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Stability Analysis for Grain Yield and Its Quality Traits of some Rice Cultivars under Six Environments

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ABSTRACT

Multi-environment trials (METs) are essential in plant breeding programs to estimate crop productivity and adaptability in various environments. The present study was carried out at rice research farm Sakha Agricultural Station – Kafrelsheikh – Egypt, during the two seasons, 2022 and 2023 under three sowing dates, April 20th, May 10th and May30th. The rice cultivars were Sakha 106, Sakha 107 and Sakha 109 . A split – plot design in a randomized complete block design with three replications was used in both seasons. Combined analysis of variance showed highly significant mean squares for the varieties (v), environments (E) and their interaction (V x E) for all studies traits**.** The environments revealed that highest values by E_2 followed by E_5 for hulling, head rice %, GT and elongation. Meanwhile the highest values for the studied characters were recorded with Sakha-106 and Sakha-109 for hulling, milling%, head rice % and GT.

Conclusively: The rice cultivars Sakha-107 and sakha-109 recorded the positive values and lower than 1 of b_i it mean that these cultivars suitable for poor environments while, Sakha-106 gave high value of bi more than 1 it mean that these genotype is suitable for cultivation in favorable environments for Milling%, traits. The results provide a foundation for targeted breeding programs aimed at optimizing rice productivity by focusing on genotypes that consistently perform well across various growing conditions, considering both stability and adaptability.

Keywords: Rice varieties, Grain quality, sowing date, Multi-environment trials (METs); performance, phenotypic stability,

INTRODUCTION

Rice (*Oryza sativa* L.) is the second staple food crop that supported the bulk of the population livelihood in Egypt. In Egypt rice is considered as the most popular and important field crop for several reasons: as a staple food after wheat for the Egyptian population, and as a land reclamation crop for improving the productivity of the saline soils widely spread in North delta and coastal area. The exact sowing date for rice is play a vital role in improving its growth and increasing the yield **Muhammad *et al.* (2010)**

Varieties of directseeded rice differ in terms of temperature and light sensitivity and growth characteristics, resulting in varying adaptability to temperature and light during the late season **(Zhang *et al*., 2020 and Wang *et al*., 2022)**. The appropriate sowing date of the different varieties may fundamentally affect their characteristics. The sowing time of rice plant is important for several reasons; firstly it ensures that vegetative growth occurs during a period of satisfactory temperatures and high levels of solar radiation, secondly, the optimum sowing time for each cultivar ensures the cold sensitive stage occurs when the minimum night temperatures are historically the warmest, thirdly, sowing on time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality **(Osman 2019).**

Development of varieties for rice in Egypt with high yield and grain quality potential coupled with wide adaptability is an important plant breeding was main objective. The interaction between genotype and environment

(G×E) plays a crucial role in determining the performance of genetic materials, tested in different sowing date and in different years, influencing the selection process. The interaction estimates help breeders to decide the breeding strategy, to breed for specific or general adaptation, which depends on stability in yield and grain quality performance under a limited or wide range of environmental conditions **Hasan *et al.*, (2015)**.

MATERIALS AND METHODS

This study was conducted at rice research farm Sakha Agricultural Station – Kafrelsheikh – Egypt, during the two seasons, 2022 and 2023 under three sowing dates, April 20th, May 10thand May30th . The rice cultivars were Sakha 106, Sakha 107 and Sakha 109). In both seasons, each experiment had a split – plot design with three replications, where Sowing dates were located at the main plots and rice varieties were located in the sub- plots. Each replication included seven rows for each variety; the length of each row was 5m and the harvested 5 m^2. Plot size was 2 x 3 m. Nursery to raise the seedlings was laid out according to the proper season of individual site. Seedling of 25-30 days old was relocated at the dispersing of 20 x 15 cm. Two seedlings for each slope were continued in all destinations. The rate of NP 60:30 kg/fed was applied as follows, 30 kg P2O5 as single upper phosphate (15%P2O5) was applied in the long-lasting field and consolidated with soil during land groundwork for all replications. 60kg N/fed as urea (46.5%) was applied in two parts, the primary portion 2/3 added as basal application and consolidated with soil during land arrangement. While, the subsequent portion was top-dressed following 30 days of relocating. Origin, pedigree and type of the three rice cultivars and Monthly, temperature means and relative humidity (RH) at the study area during the experimental period were showed in Tables (1 and 2).

