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Estimation of stability parameters for yield and its components traits under foliar application of baker's yeast at different concentrations and fermentation periods in genotypes of roselle (*Hibiscus sabdariffa*)

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ABSTRACT

A field experiment was conducted during the summer growing season of 2025 at one of the fields of the Agricultural Research and Experimentation Center, College of Agriculture, University of Kirkuk, Iraq. The study aimed to investigate the effect of genotypes (Hit Black, Hit Red, Areb, and Sudan-3) and foliar application of different concentrations of dry baker's yeast suspension under two fermentation periods (control treatment, 3 g/96 h, 6 g/96 h, 9 g/96 h, 3 g/120 h, 6 g/120 h, and 9 g/120 h). The experiment was arranged according to a Randomized Complete Block Design (R.C.B.D.) within a factorial experiment, with three replicates. The studied genotypes exhibited clear variation in their degree of stability across different environments. The genotype Hit Red demonstrated stability in most traits, including calyx yield, seed yield, and several other characteristics. However, it did not exhibit stability in days from sowing to 50% flowering, number of branches, and fresh and dry capsule weight..

KEYWORDS: (*Hibiscus sabdariffa* L.), genotypes, baker's yeast, stability.

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تقدير معاملات الثبات لصفات الحاصل ومكوناته تحت تأثير الرش الورقي بخميرة الخبز بتراكيز وفترات تخمير مختلفة في التراكيب الوراثية للكركديه (Hibiscus sabdariffa)

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الملخص

أُجريت تجربة حقلية خلال الموسم الصيفي لعام 2025 في أحد حقول مركز البحوث والتجارب الزراعية، كلية الزراعة، جامعة كركوك، العراق. هدفت الدراسة إلى تقييم تأثير التراكيب الوراثية **(Hit Black ، Hit Red ،Areb، و Sudan-3)** والرش الورقي بمعلقات خميرة الخبز الجافة بتراكيز مختلفة وتحت فترتي تخمير (معاملة المقارنة، 3 غم/96 ساعة، 6 غم/96 ساعة، 9 غم/96 ساعة، 3 غم/120 ساعة، 6 غم/120 ساعة، و9 غم/120 ساعة).

نُفذت التجربة وفق تصميم القطاعات العشوائية الكاملة **(R.C.B.D.)** ضمن تجربة عاملية وبثلاث مكررات. أظهرت التراكيب الوراثية المدروسة تبايناً واضحاً في درجة ثباتها عبر البيئات المختلفة. إذ أظهر التركيب الوراثي **Hit Red** ثباتاً في معظم الصفات، بما في ذلك حاصل الكأس الزهري وحاصل البذور وعدد من الصفات الأخرى، إلا أنه لم يُظهر ثباتاً في عدد الأيام من الزراعة حتى التزهير بنسبة 50%، وعدد الأفرع، ووزن الكبسولات الطازجة والجافة.

الكلمات المفتاحية :الكركديه***(Hibiscus sabdariffa L.)*** ، التراكيب الوراثية، خميرة الخبز، الثبات.

INTRODUCTION

Nature has long provided bioactive chemical substances suitable for medicinal use. Medicinal plants have significantly contributed to the discovery of biologically active compounds that form the basis of many modern pharmaceuticals. Since ancient times, they have been utilized as traditional herbal remedies, and their diverse chemical constituents have played a crucial role in the development of antioxidant, anti-inflammatory, anticancer, and antibacterial drugs, among others. Recent studies indicate a growing global interest in what is termed "green medicine" due to its vast chemical

diversity and promising therapeutic potential, whether in the form of purified compounds or plant extracts (Mohammed *et al*., 2025). Roselle (*Hibiscus sabdariffa* L.) is one of the important medicinal plants belonging to the family Malvaceae, a large and widely distributed family comprising approximately 82 genera and 1,500 species (Ajithadoss *et al*., 2006). Roselle is used medicinally for reducing blood pressure, treating arteriosclerosis, and as an antioxidant and antimutagenic agent. It is also considered antipyretic and has roles in ulcer treatment and improving hair density (Kilic *et al*., 2011). Genotypic stability (whether of a cultivar, strain, or hybrid) refers to the consistency of superior performance in yield and its components under varying environmental conditions. Stability in performance is considered one of the most desirable characteristics of a genotype, upon which it can be recommended as a suitable cultivar across a wide range of environmental variations. To evaluate phenotypic stability of genotypes, it is necessary to conduct trials across diverse environmental locations, over multiple years with differing environmental conditions, or across several years and locations simultaneously (Al-Zubaidi and Al-Jubouri, 2016). Singh and Chaudhary (2007) indicated that genotypic stability can also be assessed in non-replicated trials by creating variable environmental conditions through the application of different agronomic practices. These may include sowing genotypes at different planting dates within the same season, adopting varying plant or row spacing, or applying different fertilizer levels, irrigation methods, or other cultural practices. Such variations represent diverse environmental conditions under which the stability of genotypic performance for yield and its components can be evaluated despite differing management practices. The response of genotypes to environmental changes makes it difficult for plant breeders to identify superior genotypes. Therefore, breeders tend to focus on genotypes that exhibit minimal or no genotype x environment interaction. A genotype selected for high productivity under specific environmental conditions may not maintain its superiority when cultivated under different environments. Accordingly, the selection of genotypes possessing desirable traits, high productivity, and stability across a broad range of environmental conditions represents a primary objective of most plant breeding programs (Knapp *et al*., 2017). Several researchers have studied stability parameters in other crops, including Al-Zubaidi (2016), Mohammed (2020), Al-Qassi and Mohammed (2023), and Sarteb and Mohammed (2023). Studying the genetic stability of field and productivity traits of genetic combinations used under different environmental conditions.

