Effect of zeolite on growth, yield, and active substances of genotypes of Roselle (Hibiscus sabdariffa L.) and its Half–Diallel Crosses

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KEYWORDS

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ABSTRACT

Two field experiments were conducted on the private farms of a farmer in the village of Al-Jilawiyah in Al-Musayyab district (40 km north of the center of Babylon province) for the years 2021 and 2023 for the purpose of studying some genetic features of four genotypes of Roselle and their Half – Diallel Crosses. They gave the following results:The eggplant cultivar excelled in all the studied traits (plant height, chlorophyll content of leaves, number of branches in the plant, number of bolls in the plant, total yield of sepal leaves and anthospanin content), giving averages of (184.86 cm, 42.83 spad, 48.30 leaves.plant $^{-1}$, 153.50 bolls.Plant $^{-1}$, 1208.16 kg ha -1, 0.338%) respectively. As for the hybrids, the hybrid (1*2) excelled on the other hybrids by giving it the highest average for the studied traits (plant height, chlorophyll content of the leaves, number of branches, number of bolls in the plant, anthocyanin content, giving the averages (191.98 cm, 43.04 spad, 50 branches. plant $^{-1}$, 157.22 bolls.plant $^{-1}$, 0.345%), respectively.

As for the hybrid strength, the hybrid (1*2) excelled giving it the highest hybrid strength at level Z 10, amounting to 19.97%, while the hybrid (2*4) gave it the lowest hybrid strength at level Z10, amounting to -0.30%. As for the gene action, it gave the trait of chlorophyll content the highest percentage of heritability in the broad sense, amounting to 99.48%, at the level Z 10, while it gave the lowest percentage of heritability in the broad sense, amounting to 75.65%, for the trait of plant height, at the level Z 10. As for the heritability rate in the narrow sense, it reached its highest average of 60.06% for the trait number of branches at level Z 20. While it gave the lowest percentage of heritability in the narrow sense of 4.16% at the Z10 level .The average degree of dominance was 4.44% for the trait of plant height, while the lowest value for the average degree of heritability was 1.27 for the trait of the number of bolls. plant^{-1}.

1. Introduction

The Roselle plant is considered a medicinal and economic plant. Its original homeland is India and Indonesia, and some researchers believe that its origin country is the Mediterranean basin (Mohsen 2019). Its cup leaves are rich in active compounds such as malic and citric acid and protocate chunic acid, which has a major role in scavenging free radicals and thus a treatment for many diseases, including cancer (Killic et al., 2011). Its drink is rich in ascorbic acid, which makes the medium acidic (pH = 3.5). This medium does not allow fungal, bacterial and viral growth and thus increases the body's immunity ( ).

Among the active compounds in cup leaves are flavonoids, phenols, and tannins. Anthocyanin is one of the most important pigments found in sepals, and it is to it that the red color in its infusion is attributed. It is a powerful antioxidant that treats all inflammation in the body, improves vision, and protects blood vessels from high blood pressure (Louis et al., 2013(. Its productivity is low, and there are no global or local statistics regarding the cultivated areas, the average production per hectare, or the average general production globally, Arab, or Iraq. Its cultivation declined in Iraq in Diwaniyah province, and from there it spread to some Iraqi governorates, including Babylon and Baghdad (Al-Hamidi, 2023). In order to increase its cultivation areas in Iraq and its productivity, this research was conducted.Research has not addressed the response of stones to the mineral zeolite and its effects on its growth, yield, and active compounds in it. Zeolite is one of the mineral raw materials that exists naturally as well as artificially, where it consists mainly of volcanic rocks when they are present in

volcanic water with an alkaline reaction, which leads to the crystallization of the mineral and is always found near volcanoes. Because of the presence of salty water, the most famous of them are (arionite, mordenite, and phillipsite), and there are 45 zeolite minerals, and they are used in medicine, agriculture, and industry (Golic et al., 2017). Its importance lies in the fact that it contains a large group of minerals that the plant can benefit from after being dissolved in water, whether they are major or minor elements, including (nitrogen, phosphorus, potassium, iron, sulfur, magnesium, manganese, boron, and others))

Hybridization plays an essential role in increasing production by exploiting the phenomenon of hybrid vigor between genetically distant cultivars. Identifying the broad and narrow types of heritability rates for the studied traits will contribute to clarifying the picture about the extent of benefit from multiplying some cultivars that give higher averages for vegetative and fruit growth labels and active substances than the cultivars that give lower averages. ( )

The study aims to:

1- Evaluation of ten genotypes of Roselle under the influence of different levels of zeolite in terms of vegetative growth, yield, and medically active substances.