Table 1. Origin, pedigree and type of the thirteen rice cultivars

No.	Cultivar	Pedigree	Origin	Type
1	Sakha-106	(Giza 177 / Hexi 30)	Egypt	Japonica
2	Sakha-107	(Giza 177 / BL1)	Egypt	Japonica
3	Sakha-109	(Sakha101/Sakha105)	Egypt	Japonica

Table 2. Monthly, temperature means and relative humidity (RH) at the study area during the experimental period

Month	2022				2023			
	Air temperature (0C)		Relative humidity (RH)		Air temperature (0C)		Relative humidity (RH)	
	Max	Man	7:30	13:03	Max	Man	7:30	13:03
May	29	10	70.5	42.5	30	12	76.3	45
June	33	15	82.5	50	33	16.5	82.4	56
July	32	15.7	80	54.7	32.6	17.3	81	55
August	32	16.3	83.2	56	33.5	17.2	83.5	56.5
September	32.5	13	74.3	47.7	33	15	77.5	82
Mean	32	14	78.1	50.18	32.4	15.6	80.1	58.9

The studied characteristics are; hulling%, milling %, head rice %, GT, elongation, amylose and grain yield (g/plant.)

Statistical analysis: The combined analysis and comparison environment means using least significant difference (LSD) were analyzed according to **Gomez and Gomez (1984).** Every environment data was individually accustomed to analysis of Variance (ANOVA) to examine variances among genotypes for grain yield and pooled across locations to determine G x E interaction. For **Eberhart and Russell's** model, the significant G × E was used for stability analyses. A genotype with unit regression coefficient (bi=1) and deviation not significantly different from zero (S2di=0) was taken to be a stable genotype with the unit response. The mean comparisons among genotypes means were estimated by the least significant difference (LSD) test at 5% level of significance . The ANOVA was performed using RCBD to derive variance components using GenStat statistical package (12th edition) .Stability mean performance across environments was estimated according following different methods: Regression coefficient bi and deviation from regression S2di were done by **Eberhart and Russel (1966**). Ecovalence (Wi) is the contribution of genotype in the GEI (**Wricke, 1962**). Coefficient of variability (CV) of **Francis and Kannenburg (1978).** The GEA-R software was used for AMMI analysis according to **Angela *et al*. (2015).**

RESULTS

The obtained results from the present investigation in the two successive seasons 2022 and 2023 are presented and discussed in the three following topics.

1- Analysis of variance

The results in Table (3) the analysis of variance due to environments for the hulling%, milling %, head rice %, GT, elongation and amylose revealed highly significant differences. Meanwhile the analysis of variance among the Egyptian rice cultivars showed significant and highly significant for all studies traits. Moreover the sowing dates with respect to the two rice seasons as had shown significant and highly significant. Data presented showed that, highly significant mean squares due to the interaction between the rice cultivars and environments (sowing dates and two years) G x E indicating that, the rice cultivars interacted considerably with environmental conditions. Both linear and non-linear components of G x E interaction were found to be significant for all studied traits as indicated by highly significant mean squares due to G x E (linear) interaction and pooled deviation the results were agreement with found by **(Abd El-Aty *et al*., 2024)**.

Table (3): Mean square for grain quality and grain yield/plant characters during rice cultivars seasons.

SOV	Df	M.S						
		Hulling%	Milling %	Head rice %	GT	Elongation	Amylose	Grain yield/plant
Environment E	5	17718.09**	13294.57**	11704.29**	65.44**	4.85**	172171.13**	4386.41
Env . (linear) a)	1	9.62**	1.19**	2.59**	0.36**	0.00**	106.25**	71.02**
Genotypes	2	1.12**	4.23**	36.14**	0.08**	0.13**	213.75**	12.40**
Genotypes x Envir	10	8863.96**	6649.02**	5854.53**	32.98**	2.43**	86131.13**	2222.48**
V x Env. (linear) b)	2	14.80**	2.39**	8.72**	0.97**	0.00**	163.57**	107.56**
pooled deviations (c)	12	0.83**	0.95**	0.07**	0.03**	0.00**	1.86**	0.55**

2- Effects of Environments on Rice verities:

Data presented in Table (4) and Fig. (1), showed the effects of six environments (three sowing date and two years) on three cultivars for hulling and milling%. The environments revealed that highest values by E_2 (83.15) followed by E_5 (82.65) for hulling. Meanwhile the highest values for the studied characters were recorded with Sakha-106 (84.00%) and Sakha-109 (83.33%) under E_2. may be referred to the genetic background for these Japonica rice cultivars which more adaptable to earlier sowing date. The combined of analysis obtained that the cultivars Sakha-106 and Sakha-109 gave the highest values for hulling, moreover the cultivar Sakha-107 gave lowest value for this trait.