MATERIALS AND METHODS

The experiment was conducted according to a Randomized Complete Block Design (RCBD) involving four roselle genotypes: V_1= Hit Black, V_2= Hit Red, V_3= Areb, and V_4= Sudan3. These genotypes were evaluated under seven environments representing combinations of dry baker's yeast concentrations and fermentation periods, namely: water spray only (control), 3 g/96 h, 6 g/96 h, 9

g/96 h, 3 g/120 h, 6 g/120 h, and 9 g/120 h. The field trial was carried out at the Agricultural Research and Experimentation Station, College of Agriculture, University of Kirkuk (35.16° N latitude and 44.42° E longitude) during the summer growing season of 2025. Seeds were sown on 20/4/2025, and harvesting was performed on 31/10/2025. Each experimental unit measured 3 x 1.5 m (4.5 m²) and consisted of three rows spaced 0.75 m apart, with 0.5 m between plants within the row. The field was divided into three replicates, resulting in a total of 84 experimental units, with each replicate containing 28 units. The active yeast suspension was prepared following the method described by Al-Samarrai *et al.* (2011) with slight modifications. Dry baker's yeast was dissolved at concentrations of 3, 6, and 9 g/L in one liter of distilled water. Twenty grams of sugar and 0.125 g of citric acid were added to adjust medium acidity. The solution was left in an open container at 35°C for aerobic fermentation, with hourly stirring, for two fermentation periods (96 and 120 hours). Plants were sprayed to full wetness one month after sowing, and spraying was repeated at 15-day intervals. Data were analyzed for stability parameters according to the model of Eberhart and Russell (1966). A genotype was considered stable when it exhibited a regression coefficient equal to unity (bi = 1) and a non-significant deviation from regression (S_{di}^2 = 0). The Eberhart and Russell (1966) method was employed to assess stability and to determine the predictability of genotype performance under varying environmental conditions. The seven environments were represented by the combinations resulting from the interaction between genotypes and yeast spray treatments. Stability parameters were estimated across different environments based on the adopted analytical model (Al-Zubaidi and Al-Jubouri, 2016). Data analysis was performed using the Agri Analyze statistical software.In summary, the evaluation of genotypic stability—whether for pure lines, cultivars, or hybrids—in any study based on the two stability parameters (bi and S_{di}^2) can be interpreted as follows:

1. If S_{di}^2 = 0 and bi > 1, Varieties respond to good environments (high-input or optimal) environments.
2. If S_{di}^2 = 0 and bi = 1, Varieties that are less responsive to environmental changes and are highly stable.
3. If S_{di}^2 = 0 and bi < 1, These varieties grow well in unfavorable environments.
4. If S_{di}^2 > 0, the linear prediction is weakened, indicating instability and reduced reliability of performance across environments.

RESULTS AND DISCUSSION

Interaction Variance Analysis (Genetic x Environmental) for Yield and Its Components Table (1) shows that the effect of genotypes was significant for number of capsules per plant, dry calyx weight, number of seeds per capsule, and seed yield per plant; significant for fresh calyx weight and yield per plant; and non-significant for the remaining traits. The genotype x environment interaction was

significant at the 1% level for dry calyx weight and dry calyx yield per plant, and at the 5% level for number of seeds per capsule, while it was non-significant for the other traits. The pooled deviation was also significant at the 1% level for fresh capsule weight, dry capsule weight, fresh calyx weight, dry calyx weight, and number of seeds per capsule; and at the 5% level for 500-seed weight, whereas it was non-significant for the remaining traits. The appendix further indicates that the genotype Hit Black showed significance at the 1% level for dry capsule weight, dry calyx weight, and number of seeds per capsule, and also at the 1% level for 500-seed weight and dry calyx yield per plant, while it was non-significant for the other traits. The genotype Hit Red was significant at the 1% level for fresh capsule weight and dry capsule weight, and at the 5% level for number of seeds per capsule, but non-significant for the remaining traits. The genotype Areb was significant at the 1% level for dry capsule weight, fresh calyx weight, and 500-seed weight, and at the 5% level for dry calyx weight, while it was non-significant for the other traits. The genotype Sudan-3 showed significance at the 1% level for fresh capsule weight, and at the 5% level for dry capsule weight, fresh calyx weight, dry calyx weight, and number of seeds per capsule, whereas it was non-significant for the remaining traits. The presence of significant interactions for certain traits indicates differential performance of some genotypes depending on the environmental conditions under which they were grown. The results also revealed that the magnitude of variance attributed to environments was considerably greater than that attributed to genotypes and to genotype x environment interaction for some traits. In contrast, for other traits, the variance due to genotypes was greater than or comparable to that resulting from genotype x environment interaction.

Table (1): Analysis of variance for the stability of yield and its components.

Sources of Variation	Degrees of Freedom	Traits								
		Number of capsules per plant (capsule plant^{-1})	Fresh capsule weight (g plant^{-1})	Dry capsule weight (g plant^{-1})	Fresh calyx weight (g plant^{-1})	Dry calyx weight (g plant^{-1})	Number of seeds per capsule (seed capsule^{-1})	Weight of 500 seeds (g)	Dry calyx yield per plant (g plant^{-1})	Seed yield per plant (g plant^{-1})
Genotypes	3	3662.51 **	0.55 n.s	0.23 n.s	0.29 *	0.01**	25.32**	5.23 n.s	252.91*	9285.42 **
Environments + (Genotypes x Environments)	24	758.42	0.29	0.21	0.09	0.01	3.01	2.52	661.32	698.50
Environments (Linear)	1	3972.12	2.03	2.62	0.38	0.10	13.49	8.50	4111.78	7765.24
Genotypes x Environments (Linear)	3	831.17n.s	0.43 n.s	0.04 n.s	0.12 n.s	0.08**	6.27*	0.74 n.s	3271.35 **	609.28n.s
Pooled Deviation	20	586.82n.s	0.19 **	0.11 **	0.07 **	0.0017 **	2.0017 **	2.49*	97.30n.s	358.54n.s
Hit Black	5	673.91n.s	0.03 n.s	0.10 **	0.04 n.s	0.0040 **	2.51**	3.05*	158.61*	551.45n.s
Hit Red	5	609.02n.s	0.26 **	0.15 **	0.02 n.s	0.0007 n.s	2.03*	1.49 n.s	125.75n.s	322.25n.s
Areb	5	887.07n.s	0.05 n.s	0.12 **	0.07 **	0.0011 *	1.29n.s	4.12 **	54.17n.s	289.95n.s
Sudan-3	5	177.30n.s	0.41 **	0.07*	0.14*	0.0011 *	2.16*	1.29 n.s	50.66n.s	270.51n.s
Pooled Error	42	405.57	0.06	0.02	0.02	0.0004	0.65	1.09	62.09	716.48

Number of Capsules per Plant (capsule plant^{-1})

Table (2) presents the stability parameters for the trait number of capsules per plant, showing the mean performance of each genotype along with the linear regression coefficient (bi). The regression coefficient significantly deviated from zero only for the genotype Aareb, with a value of 2.07, while the other genotypes showed non-significant deviation from zero. However, the regression coefficient did not significantly deviate from unity (bi = 1), and the mean square deviation from regression (S_{di}^2) was non-significant for all genotypes with respect to this trait. The results indicate that all genotypes were stable for number of capsules per plant. Hit Black and Hit Red recorded low but stable values, whereas Aareb achieved a high value and was responsive to favorable environments. In contrast, Sudan-3 showed a high value and was responsive to unfavorable environments, as illustrated in Figure (1).