2- Obtaining the highest averages for the studied traits through hybrid vigor, broad and narrow heritability rates, and the average degree of dominance.

2. Methodology

materials

Four genotypes of Roselle and their Half – Diallel Crosses. The genotypes were obtained from the Roselle Development Center in Diwaniyah, affiliated with the Ministry of Agriculture.

Experiment location

Two field experiments were conducted in the village of Al-Jilawiyah (40) km north of the center of Babylon province, the first in the summer season of 2021 and the second in 2022 AD for the purpose of knowing Effect of the mineral zeolite on the growth, yield and some effective materials of the four genotypes (eggplant, red, white and striped) and their Half – Diallel Crosses. There are (6) hybrids in adulthood, so the total number of genotypes is 10.

The first season of growing Roselle in 2021

The experimental land was prepared correctly in terms of plowing with Mold-board plows in two opposite directions, smoothing and leveling, and dividing it into four replicates. Each replicate was divided into four experimental units. Each genetic makeup was planted in an experimental unit and distributed randomly among the four replicates. Thus, the total number of experimental units was 16 experimental units in area. The experimental unit is 6 m^2, and a completely randomized block design was used. A distance of 2 m was left between one replicate and another, and the distance between one pits and another was 50 cm, and between one replicate and another was 75 cm. The thinning process was conducted two weeks after germination, and the soil was fertilized with phosphate fertilizer in the form of super Phosphate P_2O_5 at an amount of 160 kg ha^{-1} in one batch while preparing the land for cultivation. Then the experimental land was fertilized with nitrogen fertilizer in the form of urea (46% N) at an amount of 180 kg ha^{-1} in two batches, the first 30 days after planting and the second 30 days after the second batch. Weeding, irrigation, and pest control operations were conducted whenever necessary (Nasrallah, 2012).

The process of half dialel cross was conducted according to the method of Griffing (1956 b) and the number of crosses was (6) by removing the anthers from the clones that were considered mothers and vice versa. The physiological maturity of the original clones and the crosses was harvested when they were swallowed. It became (10 genotypes), dried, germinated, and the seeds were stored in a storehouse in which all proper storage conditions were available until the next season.

The second growing season for Roselle is 2022

The seeds of the four parents and their half dialel cross resulting from the half dialel pollination amounted to (6) combinations, so the total number of genotypes planted was (16) genotypes, on April 12, 2022, in the same soil, according to the factorial arrangement, in a completely randomized block design. After the experimental land was prepared by plowing, smoothing, leveling, and dividing it into three replicates, each replicate contained (30) experimental units. Thus, the number of experimental units was (90) randomly distributed, and the area of the experimental unit was (12) m2, with (5) squares of length (3) m and the distance between one furrow and another) m and the distance between one furrow and another is 75 cm and between pit and another is 50 cm.The experimental land was fertilized with nitrogen fertilizer (urea 46% N) at an amount of 180 kg ha^{-1}, in two batches, the first after (30) days of germination, and the second after (30) days from the first batch, and phosphate fertilizer in the form of P2O5 was added at an amount of (160) kg ha^{-1} during Preparing the land for agriculture (Nasrallah, 2012) and then coundected all crop service operations whenever necessary.

Zeolite, which was obtained from the Fadak farm of the Hussein Shrine, was added in the form of stone pieces and packed in plastic boxes. It was cut, ground, and added to the field at a depth of (30) cm and in three concentrations (0 tons ha^{-1}, 10 tons ha^{-1}, 20 tons ha^{-1}).

Some chemical and physical traits of the experimental soil were studied and the results were given in (Table 1)

values	units	traits
3.12	$DS.m^{-2}$	Electrical conductivity
7.2	-	pH
18.40	$g.kg^{-1}$ soil	Organic matter
12.20	$mg.kg^{-1}$ soil	nitrogen
19.19	$mg.kg^{-1}$ soil	Phosphorous
70.22	$mg.kg^{-1}$ soil	potassium
492	$mg.kg^{-1}$	clay
360	$mg.kg^{-1}$	sand
148	$mg.kg^{-1}$	silt
	Sandy clay	texture

The zeolite mineral was analyzed in the Geological Survey Laboratory of the Ministry of Industry and Minerals/Baghdad (Al-Ardhi, 2021)

Table (2) Components of the mineral zeolite

values	Oxide
45.25%	SiO_2
14.39%	Al_2O_3
7.27%	FeO_3
8.84%	CaO
3.43%	MgO
0.12%	Na_2O
3.38%	K_2O
0.03%	P_2O_5

Studied traits

1- Plant height (cm): Plant height was measured using a tape measure from the surface of the soil to the top of the upper internode of ten randomly selected plants, and the average plant height was extracted.