Regarding the environments revealed that highest values by E_2 (71.11%) followed by E_4 (70.46%) for milling%. The cultivars Sakha-106 and Sakha-109 rice recorded the highest values of milling % (73.33 and 70.44 % respectively) under environmental E_2. The combined of analysis obtained that the cultivars Sakha-106 and Sakha-109 gave the highest values for hulling, moreover the cultivar Sakha-107 gave lowest value for this trait.

Table 4: Mean average values for hulling and milling in some rice varieties under tested sties over environments during 2022 and 2023 seasons.

Genotypes	E1	E2	E3	E4	E5	E6	Mean
	Hulling%						
Sakha 106	**80.00**	**84.00**	**80.00**	**79.67**	**83.50**	**79.33**	**81.08**
Sakha 107	**79.78**	**82.11**	**80.33**	**78.67**	**82.33**	**80.08**	**80.55**
Sakha 109	**78.67**	**83.33**	**82.55**	**79.50**	**82.13**	**82.23**	**81.40**
Mean	**79.48**	**83.15**	**80.96**	**79.28**	**82.65**	**80.55**	**81.01**
	Milling %						
Sakha 106	**69.78**	**73.33**	**71.78**	**69.83**	**71.41**	**70.67**	**71.13**
Sakha 107	**69.33**	**69.56**	**69.11**	**72.03**	**68.73**	**68.73**	**69.58**
Sakha 109	**69.78**	**70.44**	**69.78**	**69.53**	**69.67**	**69.58**	**69.80**
Mean	**69.63**	**71.11**	**70.22**	**70.46**	**69.94**	**69.66**	**70.17**

The results in Table (5) the effects of six environments (three sowing date and two years) on three cultivars for head rice % and GT. The environments revealed that highest values by E_2 (67.26 %) followed by E_5 (67.05 %) for head rice %. Meanwhile the highest values for the character were recorded with Sakha-106 (69.78%) and Sakha-109 (67.78%) under E_2. The combined of analysis obtained that the cultivars Sakha-106 and Sakha-109 gave the highest values for head rice, moreover the cultivar Sakha-107 gave lowest value for this trait.

Meanwhile For GT the environments revealed that highest values by E2 (5.22) followed by E5 (5.11) for GT. The cultivar Sakha107 gave the high value for GT 5.33 in E_1, E_2 and E_5. While, Sakha-107 gave the lowest value of GT under environmental E_3 and E_6. The combined of analysis obtained that the cultivars Sakha-109 (5.06) and Sakha-106 (4.89) were the highest values for GT, moreover the cultivar Sakha-107 gave lowest value for this trait.

Table 5: Mean average values for Head rice %and GT of some rice varieties under tested sties over environments during 2022 and 2023 seasons.

Genotypes	E1	E2	E3	E4	E5	E6	Mean
	Head rice %						
Sakha 106	68.00	69.78	66.89	67.28	69.48	65.83	67.88
Sakha 107	63.56	64.22	62.44	62.75	64.33	61.40	63.12
Sakha 109	66.44	67.78	66.44	66.54	67.33	64.67	66.53
Mean	66.00	67.26	65.26	65.52	67.05	63.97	65.84
	GT						
Sakha 106	5.00	5.00	4.67	4.67	5.00	5.00	4.89
Sakha 107	5.33	5.33	4.00	5.00	5.33	4.00	4.83
Sakha 109	5.33	5.33	5.00	5.00	5.00	4.67	5.06
Mean	5.22	5.22	4.56	4.89	5.11	4.56	4.93

The results in Table (6) the effects of six environments (three sowing date and two years) on three cultivars for elongation and amylose. The environments revealed that highest values by E_2 and E_5 (1.37) for elongation. Meanwhile the highest values for the character were recorded with Sakha-109 (1.55 and 151) under E_2, E_3 and E_5 respectively. The combined of analysis obtained that the cultivars Sakha-109 (1.49) and Sakha106 (1.33) were these highest values for elongation; moreover the cultivar Sakha-107 gave lowest value for this trait.