Table (2): Stability parameters for number of capsules per plant (capsule plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S_{di}^2	Inference
Hit Black	197.39	1.56	1.89 n.s	-0.68 n.s	268.34 n.s	Low value, but stable.
Hit Red	218.73	0.0076	0.0097 n.s	1.26 n.s	203.44 n.s	Low value, but stable.
Areb	245.61	1.96	2.07 *	-1.01 n.s	481.50 n.s	High value, responsive to favorable environments, and stable.
Sudan-3	243.72	0.46	1.10 n.s	1.25 n.s	-228.26 n.s	High value, responsive to unfavorable environments, and stable.

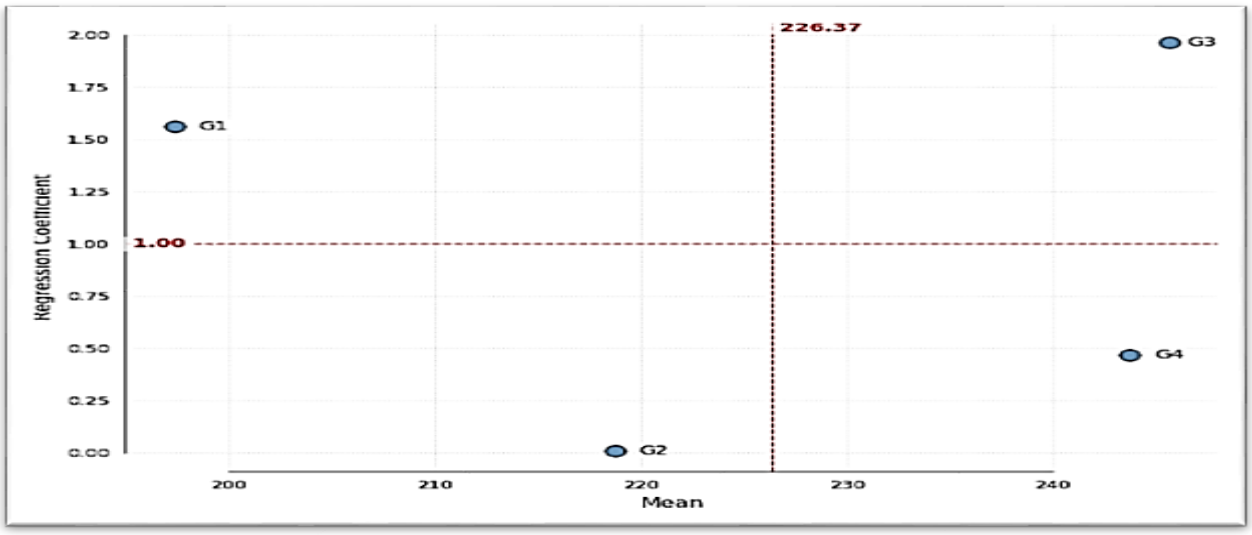

Figure 1. Regression coefficient (bi) for number of capsules per plant (capsule plant^{-1}).

Fresh Capsule Weight (g plant^{-1})

Table (3) presents the stability parameters for fresh capsule weight, including the mean performance of each genotype and the linear regression coefficient (bi). The regression coefficient significantly deviated from zero for Hit Black (3.03), Aareb (4.05), and Sudan-3 (2.23), whereas Hit Red showed a non-significant deviation. The regression coefficient did not significantly deviate from unity (bi = 1) for any of the genotypes. However, the mean square deviation from regression (S_{di}^2) was significant for Hit Red and Sudan-3, with values of 0.19 and 0.35, respectively, while it was non-significant for the remaining genotypes for this trait. The results indicate that some genotypes were stable, such as Hit Black and Aareb, whereas Hit Red and Sudan-3 were unstable. Aareb exhibited a high mean value and good responsiveness to favorable environments, while Hit Black recorded a low value. In contrast, Hit Red and Sudan-3 achieved high values but lacked stability, as illustrated in Figure (2).

Table 3. Stability parameters for fresh capsule weight (g plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S_{di}^2	Inference
Hit Black	5.18	0.79	3.03 **	0.77 n.s	-0.03 n.s	Low value, but stable.
Hit Red	5.58	-0.16	-0.23 n.s	1.63 n.s	0.19 **	High value, but unstable.
Areb	5.84	1.34	4.05**	-1.04 n.s	-0.0099 n.s	High value, responsive to favorable environments, and stable.
Sudan-3	5.70	2.02	2.23*	-1.12 n.s	0.35**	High value, but unstable.