2- Number of branches (branch plant $^{-1}$): The number of secondary branches of the ten plants taken randomly was calculated and the average number of branches was extracted.

3- The chlorophyll content of the leaves: The chlorophyll content of the leaves was estimated using a device (Chlorophyll meter Model Spad - 502), manufactured by the Japanese company Minolta. Readings were taken for ten fully expanded leaves at the peak of their physiological activity, then the average was calculated (Williams and Jemison, 2006).

4- Number of bolls per plant (bolls . plant $^{-1}$): The number of bolls from the ten plants taken at random was calculated and then the average was extracted (Idan, etal.,2022).

5- Total yield of sepal leaves (kg ha^{-1}): After the sepal leaves of the ten plants taken randomly for each experimental unit were dried separately, after the weight was constant, then the total yield of sepal leaves was calculated through the yield of one plant * plant density.

6- Estimation of anthocyanin content (%): Anthocyanins were estimated in calyx leaves using the pH differential method and according to the method of AlHussainy (2010)

statistical analysis

Statistical analysis of the studied traits was conducted using the statistical program Genstat 2012. The results were also tested to determine the significant differences between the various experimental parameters using the least significant difference (L.S.D.). Between the arithmetic averages at the 0.05 level (Al-Rawi and Khalaf Allah, 1980).

3. Result and Discussion

Plant height:

Table (3) shows the significant differences between the genotypes of Roselle plant (cultivars and Half – Diallel Crosses). The eggplant cultivar (1) excelled on the rest of the cultivars, giving the highest average for the trait, amounting to 184.86 cm, while the striped cultivar (4) gave the lowest average of the cultivars, amounting to 141.55 cm. Thus There was an increase in the trait amounting to 23.42%. As for the hybrids, the hybrid (1)As for the addition of the mineral zeolite, the treatment (Z10) excelled on the rest of the treatments, giving the highest average for trait, which amounted to 192.25 cm, while the control treatment gave an average of 146.65 cm. Thus, an increase in trait was achieved, amounting to 23.71%. As for the interaction between the cultivars and the mineral zeolite, the combination (eggplant cultivar reached 39.99%.As for the interaction between hybrids and zeolite rates, the combination [(1X2).The lowest average for the trait was 139.70 cm, so an increase in the trait was achieved amounting to 40.62%. This difference in trait can be explained by the difference in genotypes in their efficiency in absorbing water and nutrients, as well as a difference in the efficiency of the photosynthesis process between genotypes.As for the difference between cultivars and hybrids as a result of adding the mineral zeolite or not, this can be explained by the fact that it is important in preserving the cohesion and hardness of the soil crust, where it is considered one of the problems that hinders production in general and in the Middle Euphrates Basin region due to the construction nature of this mineral, which contains voids that limit and reduce the formation of The hard shell prevents seed germination and prevents air exchange between the covering layer and the layer in which the roots grow. Thus, zeolite contributes to increasing the germination rate and gas exchange between the plant and the soil, which helps the roots to grow and absorb easily.

Table (3) Effect of the mineral zeolite on the compositions of Roselle plant and Half – Dillel Crosses

Zeolite / genotype	0 ton.ha-1	10 ton.ha-1	20ton.ha-1	verage genotype

184.86	175.79	222.57	156.22	Eggplant 1
152.04	148.37	169.66	138.10	Red 2
162.17	161.59	182.27	142.66	White 3
141.55	138.61	152.49	133.55	striped 4
191.98	180.24	235.29	160.42	1*2
185.80	179.89	224.91	152.59	1*3
182.12	175.88	212.22	158.27	1*4
161.95	156.44	185.18	144.24	2*3
148.66	145.71	160.59	139.70	2*4
160.03	161.91	177.30	140.89	3*4
	162.44	192.25	146.65	Zeolite
	nteraction = 7.11	Zeolite 4.10	cultivar = 3.62	LSD

As for the hybrid vigor for the trait plant height (Table 4), the hybrid (1*2) excelled by giving it the highest hybrid vigor at the level of 10 tons ha^{-1}, amounting to 19.97%, while the highest hybrid (2*4) had the lowest hybrid vigor for the trait studied at the level of 10 tons. ha^{-1}.

