability analysis for ear width

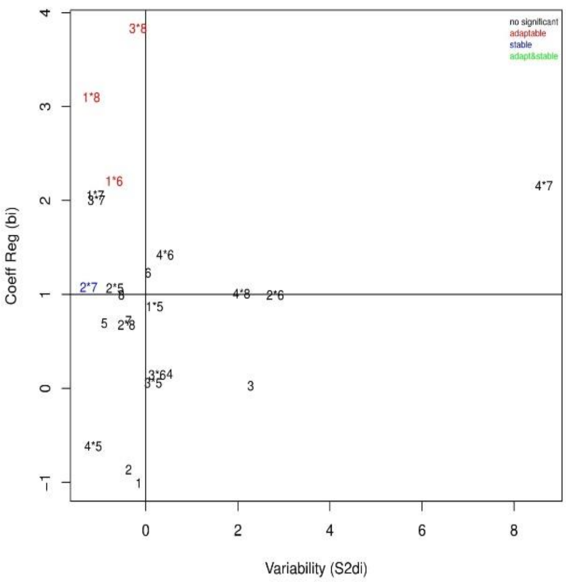

Figure 3. Stability and adaptability analysis for ears length

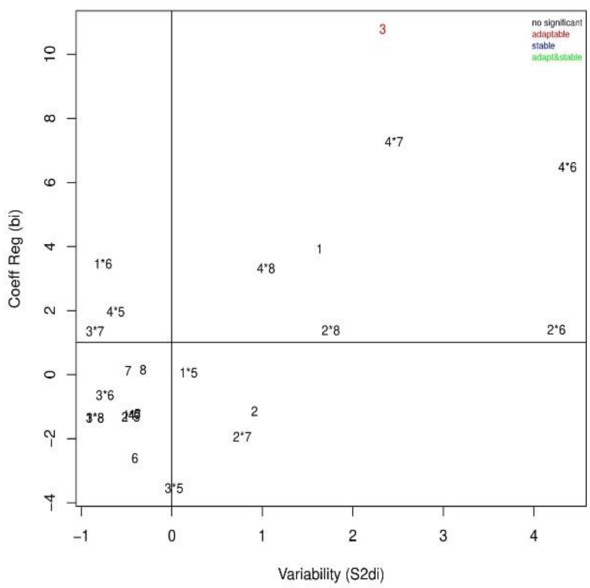

Figure 4 Stability and adaptability for Number of rows ear-1

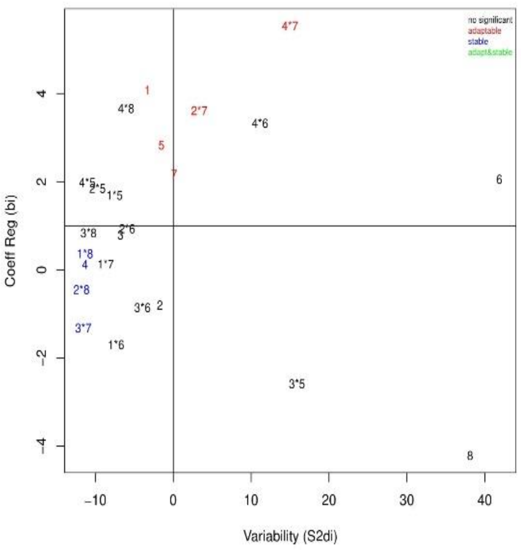

Figure 5. Stability and adaptability analysis for number of kernel row^{-1}

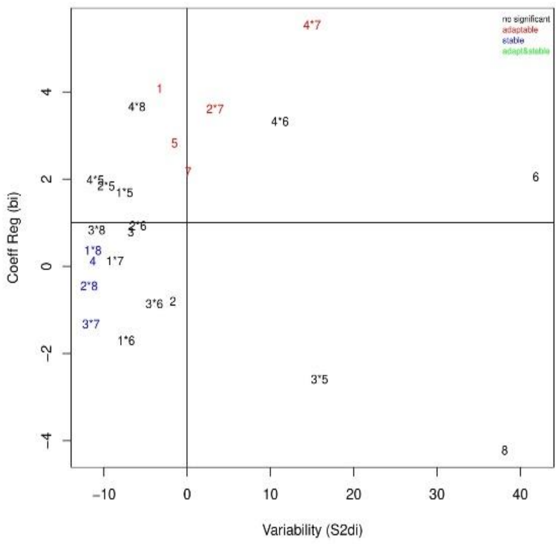