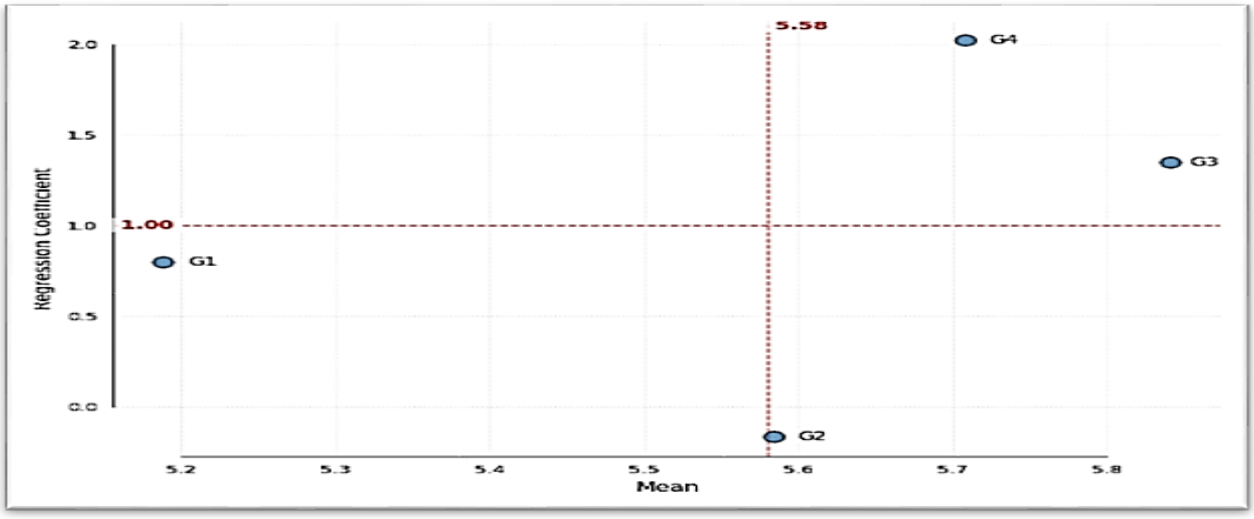

Figure 2. Regression coefficient (bi) for fresh capsule weight (g plant^{-1}).

Dry Capsule Weight (g plant^{-1})

Table (4) presents the stability parameters for dry capsule weight, including the mean performance of each genotype and the linear regression coefficient (bi). All genotypes showed a significant deviation of the regression coefficient from zero: Hit Black (2.58), Hit Red (2.75), Aareb (2.02), and Sudan-3 (2.17). However, the regression coefficient did not significantly deviate from unity (bi = 1) for any genotype. The mean square deviation from regression (S_{di}^2) was significant for all genotypes: Hit Black (0.07), Hit Red (0.12), Aareb (0.10), and Sudan-3 (0.04), indicating instability for this trait. The results demonstrate that Hit Black did not exhibit stability and recorded a low mean value. Although Aareb was characterized by a high mean value, it was unstable. Similarly, Hit Red and Sudan-3 were also unstable, as illustrated in Figure (3).

Table 4. Stability parameters for dry capsule weight (g plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S_{di}^2	Inference
Hit Black	1.86	1.03	2.58*	-0.08 n.s	0.07**	Low value, moderately responsive, and unstable.
Hit Red	1.94	1.34	2.75**	-0.69 n.s	0.12**	Low value, responsive to favorable environments, and unstable.
Areb	2.10	0.89	2.02*	0.22 n.s	0.10**	High value, but unstable.
Sudan-3	2.27	0.72	2.17*	0.82 n.s	0.04 *	High value, but unstable.

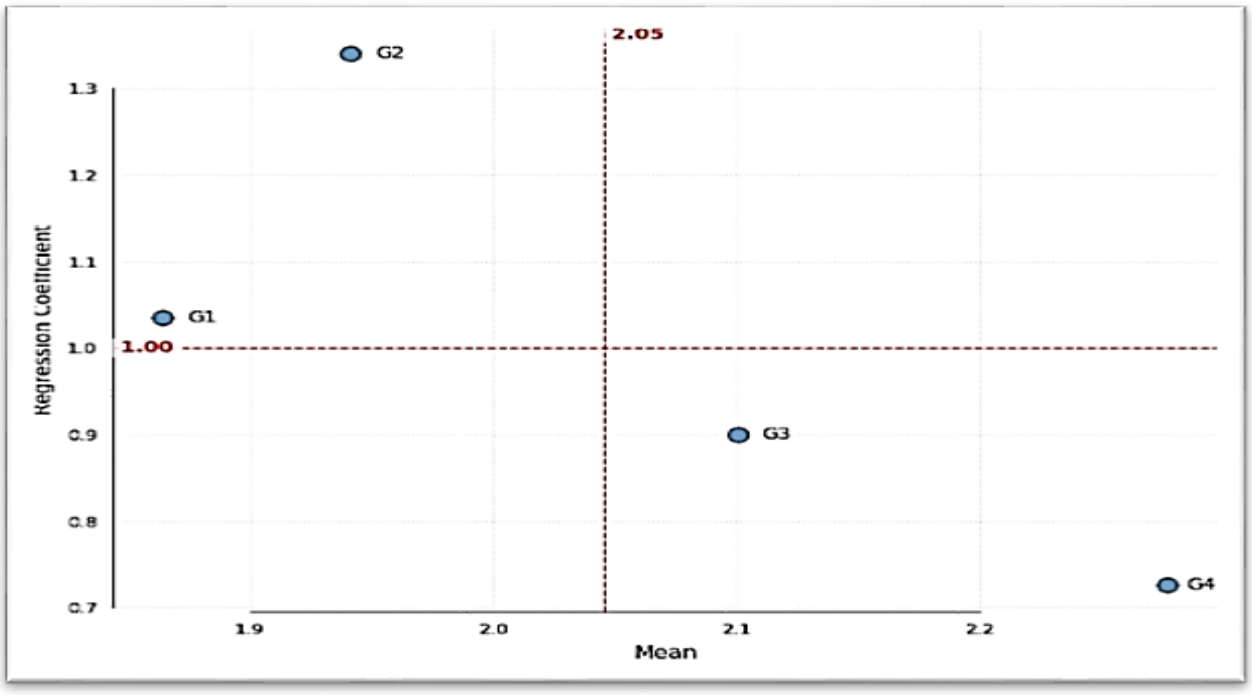

Figure 3. Regression coefficient (bi) for dry capsule weight (g plant^{-1}).