Table (4) Hybrid vigor of hybrids resulting from Half – Dillel Crosses of the studied genotypes for the height trait of Roselle plant**.**

20 ton.ha-1	10 ton.ha-1	0ton.ha-1	hybrid
11.20	19.97	9.01	1*2
6.63	11.11	2.10	1*3
11.88	18.68	9.24	1*4
0.92	5.40	2.74	2*3
1.54	-0.30	2.84	2*4
7.86	2.92	2.02	3*4
			SE

As for the gene action (Table 5), the percentage of heritability in the broad sense was studied, and at the level of 0 tons ha^{-1} it amounted to 89.53%, while the narrow rate at the same level amounted to 20.72%, while the average degree of dominance was more than one, and this indicates the excelled of the gene action. On the action of the additional gene, this leads us to hybridization for the purpose of obtaining greater additional variation, and then we go to selection. As for the second level, 10 tons ha^{-1}, the heritability rate in the broad sense was 75.65%, while the heritability rate in the narrow sense was 7.82%. The average degree of dominance reached 4.16, and this clearly indicates the dominance of the dominant variation on the additional one, and this concentation us to go to hybridization to increase the additional variation and then select for the plant that is distinguished in the studied trait.As for the third level, 20 tons ha^{-1}, the percentage of heritability in the broad sense was 90.39%, while the percentage of heritability in the narrow sense was 8.31%, and the average degree of dominance was greater than one, reaching 4.44. This confirms the excelled of the dominant gene over the additional

one, and thus we resort to hybridization again.

Table (5) shows the broad and narrow heritability rates and the average degree of dominance for the different levels of added zeolite mineral**.**

20ton.ha-1	10 ton.ha-1	0ton.ha-1	Zeolite Gene action
90.39	75.65	89.53	Broad sense heritability
8.31	7.62	20.72	Narrow heritability rate
4.44	4.16	2.57	Average degree of dominance

The chlorophyll (spad) content of leaves

Table (6) shows the significant differences between the genotypes of Roselle and their Half – Dillel Crosses. The eggplant cultivar excelled on the rest of the cultivars, giving the highest average for the trait, amounting to 42.83 spades, while the striped cultivar gave the lowest averages for the trait, amounting to 34.69 spades. Thus, there was an increase in the trait amounting to 19%.

As for the hybrids, the hybrid (1*2) excelled in giving the highest average for the trait, amounting to 43.04 spad, while the hybrid (2*4) gave the lowest average for the trait, amounting to 36.64 spad. Thus, an increase in the trait was achieved, amounting to 14.86 spad, and the difference in the trait can be explained as a result of genetic differences. Between the cultivars on the one hand and the Half – Dillel Crosses on the other hand, this is physiologically reflected in the performance of each genetic structure, and thus the differences between the genotype of the studied trait appear.

As for the addition of the mineral zeolite, the 10 ton ha^{-1} treatment excelled on the rest of the treatments by giving it the highest average for the trait, which amounted to 45.31 SPAD, while the control treatment gave the lowest averages for the trait, amounting to 33.43 SPAD. Thus, an increase in the trait occurred by 26.21 SPAD. As for the interaction between the cultivars and the mineral zeolite, the combination (aubergine * Z10) excelled, as it obtained the highest average for the trait, amounting to 51.24 SPAD, while the combination (Planned * Z0) gave the lowest averages for the trait, amounting to 30.37 SPAD. Thus, an increase in the trait was achieved, amounting to 40.72 SPAD. As for the interaction between hybrids and zeolite averages, the combination [(1*2) × Z10] excelled, giving the highest average for the trait, reaching 51.82 SPAD. The combination [(2*4 x Z0) gave the lowest average for the trait, which was 31.09 SPAD. Thus, an increase in the trait was achieved, amounting to 40.00 SPAD. This can be explained by the fact that the use of zeolite in fertilization removes radioactive isotopes from the irrigation water. In addition, the soil is contaminated with heavy metals such as lead and copper. Cadmium and radioactive isotopes such as cesium 134 Cs, strontium 90 Sr, and cesium 137 Cs thus prevent their absorption by the roots, allowing the plant to absorb other useful elements in the process of photosynthesis (Mohamed et al., 2015).

Table (6) Effect of the mineral zeolite on the compositions of Roselle plant and Half-Diall Crosses regarding the chlorophyll content in the leaves.