Figure 6. Stability and adaptability analysis for weight of kernel ear^{-1}

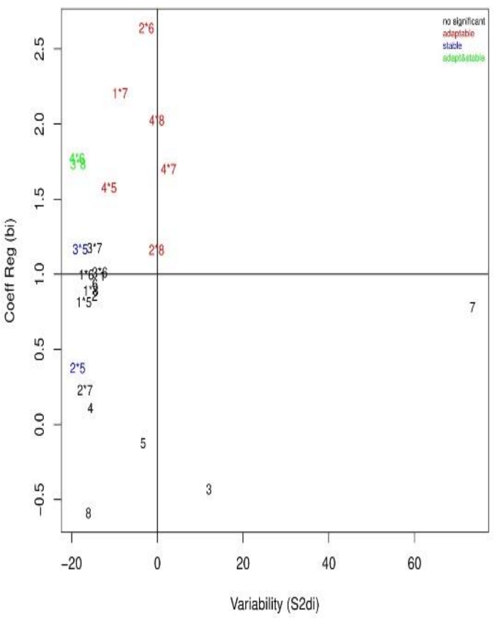

Figure 7. Stability and adaptability analysis for 300 kernel yield

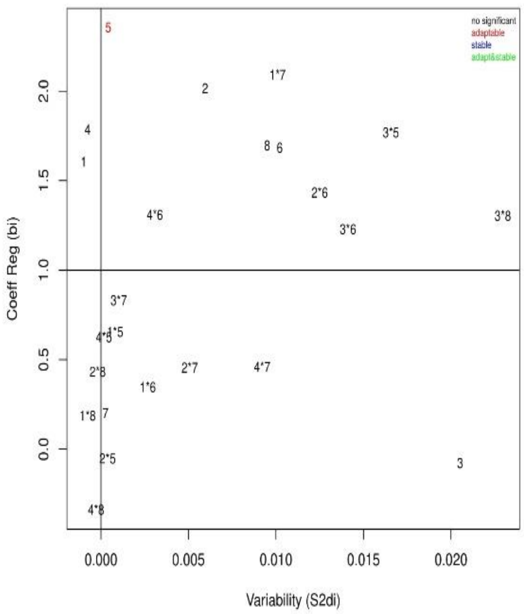

Figure 8. Stability and adaptability analysis for harvest index

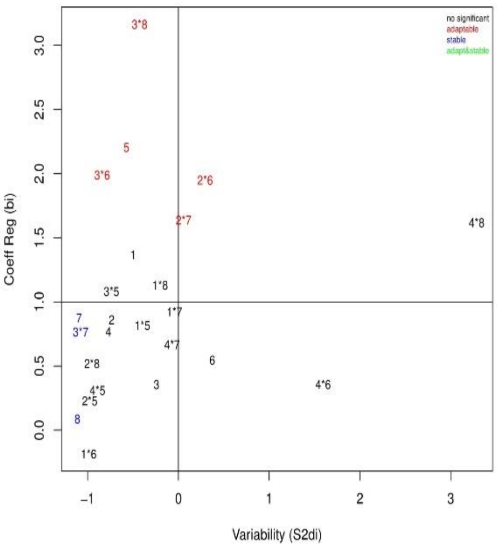

Figure 9: Stability and adaptability analysis for biological yield.