Fresh Calyx Weight (g plant^{-1})

Table (5) presents the stability parameters for fresh calyx weight, showing the mean performance of each genotype along with the linear regression coefficient (bi). The regression coefficient significantly deviated from zero only for the genotype Hit Red (5.03), while Hit Black, Aareb, and Sudan-3 showed non-significant deviation. The regression coefficient's deviation from unity (bi = 1) was significant for Hit Black (2.12) and Hit Red (-2.94), but non-significant for the remaining genotypes. The mean square deviation from regression (S_{di}^2) was significant for Aareb (0.05) and Sudan-3 (0.12), whereas it was non-significant for Hit Black and Hit Red.These results indicate that Hit Black and Hit Red had low but stable values, reflecting consistent performance across different environments. In contrast, Aareb and Sudan-3 exhibited high values but were unstable, as illustrated in Figure (4). The regression coefficient highlights the instability of Aareb and Sudan-3 compared to the stable behavior of Hit Black and Hit Red.

Table 5. Stability parameters for fresh calyx weight (g plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S_{di}^2	Inference
Hit Black	2.19	-0.43	-0.64 n.s	2.12*	0.02 n.s	Low value, but stable.
Hit Red	2.32	2.40	5.03**	-2.94**	-0.0007 n.s	Low value, but stable.
Areb	2.67	1.10	1.23 n.s	-0.11 n.s	0.05*	High value, but unstable.
Sudan-3	2.4562	0.9220	0.7509 n.s	0.0635 n.s	0.1224 **	High value, but unstable.

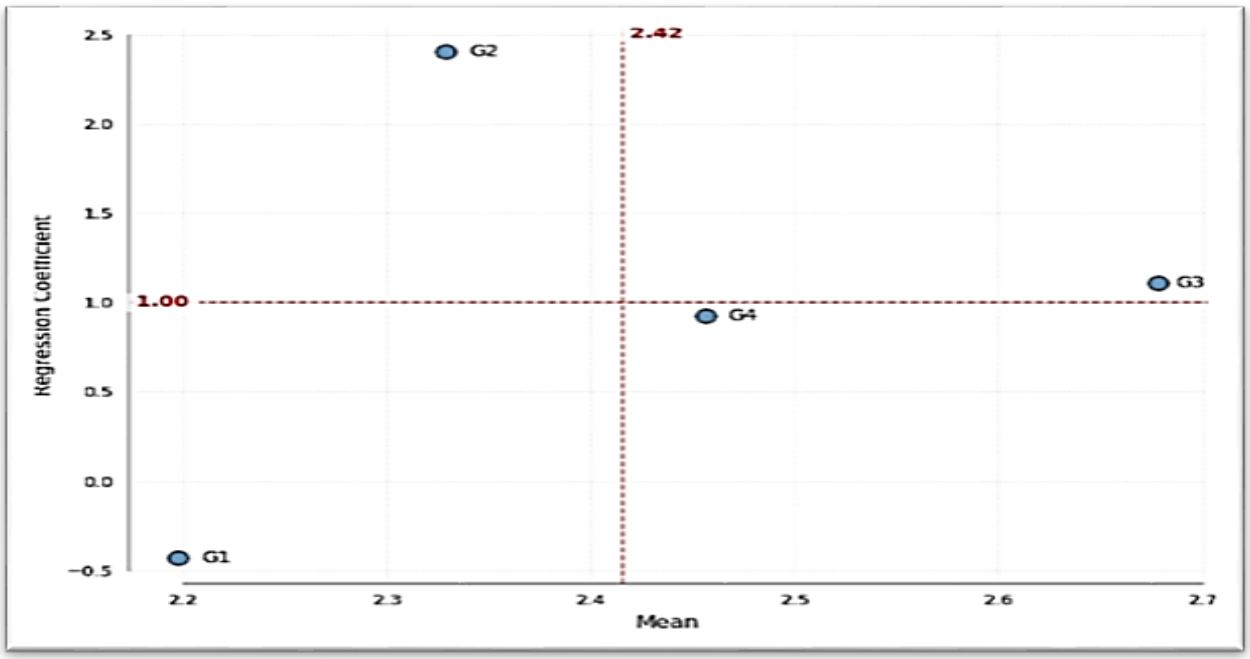

Figure 4. Regression coefficient (bi) for fresh calyx weight (g plant^{-1}).

Dry Calyx Weight (g plant^{-1})

Table (6) presents the stability parameters for dry calyx weight, including the mean performance of each genotype and the linear regression coefficient (bi). The regression coefficient significantly deviated from zero only for Hit Black (9.45), while all other genotypes showed non-significant deviation. The regression coefficient's deviation from unity (bi = 1) was significant for all genotypes: Hit Black (-6.85), Hit Red (4.49), Aareb (4.67), and Sudan-3 (4.70). The mean square deviation from regression (S_{di}^2) was significant for Hit Black, Aareb, and Sudan-3, with values of 0.0036, 0.0008, and 0.0007, respectively, while it was non-significant for Hit Red. These results indicate that Hit Red had a low but stable value. In contrast, Hit Black and Aareb exhibited high values but were unstable. Sudan-3 showed a low value with markedly variable response and instability, as illustrated in Figure (5), highlighting the lack of stability of Hit Black, Aareb, and Sudan-3.

Table 6. Stability parameters for dry calyx weight (g plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S_{di}^2	Inference
Hit Black	0.39	3.63	9.45**	-6.85**	0.0036 **	High value, but unstable.
Hit Red	0.29	0.27	1.68 n.s	4.49**	0.0003 n.s	Low value, but stable.
Areb	0.32	0.03	0.19 n.s	4.67**	0.0008 *	High value, but unstable.
Sudan-3	0.29	0.05	0.28 n.s	4.70**	0.0007 *	Low value, with markedly variable response, and unstable.