Average genotype	Z20	Z10	Z0	Zeolite genotype
42.83	42.65	51.24	34.60	Eggplant 1
36.89	36.89	41.88	31.89	Red 2
38.20	37.59	43.57	33.45	White 3

34.69	34.96	38.74	30.37	striped 4
43.04	43.20	51.82	35.09	1*2
42.67	42.77	50.53	34.71	1*3
41.36	40.64	48.29	35.17	1*4
37.12	36.69	40.57	34.10	2*3
36.64	36.92	41.90	31.09	2*4
38.51	37.11	44.56	33.87	3*4
	38.94	45.31	33.43	average Zeolite
	interaction = 2.12	Zeolite 1.15	cultivar = 0.94	LSD

As for the hybrid vigor (Table 7), it is shown that the highest hybrid vigor for the trait was 21.99% for the hybrid (1*2) at level Z10 for the trait of chlorophyll content in the leaves, while the hybrid (2*3) gave the lowest hybrid vigor of -5.18%.

Table (7) Hybrid vigor of Half – Dillel Crosses according to the chlorophyll content in the leaf

20 ton.ha-1	10 ton.ha-1	0 ton.ha-1	Zeolite / hybrid
14.79	21.99	9.28	1*2
6.06	6.60	2.02	1*3
4.74	7.33	8.28	1*4
- 1.47	- 5.18	4.37	2*3
2.78	3.94	- 0.12	2*4
2.13	8.28	6.14	3*4
			SE

Table (8) shows the gene action of the studied trait. The heritability rate was studied in the broad sense. It gave the highest rate of 99.48% for the studied trait at the Z1 level, while treatment Z 20 gave the lowest rate of 94.30%. As for the narrow sense heritability rates, it excelled level 10Z for the mineral zeolite, while the lowest narrow sense heritability rate was 32.59%. At the first level. As for the average degree of dominance, they were all more than one, and this means the continuation of the hybridization process. Z10 excelled at the rest of the levels, reaching 2.24%.While it gave an average degree of sovereignty at level Z 20 of 1.47. From the above, it is clear that the dominant gene is superior to the additional gene, so the researcher must continue hybridizing for the purpose of obtaining more additional variation.

Table (8): The percentage of broad and narrow heritability and the average degree of dominance for the trait chlorophyll content in the leaves of Roselle plant.

Z20	Z10	Z0	Zeolite Gene action
94.30	99.48	96.80	Broad sense heritability
45.29	47.35	32.59	Narrow heritability

			rate
1.47	2.24	1.97	Average degree of dominance

Number of branches (branch plant $^{-1}$)

Table (9) shows the significant differences between the genotypes of the Roselle, which includes the cultivars and hybrids resulting from their Half – Diallel Crosses. The eggplant cultivar 1 excelled on the rest of the cultivars, where it gave the highest average for the trait, amounting to 48.30, plant branch $^{-1}$, while the planed cultivar 4 gave the lowest averages for the trait, amounting to 31.77. branch Plant $^{-1}$. Thus, an increase in the trait amounted to 34.22%.As for the hybrids, the hybrid (1*2) excelled by giving it the highest average for the studied trait, amounting to 50.40 branch $^{-1}$, while the hybrid (2 * 4) gave the lowest averages for the trait, amounting to 35.77 branch Plant $^{-1}$. Thus, an increase in the trait was achieved, amounting to 29.02%. As for the mineral zeolite, the Z10 treatment excelled on the rest of the levels, giving the highest average for the trait, amounting to 50.78 branch Plant $^{-1}$, while control treatment (0 tons ha $^{-1}$) gave the lowest averages for the trait, amounting to 35.63 branch Plant $^{-1}$. Thus, an increase in the studied trait was achieved by 29.38%. This can be explained by the fact that the mineral zeolite has an important role in treating soil salinity and improving its quality (Almulla *etal*., 2022). This makes the roots absorb water and necessary nutrients easily. What confirms this is the increase in the proportion of magnesium, calcium, phosphorus, potassium and nitrogen in the plant, and thus the efficiency of the photosynthesis process increases, and this in turn increases. It increases the number of branches in the plant (Abdi et al., 2010).As for the interaction between cultivars and the mineral zeolite, the combination (eggplant x 10 tons ha^{-1}) excelled. Giving the highest average for the trait amounted to 62.10 branch Plant $^{-1}$, while the combination (plan It gave an increase in the trait amounting to 54.75%. As for the interaction between the hybrids and the levels of the mineral zeorite, the combination [(1*2) * 10 tons ha^{-1}) excelled and gave the highest average for the trait, amounting to 65.29 branch Plant $^{-1}$, while the combination [(2*4) * 0 tons ha^{-1} gave [The lowest average for the trait was 29.43 branch Plant $^{-1}$there was an increase in the trait reaching 54. 92%.As for the difference between cultivars, and the increase of a trait in one genotype on the amount of a trait in another structure, this is due to the difference in their genetic composition, and this is reflected in the efficiency of the genetic composition in absorbing water and nutrients, and thus its efficiency in the process of photosynthesis (ALrufaye *etal*.,2018).