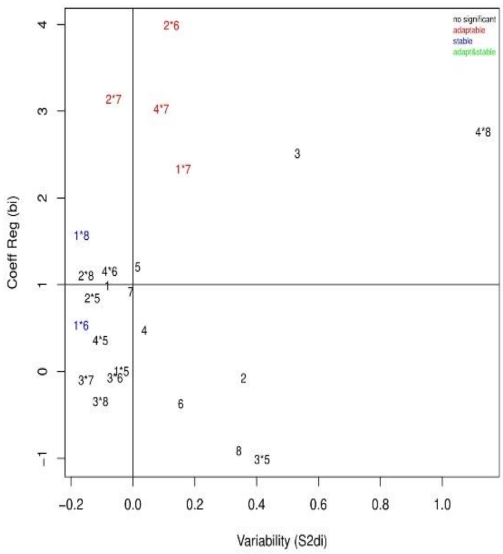

Figure 10: Stability and adaptability analysis for kernel

Their CV% were 16.80, 11.33, 14.72, 11.10, 16.84 and 9.10% respectively (Figure 16). For 300 kernel weight., it was found that the parents 1, 2, 3, 4, 5 and 6. were determined to be good performance and stable, recording 71.370, 66.868, 66.897, 62.647, 64.760 and 69.294 g respectively, with CV%% of 11.36, 10.47, 8.49, 2.74, 5.21 and 10.98%, respectively (Figure 17). The Crosses 1×5, 2×5, 2×8, and 4×8 with the parents1 and 5 were good performance and stable for the character. harvest index, recording 0.44, 0.407, 0.453, 0.461, 0.415 and 0.417 respectively their CV% were 9.27, 8.32, 6.52, 6.03, 9.69 and 16.06% respectively (Figure 18). Concerning biological yield, the crosses. 1×7, 4×6 and 4×7 were good performance and stable, with the mean values of 12.831, 13.710 and 16.07ton ha^{-1}, and their CV% were 13.42 910.68 and 8.52% respectively (Figure 19). According to Francis method the crosses 2×5, 2×8 and 4×6 with the parents and 5 were good performance and stable for the character kernel yield, recording 4.702, 4.555, 4.993, 4.822 and 4.657ton ha^{-1} respectively, and their CV% were 11.15, 14.46, 14.49, 13.08 and 16.99% respectively (Figure 20). The coefficient of variation (CV), which measures experimental accuracy, was 14.49%, classified as average for the productivity of maize grain (Fritsche-neto, 2012), and indicating good experimental precision. In other studies, with maize, the value for the coefficient of variation ranged from 10.66% (Cargnelutti, 2009) to 22.0% (Cardoso, 2012) for the characteristic of grain yield. Such satisfactory precision was confirmed by the high value for accuracy (0.76) obtained with the combined analysis (Resende and Duarqte, 2007). According to the results, it can be seen that the use of more than one method to estimate genetic parameters is a strategy that allows for greater reliability in the interpretation of data for the subsequent recommendation of cultivars. For (Cruz *et al.*, 2014), some methods are seen as alternatives, while others are complementary and can be used together.

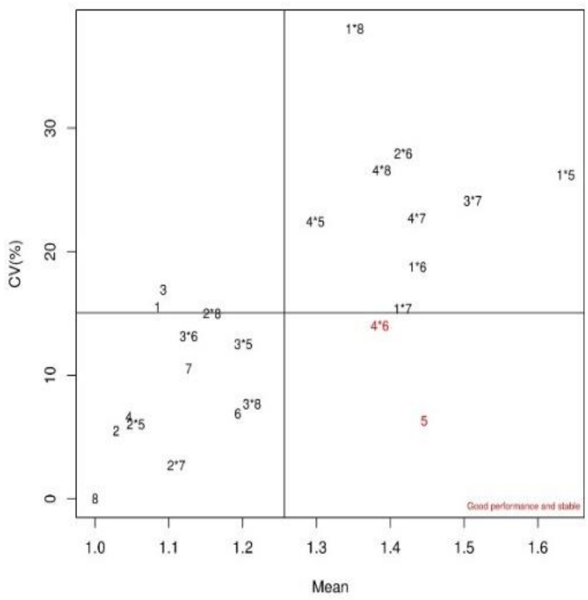

Figure 11: Stability and adaptability analysis for No. of ears plant[-1]