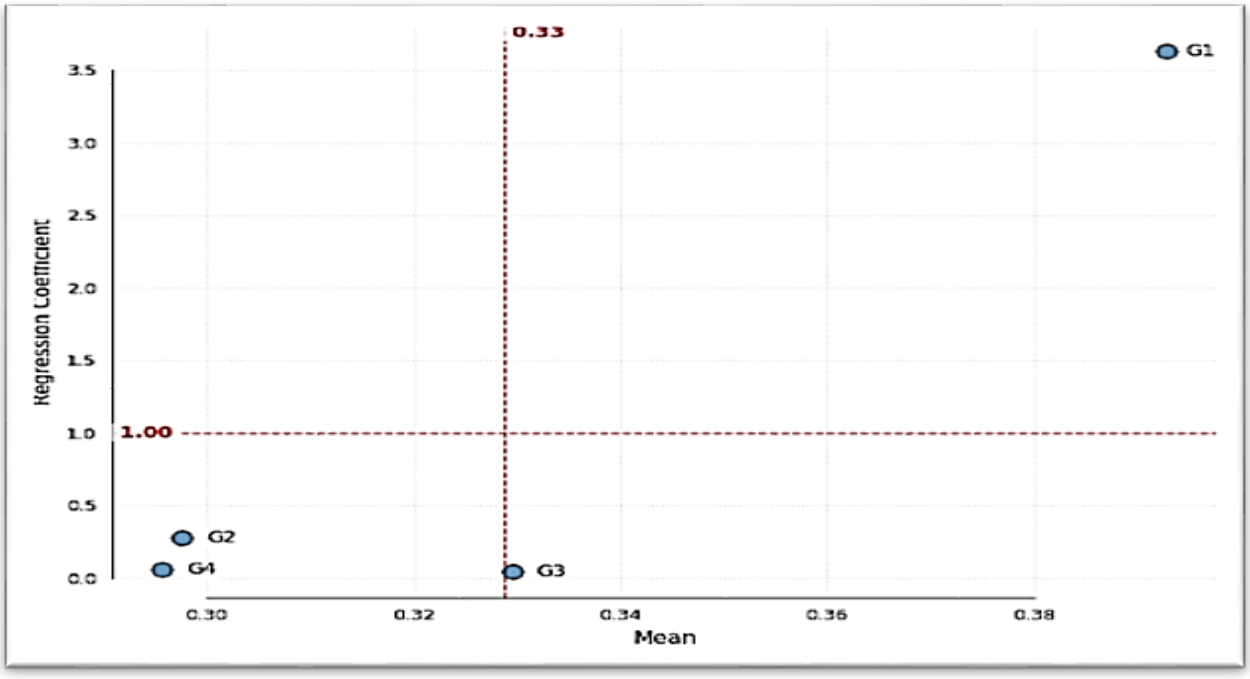

Figure 5. Regression coefficient (bi) for dry calyx weight (g plant^{-1}).

Number of Seeds per Capsule (seed capsule^{-1})

Table (7) presents the stability parameters for the number of seeds per capsule, showing the mean performance of each genotype along with the linear regression coefficient (bi). The regression coefficient significantly deviated from zero for Hit Red (2.90) and Sudan-3 (2.20), while Hit Black and Aareb showed non-significant deviation. The regression coefficient's deviation from unity (bi = 1) was significant only for Aareb (2.96), whereas it was non-significant for the other genotypes. The mean square deviation from regression (S^2_{di}) was significant for Hit Black (1.85), Hit Red (1.38), and Sudan-3 (1.50), while it was non-significant for Aareb. These results indicate that Aareb had a low but stable value, whereas Hit Black exhibited a high value but was unstable. Hit Red and Sudan-3 showed low values and were responsive to favorable environments but were unstable, as illustrated in Figure (6). The regression coefficient highlights that all genotypes except Aareb were unstable for this trait.

Table 7. Stability parameters for number of seeds per capsule (seed capsule^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S^2_{di}	Inference
Hit Black	27.79	0.81	0.94 n.s	0.21 n.s	1.85**	High value, but unstable.
Hit Red	24.77	2.26	2.90**	-1.62 n.s	1.38*	Low value, responsive to favorable environments, and unstable.
Areb	23.34	-0.83	-1.35 n.s	2.96**	0.63 n.s	Low value, but stable.
Sudan-3	24.44	1.76	2.20*	-0.95 n.s	1.50*	Low value, responsive to favorable environments, and unstable.

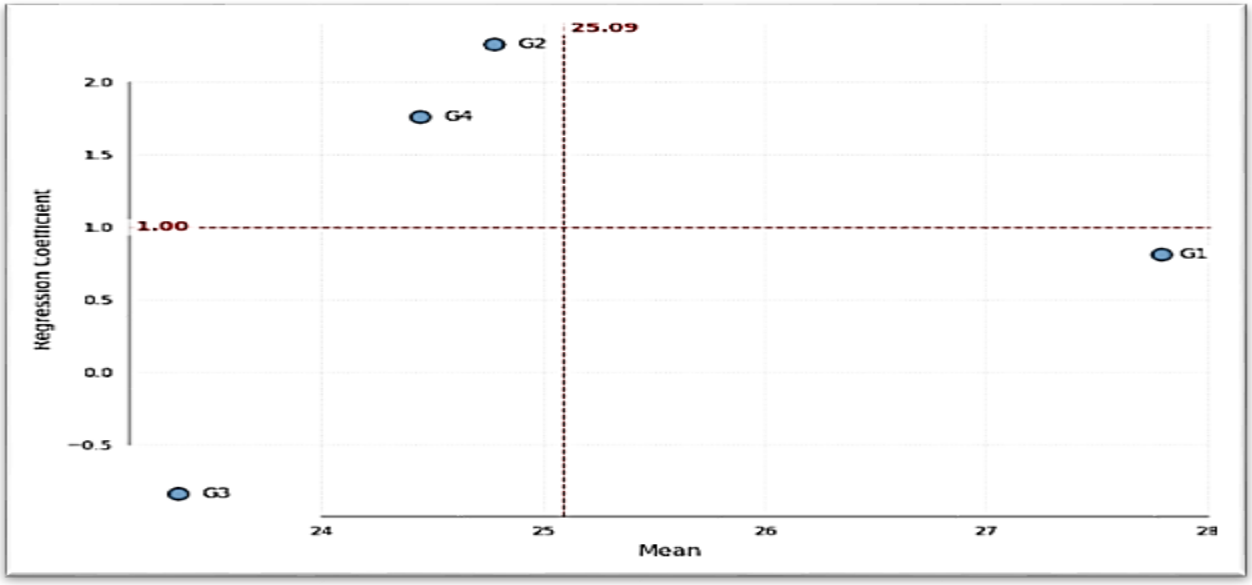

Figure 6. Regression coefficient (bi) for number of seeds per capsule (seed capsule^{-1}).