Table (9) Effect of the mineral zeolite on the compositions of the Roselle plant and its Half – Diallel Crosses for the number of branches in the plant.

average genotype	Z 20	Z10	Z 0	Zeolite genotype
48.30	44.36	62.10	38.44	Eggplant 1
37.37	36.66	41.76	33.71	Red 2
41.46	40.28	48.22	35.89	White 3
31.77	31.70	35.50	28.10	striped 4
50.40	46.50	65.29	3942	1X2
49.12	45.45	63.10	38.82	1X3
48.47	44.72	60.60	40.10	1X4
41.40	40.30	47.92	35.97	2X3
35.77	35.20	42.67	29.43	2X4
39.05	40.09	40.65	36.42	3X4
	40.53	50.78	35.63	الaverage
	interaction = 2.02	Zeolite 1.22	cultivar = 0.90	L S D

As for the vigor of the hybrid (Table 10) for different levels of fertilization with the mineral Zeolite, the hybrid (1*2) at the level of Zeolite Z 10 excelled on the rest of the hybrid, giving the highest hybrid vigor of 25.72%. While the hybrid (2*4) gave the lowest hybrid vigor for the trait. The studied rate reached - 4.75%. It was at the level (Z 0).

Table (10) Hybrid strength for the resulting crosses between the four genotypes of the Roselle plant for the number of branches

20 ton.ha-1	10 ton.ha-1	0ton.ha-1	Zeolite hybrid
14.78	25.72	9.28	1*2
7.39	14.39	4.46	1*3
17.59	24.18	20.52	1*4
4.75	6.51	3.36	2*3
2.98	9.18	-4.75	2*4
11.39	- 2.89	13.84	3*4
			SE

As for Table (11), it shows the Gene action for the studied trait after the additional, dominant, environmental, and phenotypic variation was extracted. The broad sense heritability rate was extracted, as it gave the highest percentage for the studied trait, reaching 97.73% at the Z level of 10, while the broad sense heritability percentage was 89.08% at Z 0 . As for the heritability in the narrow sense, it gave the highest percentage of the studied trait at 60.06% at the Z20 level, while the lowest percentage of heritability in the narrow sense was 45.58% at the Z0 level for zeolite. It gave the highest average degree of dominance of 1.97 at level Z 0, while it gave the lowest average degree of dominance of 1.58 at level Z 10.From the above, it is clear that the average degree of dominance is greater than one, and this means that the dominant gene is superior to the additional gene in the studied trait. Therefore, hybridization must continue for the purpose of obtaining greater additional variation.

Table (11): The percentage of heritability in the broad and narrow senses and the average degree of dominance for the trait of the number of branches in the germination of buds.

Z 20	Z 10	Z 0	Zeolite Gene action
97.73	92.71	89.08	Broad sense heritability
60.06	47.35	54.58	Narrow heritability rate
1.80	1.58	1.97	Average degree of dominance

Number of bolls in a plant (plant bolls $^{-1}$)

Table (12) shows the significant differences between the genotypes of Roselle, which includes the cultivars and hybrids resulting from their Half – Diallel Crosses. The eggplant cultivar excelled on the rest of the cultivars, as it gave the highest average number of bolls per plant, amounting to 153.50 bolls plant $^{-1}$, while the striped cultivar gave the lowest averages for the studied trait, amounting to 153.50 bolls per plant. 92.78 bolls plant $^{-1}$ Thus, there was an increase in the trait amounting to 39.55%.As for the hybrids, the hybrid (1*2) excelled by giving the highest average for the trait, amounting to 157.22 bolls plant $^{-1}$, while the hybrid (2*4) gave the lowest average for the trait, amounting to 110.87 bolls plant $^{-1}$. Thus, an increase in the trait was achieved, amounting to 29.48%.As for the zeolite mineral, the Z 10 treatment excelled on the rest of the levels, giving the highest average for the trait, amounting