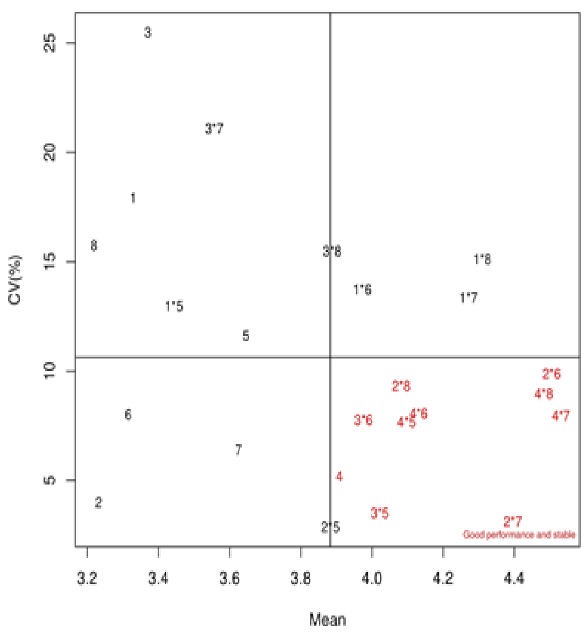

Figure 12: Stability and adaptability analysis for ears width

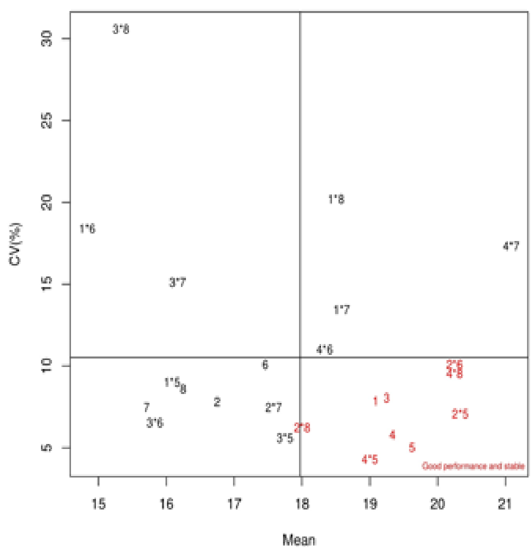

Figure 13: Stability and adaptability analysis for ear length.

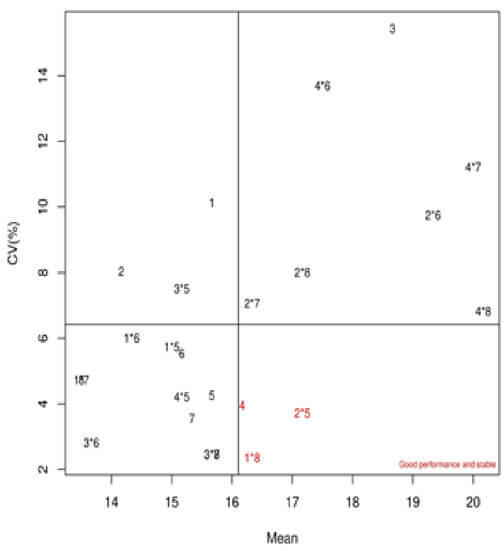

Figure 14: Stability and adaptability analysis for No. of rows ear-[1]