Meanwhile For amylose the environments revealed that highest values by E_1 (257.45) followed by E_2 (256.33) for Amylose. The cultivar Sakha109 gave the high value for amylose (265.67 and 263.33) in E_1 and E_4 respectively. While, Sakha-107 gave the lowest value of Amylose under environmental E_6. The combined of analysis obtained that the cultivars Sakha-109 (258.00) and Sakha-106 (253.44) were the highest values for amylose; moreover the cultivar Sakha-107 gave lowest value for this trait.

Table 6: Mean average values for Elongation and Amylose of some rice varieties under tested sties over environments during 2022 and 2023 seasons.

Genotypes	E1	E2	E3	E4	E5	E6	Mean
	Elongation						
Sakha 106	1.34	1.35	1.31	1.32	1.34	1.32	1.33
Sakha 107	1.17	1.22	1.17	1.18	1.25	1.20	1.20
Sakha 109	1.49	1.55	1.51	1.42	1.51	1.47	1.49
Mean	1.33	1.37	1.33	1.31	1.37	1.33	1.34
	Amylose						
Sakha 106	257.00	258.33	247.33	256.67	254.67	246.67	253.44
Sakha 107	249.67	250.67	241.33	247.67	248.33	239.33	246.17
Sakha 109	265.67	260.00	252.00	263.33	258.33	248.67	258.00
Mean	257.45	256.33	246.89	255.89	253.78	254.07	257.45

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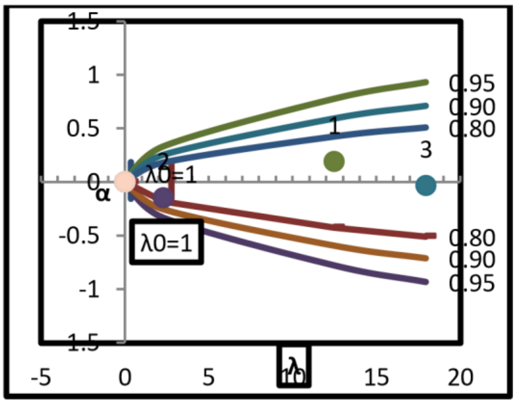
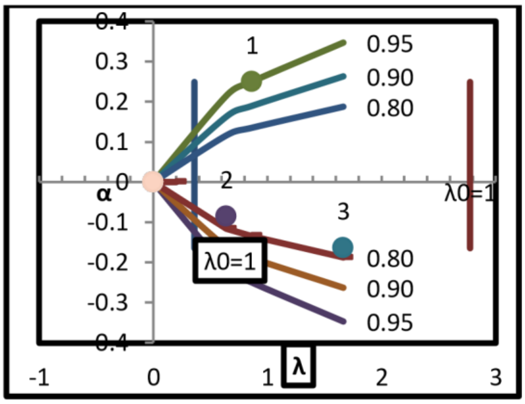
The results in Table (7) the effects of six environments (three sowing date and two years) on three cultivars for grain yield/plant. The environments revealed that highest values by E_4 (45.81) and E_5 (44.22) for grain yield. The cultivars Sakha-106 and Sakha-109 gave the heaviest grain yield 40.02 and 41.95 (g), respectively under environmental E_1. While, Sakha-107 gave the lowest value of grain yield 34.37 (g) under environmental E_3. According to these results, it could conclude that Sakha-106 and Sakha-109 were the best varieties regarding to grain yield and its components as average of these traits in two years and three sowing date of the investigation. This obtained results in agreement with **by (Sedeek *et al.*, 2009; Rawte *et al.*, 2021; Zhang *et al.*, 2023; AboYousef *et al.*, 2024; Abd El-Aty *et al.*, 2024; Ghazy *et al.*, 2024).**

Table 7: Mean values for grain yield/ plant of some rice varieties under tested sties over environments during 2022 and 2023 seasons.