to 170.98 bolls plant $^{-1}$, while the control treatment gave the lowest averages for the trait, amounting to 83.29 bolls plant $^{-1}$. Thus, an increase in the trait was achieved, amounting to 51.28 bolls plant $^{-1,}$ and it can be The explanation for this is that the mineral zeolite is used in several uses by adsorbing water molecules on its internal cavities, thus increasing the storage of nutrients in all types of soil. Thus, the need for fertilization and mineral nutrients is reduced by half and the toxicity of elements such as iron and aluminum is reduced, thus increasing the rate of fertilization and flowering, and finally a number. bolls in plants. The results agreed with the findings of (Disarovic et al., 2017).As for the interaction between genotypes and zeolite levels, the combination (the eggplant cultivar An increase in the trait amounted to 67.55%.As for the bi- interaction between the hybrids and zeolite mineral levels, the hybrid [(1*2) 77.79%.

Table (12) Effect of the mineral zeolite on compositions of Roselle plant and Half – Dillel Crosses for the number of bolls in the plant

average genotype	Z 20	Z 10	Z 0	Zeolite genotype
153.50	162.87	205.54	92.10	Eggplant 1
107.10	115.24	130.35	75.71	Red 2
124.14	125.57	165.98	80.87	White 3
92.78	91.81	119.84	66.69	striped 4
157.22	167.77	210.33	93.57	1X2
154.70	165.80	207.57	90.73	1X3
148.85	160.91	192.84	92.82	1X4
122.21	114.80	170.43	81.40	2X3
110.87	118.47	136.36	77.79	2X4
127.93	132.32	170.53	80.93	3X4
	135.55	170.98	83.29	**average Zeolite**
	interaction = 4.150	Zeolite 2.50	cultivar = 1.80	L S D

As for the hybrid vigor (Table 13) of the hybrids resulting from Half – Dillel Crosses of the aforementioned cultivars and different levels of fertilization with the mineral zeolite for the trait of the number of bolls in the plant, the hybrid (1x2) excelled by giving it the highest hybrid vigor for the trait studied at the second level (z10) amounting to 25.24%. While the hybrid (2x3) gave the lowest hybrid for the aforementioned trait at the third level of fertilization with the mineral zeolite, which amounted to - 4.65%.

Table (13): Vigor values of hybrids for crosses resulting from four genotypes for the number of bolls in Roselle plant**.**

Z 20	Z 10	Z 0	Zeolite hybrid
20.65	25.24	11.52	1*2
14.96	11.60	4.91	1*3
26.36	18.53	16.90	1*4
- 4.65	15.03	3.97	2*3
14.44	9.00	9.25	2*4
21.74	19.32	9.69	3*4
			S E

Table (14) shows the gene action for the studied trait. Dominant, additive, environmental, and

phenotypic variation were studied, and then the percentage of heritability in the broad sense was extracted. It gave a percentage of heritability for the trait amounting to 94.94% at the z10 level, while treatment Z0 gave the lowest percentage of heritability in the broad sense, amounting to 86.62%. As for the heritability rates in the narrow sense, treatment Z0 excelled by giving it the highest rate of 53.73%, while treatment Z 20 gave it the lowest rate of 41.02%. As for the average degree of dominance, it excelled at the level Z 20 by giving it 1.51. While the value of the average degree of dominance was the lowest at the second level for the mineral zeolite, amounting to 1.27. It is clear that the dominant gene is excelled to the additional one, so hybridization must continue until greater additional variation is reached.

Table (14): The percentage of broad and narrow heritability and the average degree of dominance for the trait number of bolls in Roselle plant.

Z 20	Z 10	Z 0	Zeolite / Gene action
88.04	94.94	86.62	Broad heritability rate
41.02	52.53	53.73	Narrow heritability rate
1.51	1.27	1.31	Average degree of dominance

Total yield of sepals leaves

Table (14) shows the significance of the differences between the genotypes of Roselle plant used in the experiment. We note that the eggplant cultivar excelled on the rest of the cultivars with significant differences when given the highest average for the studied trait, which is the total yield of the calyx leaves of the plant, amounting to 1208.16 kg ha^{-1}, while the striped cultivar gave the lowest averages. The trait reached 738.27 kg ha^{-1}, thus achieving an increase in the trait amounting to 38.89%.As for the hybrids, the hybrid (1)As for Effect of adding zeolite, treatment Z 10 excelled on the rest of the treatments, giving the highest average for the trait, amounting to 1312.84 kg ha^{-1}, while level Z0 (the control treatment) gave the lowest averages for the trait, amounting to 754.27 kg ha^{-1}. Thus, there was an increase in the trait amounting to 42.54%. As for the bi-interaction between the cultivars and the mineral zeolite, the combination (eggplant %.