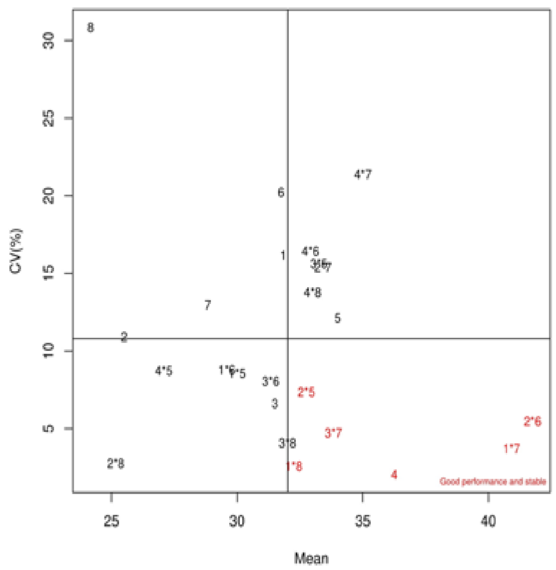

Figure 15: Stability and adaptability analysis for No. of kernel row^{-1}

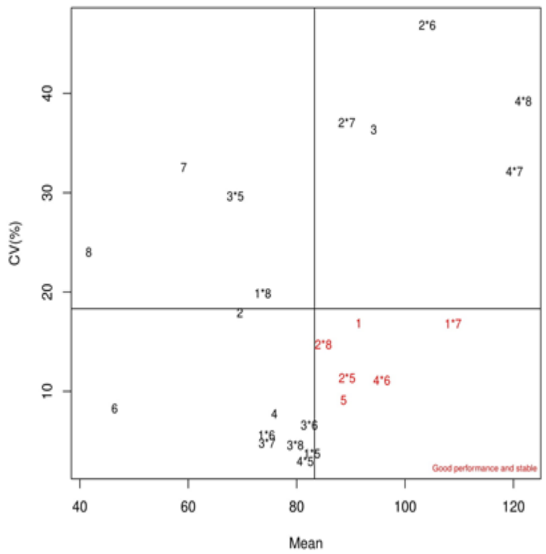

Figure 16: Stability and adaptability analysis for weight of kernel ear^{-1}

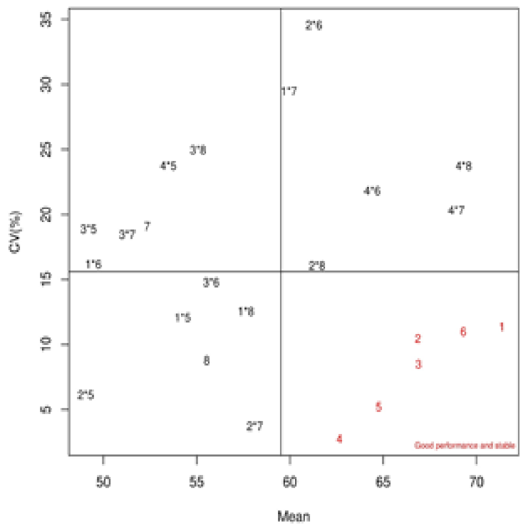

Figure 17: Stability and adaptability analysis for 300 kernel weight

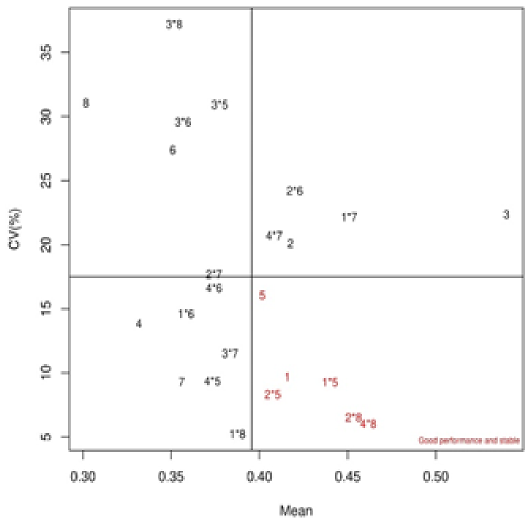

Figure 18: Stability and adaptability analysis for harvest index

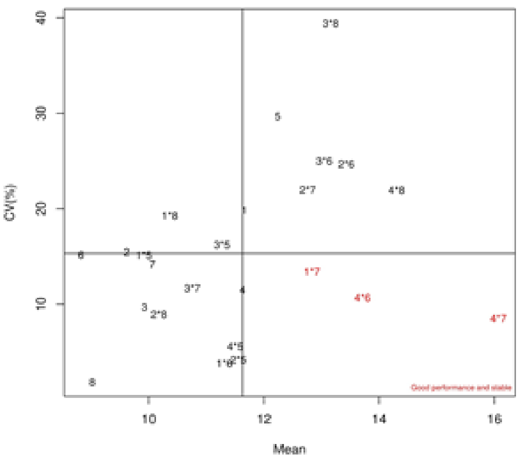

Figure 19: Stability and adaptability analysis for biological yield

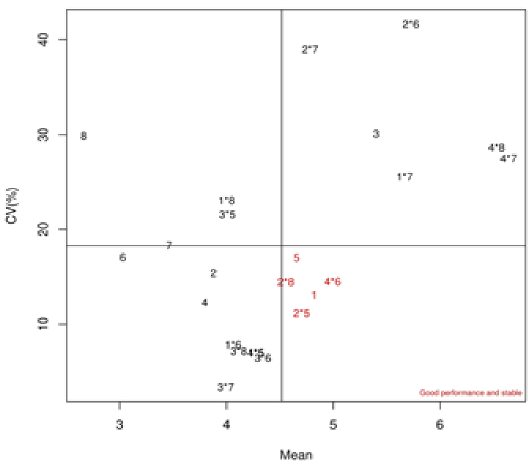

Figure 20: Stability and adaptability analysis for kernel yield

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