Weight of 500 Seeds (g plant^{-1})

Table (8) presents the stability parameters for the weight of 500 seeds, showing the mean performance of each genotype along with the linear regression coefficient (bi). The regression coefficient significantly deviated from zero only for Sudan-3 (2.22), while it was non-significant for all other genotypes. The regression coefficient's deviation from unity (bi = 1) was non-significant for all genotypes. The mean square deviation from regression (S_{di}^2) was significant for Hit Black (1.95) and Aareb (3.03), whereas it was non-significant for Hit Red and Sudan-3. These results indicate that Hit Red had a low but stable value. Hit Black exhibited a high value but was unstable. Aareb had a low value and was responsive to unfavorable environments, yet unstable. Sudan-3, in contrast, displayed a high value, performed well under favorable environments, and was relatively stable, as illustrated in Figure (7).

Table 8. Stability parameters for the weight of 500 seeds (g plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S_{di}^2	Inference
Hit Black	21.06	1.11	0.93 n.s	-0.09 n.s	1.95*	High value, but unstable.
Hit Red	19.35	0.83	0.99 n.s	0.19 n.s	0.40 n.s	Low value, but stable.
Areb	19.63	0.31	0.22 n.s	0.49 n.s	3.03**	Low value, responsive to unfavorable environments, and unstable.
Sudan-3	20.88	1.73	2.22*	-0.94 n.s	0.20 n.s	High value, responsive to favorable environments, and stable.

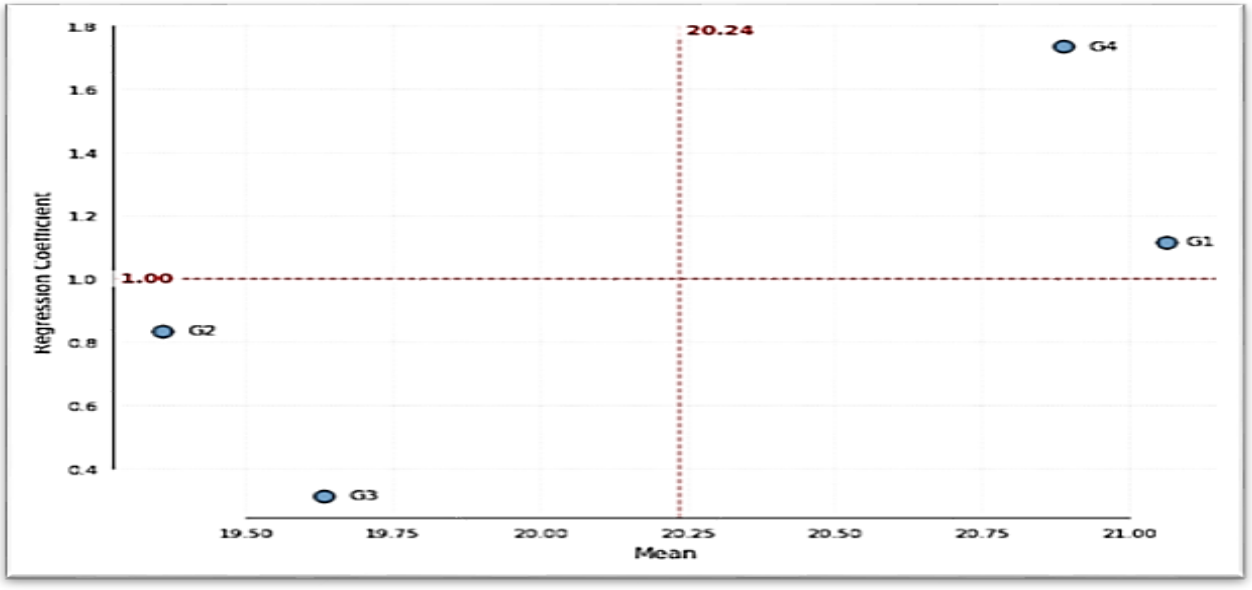

Figure 7. Regression coefficient (bi) for the weight of 500 seeds (g plant^{-1}).

Dry Calyx Yield per Plant (g plant^{-1})

Table (9) presents the stability parameters for dry calyx yield per plant, showing the mean performance of each genotype along with the linear regression coefficient (bi). The regression coefficient significantly deviated from zero only for Hit Black (9.18), while all other genotypes showed non-significant deviation. The regression coefficient's deviation from unity (bi = 1) was significant for Hit Black (-6.63), Aareb (6.04), and Sudan-3 (3.68), whereas it was non-significant for Hit Red. The mean square deviation from regression (S_{di}^2) was significant only for Hit Black (96.52) and non-significant for all other genotypes. These results indicate that Hit Red and Sudan-3 had low but stable values. Hit Black showed a high value but was unstable, whereas Aareb exhibited a high value with markedly variable response but remained stable, as illustrated in Figure (8). The figure highlights the stability of all genotypes except Hit Black, while Aareb showed a noticeably variable response across environments.

Table 9. Stability parameters for dry calyx yield per plant (g plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S_{di}^2	Inference
Hit Black	76.73	3.60	9.18 **	-6.63**	96.52*	High value, but unstable.
Hit Red	66.33	0.59	1.71 n.s	1.14 n.s	63.65 n.s	Low value, but stable.
Areb	80.24	-0.38	-1.69 n.s	6.04**	-7.92 n.s	High value, with markedly variable response, and stable.
Sudan-3	72.19	0.18	0.82 n.s	3.68**	-11.43 n.s	Low value, but stable.