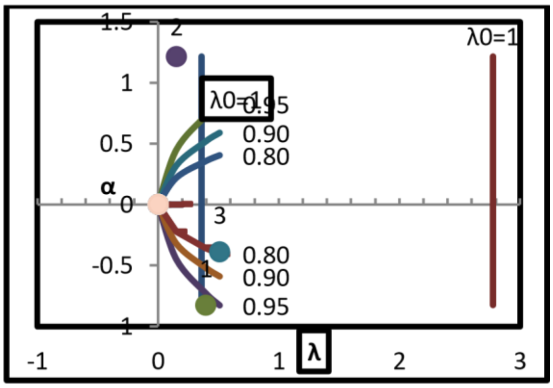
Genotypes	E1	E2	E3	E4	E5	E6	Mean
	Grain yield/ plant						
Sakha-106	**44.37**	**38.67**	**34.95**	**46.31**	**40.40**	**35.45**	**40.02**
Sakha-107	**42.74**	**40.48**	**34.37**	**43.20**	**39.53**	**34.52**	**39.14**
Sakha-109	**45.54**	**42.77**	**36.93**	**47.93**	**42.53**	**36.00**	**41.95**
Mean	**44.22**	**40.64**	**35.42**	**45.81**	**40.82**	**35.32**	**40.37**



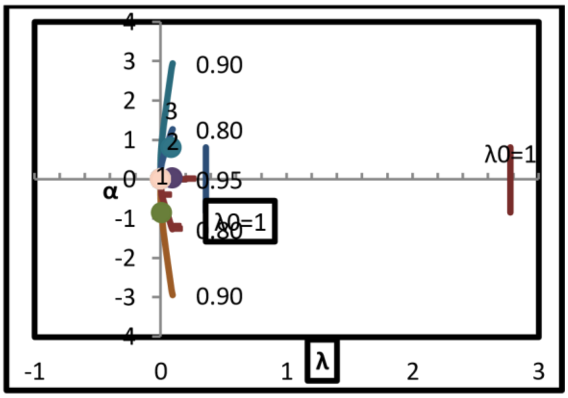
Hulling %



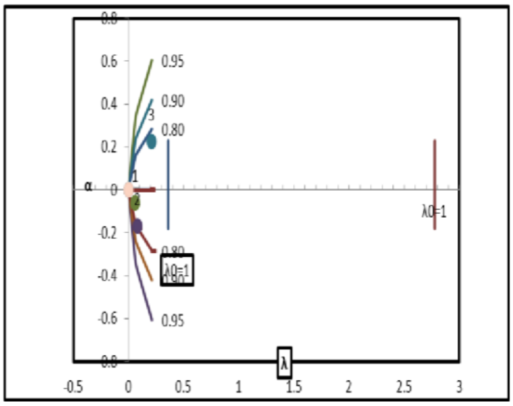
Milling %



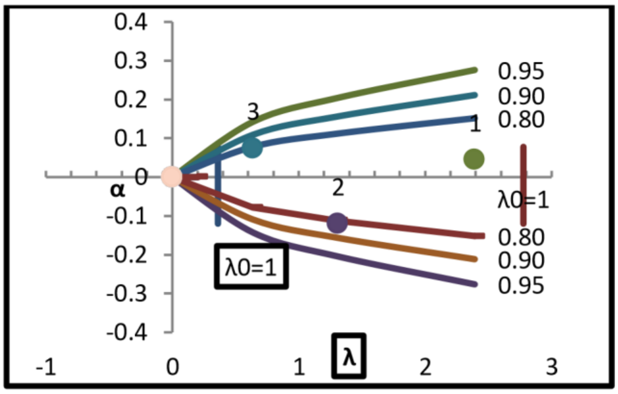
Head rice %



GT



Elongation



Grain yield / plant

3- Mean performance and Stability parameters:

Mainly, the genotype performance is depending on environmental interaction. It has been proved that estimation of phenotypic stability involving regression analysis is a suitable technique for the response assessment of different cultivars under environmental change. The evaluation of genotype- environmental interactions which is giving an idea of the buffering capacity of the population is still under study. The low magnitude of cultivars by environmental interaction consistent performance of a population over variable environments. Thus, stability analysis was done from the data of replicated trails conducted over three different locations for five years. However, the stability analysis depends on if the genotypes by environments interaction (G x E) found significant, the stability analysis can be carried out using one of the four known models. Thus, in our study, the Model was performed **(Eberhart and Russell, 1966)**.

The results in Table (8) showed the rice cultivars Sakha-107 and sakha-109 recorded the positive values and lower than 1 of b_i it mean that these cultivars suitable for poor environments while, Sakha-106 gave value of bi more than 1 it mean that these genotype is suitable for cultivation in favorable environments. Regarding to S^2di only Sakha-107 gave value near of 0 for hulling. on the other hand the rice cultivars Sakha-107 and sakha109 recorded the positive values and lower than 1 of b_i it mean that this cultivars suitable for poor environments while, Sakha-106 gave value of bi more than 1 it mean that these genotype is suitable for cultivation in favorable environments. Regarding to S^2di only Sakha-109 gave value near of 0 for milling.