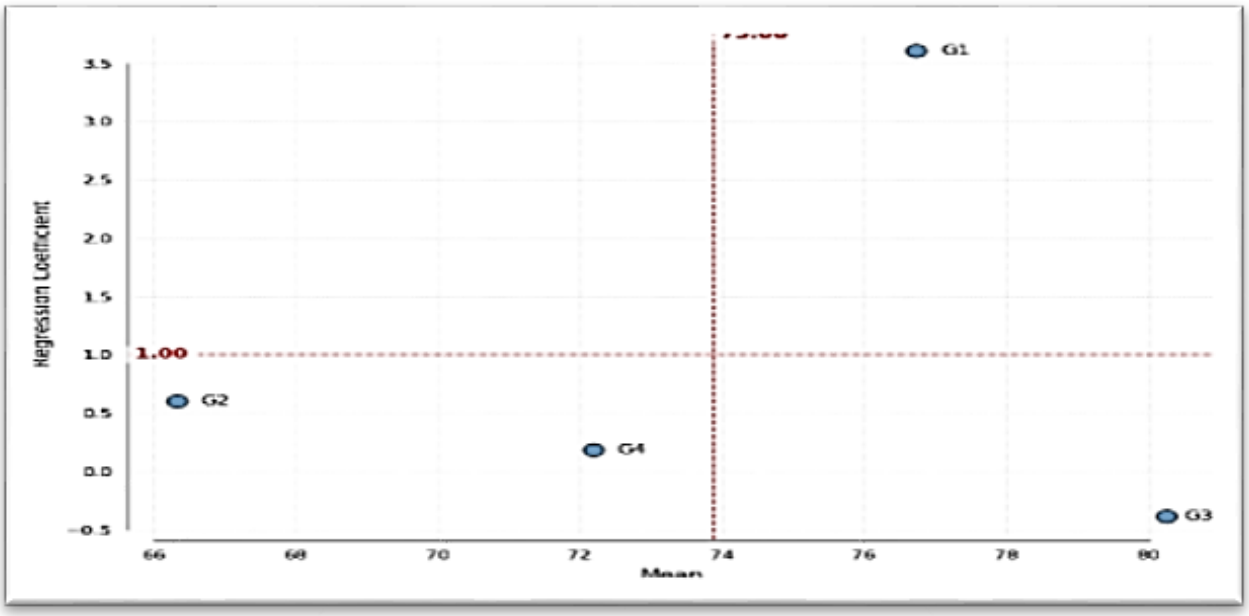

Figure 8. Regression coefficient (bi) for dry calyx yield per plant (g plant^{-1}).

Seed Yield per Plant (g plant^{-1})

Table (10) presents the stability parameters for seed yield per plant, showing the mean performance of each genotype along with the linear regression coefficient (bi). The regression coefficient significantly deviated from zero for Hit Black (2.13), Aareb (3.09), and Sudan-3 (3.95), whereas Hit Red showed a non-significant deviation. The regression coefficient's deviation from unity (bi = 1) was non-significant for all genotypes. The mean square deviation from regression (S^2_{di}) was also non-significant for this trait across all genotypes. These results indicate that Hit Black and Hit Red had low but stable values. Aareb exhibited a high value that was stable and adaptable across a wide range of environments, while Sudan-3 showed a high value that was responsive to favorable environments and stable. Figure (9) illustrates the stability of all genotypes, highlighting Aareb's broad adaptability across different environments.

Table 10. Stability parameters for seed yield per plant (g plant^{-1}).

Genotypes	ȳ	bi	t Cal. for bi=0	t stat. for bi=1	S^2_{di}	Inference
Hit Black	198.23	1.13	2.13*	-0.25 n.s	-165.02 n.s	Low value, but stable.
Hit Red	223.59	0.18	0.46 n.s	1.98 n.s	-394.22 n.s	Low value, but stable.
Areb	259.78	1.19	3.09**	-0.50 n.s	-426.52 n.s	High value, stable and adaptable across a wide range of environments.
Sudan-3	279.68	1.47	3.95**	-1.27 n.s	-445.96 n.s	High value, responsive to favorable environments, and stable.

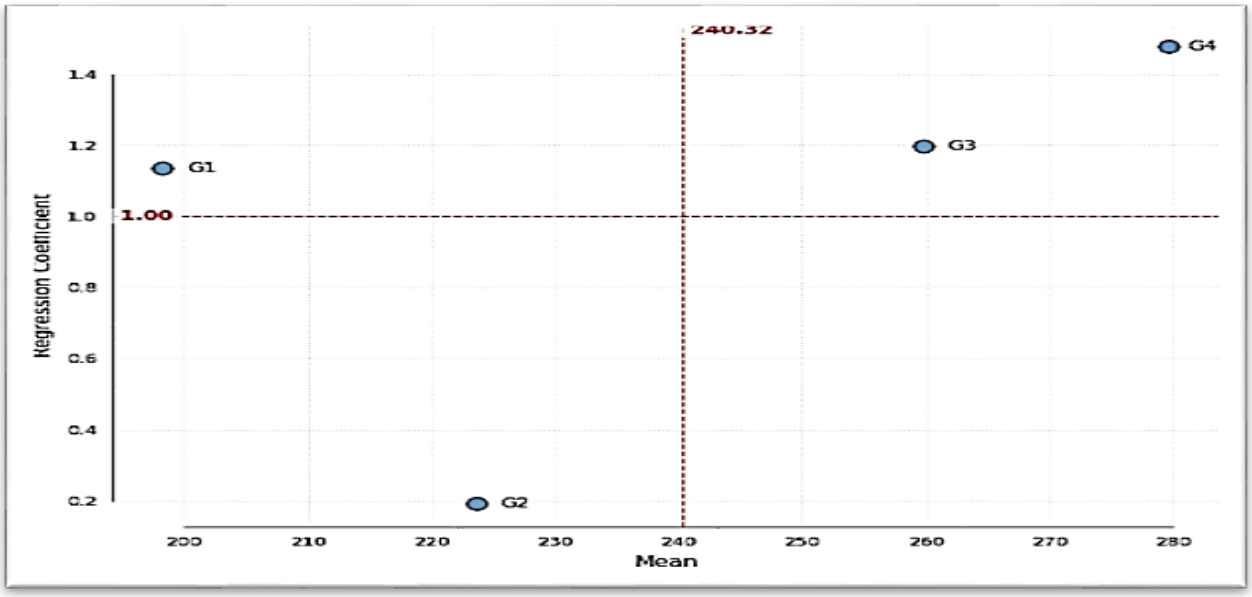

Figure 9. Regression coefficient (bi) for seed yield per plant (g plant^{-1}).

CONCLUSIONS

The genotype Hit Black demonstrated a good level of stability for several studied traits, particularly leaf number, number of capsules per plant, and seed yield per plant, in addition to certain bioactive compounds. This indicates consistent performance and adaptability across different environmental conditions within the scope of this study.

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