Table (8) Mean performance and phenotypic stability measurements Hulling % and Milling % for three genotypes over six environments.

	Hulling %					Milling %				
Genotypes	**Mean**	**b i**	**S^2 di**	**W^2 i**	**CV i**	**Mean**	**b i**	**S^2 di**	**W^2 i**	**CV i**
Sakha 106	**81.08**	**1.18**	**0.949**	**4.23**	**2.57**	**71.13**	**1.66**	**1.175**	**5.41**	**1.89**
Sakha 107	**80.55**	**0.85**	**0.174**	**0.98**	**1.76**	**69.58**	**0.91**	**1.599**	**6.43**	**1.79**
Sakha 109	**81.40**	**0.96**	**1.364**	**5.48**	**2.29**	**69.80**	**0.43**	**0.059**	**0.77**	**0.48**
Mean	**81.01**					**70.17**				
LSD 0.05	**0.89**	**0.55**				**0.95**	**1.69**			
LSD 0.01	**1.24**	**0.78**				**1.33**	**2.37**			

The results in Table (9) showed the rice cultivars Sakha-107 and sakha-109 recorded the positive values and lower than 1 of bi it mean that these cultivars suitable for poor environments while, Sakha-106 gave value of bi more than 1 it mean that these genotype is suitable for cultivation in favorable environments. Regarding to S^2di only Sakha-107 gave value near of 0 for head rice %. moreover the rice cultivars Sakha-106 and sakha-109 recorded the positive values and lower than 1 of bi it mean that this cultivars suitable for poor environments while, Sakha-107 gave value of bi more than 1 it mean that these genotype is suitable for cultivation in favorable environments. Regarding to S^2di only Sakha-109 gave value near of 0 for GT.

Table (9) Mean performance and phenotypic stability measurements Head rice % and GT for three genotypes over six environments.

	Head rice %					GT				
Genotypes	**Mean**	**b i**	**S^2 di**	**W^2 i**	**CV i**	**Mean**	**b i**	**S^2 di**	**W^2 i**	**CV i**
Sakha 106	**67.88**	**1.24**	**0.056**	**0.66**	**2.25**	**4.89**	**0.28**	**0.027**	**0.36**	**3.52**
Sakha 107	**63.12**	**0.92**	**0.039**	**0.21**	**1.80**	**4.83**	**2.06**	**0.026**	**0.65**	**13.62**
Sakha 109	**66.53**	**0.84**	**0.104**	**0.61**	**1.60**	**5.06**	**0.66**	**0.025**	**0.16**	**4.96**
Mean	**65.84**					**4.93**				
LSD 0.05	**0.25**	**0.21**				**0.16**	**0.51**			
LSD 0.01	**0.35**	**0.29**				**0.22**	**0.72**			

The results in Table (10) showed the rice cultivar Sakha-106 recorded the positive value and lower than 1 of bi it mean that this cultivar suitable for poor environments while, Sakha-107 and Sakha-109 gives values of bi more than 1 it mean that these genotypes is suitable for cultivation in favorable environments. Regarding to S^2di only Sakha-107 and Sakha-106 gave value equal of 0 for elongation. Moreover the rice cultivars Sakha106 and sakha-107 recorded the positive values and lower than 1 of bi it mean that these cultivars suitable for poor environments while, Sakha-109 gave value of bi more than 1 it mean that these genotype is suitable for cultivation in favorable environments. Regarding to S^2di only Sakha-106 gave value near of 0 for amylose.

Table (10): Mean performance and phenotypic stability measurements Elongation and Amylose for three genotypes over six environments.

Genotypes	**Elongation**					**Amylose**				
	Mean	**b i**	**S^2 di**	**W^2 i**	**CV i**	**Mean**	**b i**	**S^2 di**	**W^2 i**	**CV i**
Sakha 106	**1.33**	**0.50**	**0.000**	**0.00**	**1.36**	**253.44**	**0.95**	**0.746**	**4.01**	**2.03**
Sakha 107	**1.20**	**1.02**	**0.000**	**0.00**	**2.76**	**246.17**	**0.86**	**1.138**	**8.09**	**1.90**
Sakha 109	**1.49**	**1.48**	**0.001**	**0.00**	**2.96**	**258.00**	**1.19**	**3.171***	**18.55**	**2.54**
Mean	**1.34**					**252.54**				
LSD 0.05	**0.02**	**0.76**				**1.33**	**0.25**			
LSD 0.01	**0.03**	**1.07**				**1.86**	**0.35**			

The results in Table (11) showed the rice cultivar Sakha-107 recorded the positive value and lower than 1 of bi it mean that this cultivar suitable for poor environments while, Sakha-106 and Sakha-109 gives values of bi more than 1 it mean that these genotypes is suitable for cultivation in favorable environments. Regarding to S^2di only Sakha-107 gave value near of 0 for grain yield/plant.

Table (11) Mean performance and phenotypic stability measurements of grain yield/plant for three genotypes over six environments.

	Grain yield/ plant				
Genotypes	**Mean**	**b i**	**S^2 di**	**W^2 i**	**CV i**
Sakha 106	**40.02**	**1.04**	**0.907**	**3.84**	**11.56**
Sakha 107	**39.14**	**0.88**	**0.496**	**3.34**	**9.93**
Sakha 109	**41.95**	**1.07**	**0.239**	**1.50**	**11.19**
Mean	**40.37**				
LSD 0.05	**0.72**	**0.17**			
LSD 0.01	**1.01**	**0.23**			

DISCUSSION

The results of our study indicate that the genotypes we tested in different sowing date over two consecutive years are extremely susceptible to climatic and environmental factors **(Chandramohan *et al*., 2023).** The variations seen may be climatic circumstances among various sowing date and years where the experiments were carried out. Achieving effective breeding outcomes for yield and its quality traits in rice necessitates precise measurement and analysis of genotype, environment, years, and their interactions within the breeding protocol **(Thirumalai *et al*., 2018).** Significant effects of both linear and nonlinear components of G × E interaction were seen for all examined traits, as evidenced by highly significant mean squares resulting from G × E (linear) interaction and pooled deviation. The reported results are consistent with those obtained by **(Zewdu *et al*., 2020).** The grain production of different rice varieties exhibited significant variations in response to changes in climatic variables, such as planting dates and years Singh, A.K. and Kumar, S. (2019).Therefore, the phenotypic stability assessment took into account both the linear (bi) and nonlinear (S^2di) components of G × E interactions [**Ali *et al*., 2022**]. Moreover, it has been documented that a high average value of the linear regression coefficient, equivalent to the nonlinear coefficient, is advised for achieving a diverse range. The ideal cultivars would be the one with high mean, regression coefficient equal to unity (b=1) and low deviation mean squares (Sd1=0). The statistics “b” measures the linear response of individual cultivar to an environmental index, whereas S^2di refers to deviations from this response. Hence, linear (bi) and nonlinear (S^2di) component of G x E interactions were considered in the phenotypic stability assessment. Furthermore, it has been reported that, the high mean of linear regression coefficient equal to non-linear is recommended for good variety. Also, it has been indicated that the non-linear regression could be used for stability measurement whereas the linear regression could be used to measure, the varietal response to various environmental conditions **(Ravindra *et al*., 2012 and Girma 2018).**

They further pointed out that the varieties exhibiting high regression coefficients (b>1) could be considered as below average stable varieties. Such varieties will perform well only in favorable environments while their performance will be poor in unfavorable environments. The varieties with low regression coefficients (bi<1) are above average stable and are adapted especially to poor environments **(Abo-Yousef *et al*., 2024; Abd El-Aty *et al*., 2024and Ghazy *et al*., 2024).** This indicates that the system is well suited for favorable situations, but its performance will be subpar in unfavorable environments. Therefore, these rice cultivars possess significant value for conducting investigations in harsh environments, as the identified types have been suggested for their suitability in unfavorable environmental conditions. The results were obtained reported by **(El-Aty *et al*., 2022). Hasan *et al*., (2015) and Parimala *et al*., (2019). (Abo-Yousef et al., 2024; Abd El-Aty *et al*., 2024 and Ghazy *et al.*, 2024).**

Conclusions

This study highlights that environmental factors are the primary drivers of variations in rice yield and and grain quality traits among Egyptian rice genotypes, with genotype environment interactions playing a secondary role. These findings underscore the importance of multi-environmental trials for selecting stable, high-yielding rice cultivars. The results provide a foundation for targeted breeding programs aimed at optimizing rice productivity by focusing on genotypes that consistently perform well across various growing conditions, considering both stability and adaptability.

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