Table (14) Effect of the mineral zeolite on the genotypes of Roselle and Half-Diall Crosses for the total yield of sepals leaves**.**

average genotype	Z 20	Z 10	Z 0	Zeolite genotype
1208.16	1250.40	1551.19	822.90	Eggplant 1
899.60	903.79	1097.66	697.35	Red 2
1001.78	983.81	1287.71	733.84	White 3
738.27	711.88	865.44	637.51	striped 4
1206.92	1267.66	1560.69	792.40	1X2
1224.52	1271.44	1571.82	829.30	1X3
1218.74	1255.89	1559.59	840.75	1X4
985.37	990.91	1230.10	735.11	2X3
907.30	910.59	1110.22	701.09	2X4
978.08	888.80	1292.94	752.52	3X4
	1043.52	1312.84	754.27	average Zeolite
	interaction = 22.90	Zeolite 17.84	cultivar = 11.66	L S D

As for the hybrid vigor (Table 15), it was highest for the studied trait, amounting to 29.07% for the hybrid (1

Table (15) Hybrid vigor of Half – Diallel Crosses for the four genotypes for the total yield of sepals leaves of Roselle plant.

Z 20	Z 10	Z 0	Zeolite hybrid
17.69	19.17	4.24	1X2
13.81	10.80	6.54	1X3
28.00	29.07	15.13	1X4
4.99	3.13	2.72	2X3
12.71	13.10	5.04	2X4
4.84	20.09	9.72	3X4
			L S D

Table (16) shows the gene action on the trait of the total yield of sepals leaves. The percentage of heritability in the broad sense was studied, and it gave the highest percentage of the studied trait, amounting to 98.59%, at the Z level of 10, while the treatment Z 20 gave the lowest percentage of broad heritability, amounting to 98.48%. As for the percentages of heritability in the narrow sense, they were The highest percentage of the studied trait, amounting to 37.40%, was at level Z 10, while the lowest percentage of heritability in the narrow sense amounted to 21.28%, and was at level Z 20. As for the average degree of dominance, they were all more than one, and this means continuing the process of hybridization, not selection. The highest value of the average degree of dominance was 2.69, while it gave the lowest average value of the degree of dominance of 1.80 at the second level of fertilization with the mineral zeolite. What is clear is the superiority of the dominant gene over the additional gene for the studied trait.

Table (16): The percentage of broad and narrow heritability, the average degree of dominance, and the average degree of dominance for the total yield of the sepals leaves of Roselle plant.

Z 20	Z 10	Z 0	Zeolite Gene action
98.48	98.59	98.53	Broad sense heritability
21.28	37.40	31.12	Narrow heritability rate
2.69	1.80	2.08	Average degree of dominance

Anthocyanin content (%)

Table (17) shows the significant differences occurring between the genotypes of Roselle plant. The eggplant cultivar excelled on the rest of the cultivars, giving the highest percentage of the trait, reaching 0.338%, while the striped cultivar gave the lowest percentages (Al-Jameel, & Abd Fleih, (2023. 0.175%, and there was an increase rate of 48.22%. The results agreed with what was found (Al-Taie, 2017). As for hybrids, the hybrid (1*2) excelled the rest of the hybrids, giving the highest percentage of the trait, amounting to 0.345%, while the hybrid (2*4) gave the lowest percentage of the trait, amounting to 0.201%. Thus, there was an increase in the trait amounting to 41.73%. As for the addition of the mineral zeolite, treatment Z 10 excelled, giving the highest percentage of the trait, which amounted to 0.345%, while treatment Z0 (control treatment) gave the lowest percentage of the studied trait, amounting to 0.159%. Thus, an increase in the trait amounted to 53.91%. As for the interaction between the cultivars and the mineral zeolite, the combination (striped cultivar * Z0) percentage increase in the trait amounting to 71.45% was achieved. As for the interaction between hybrids and the mineral zeolite, [(1*2)While the combination [(2*4) The increase in the percentage of anthocyanins

can be explained by increasing the quality of the total yield of Roselle leaves, and thus the percentage of anthocyanins increases. The results agreed with the findings of (Supapron *et al.*, 2020) and (Ramesh *et al.*, 2015)

Table (16) Effect of the mineral zeolite on compositions of Roselle plant and Half-Diallel Crosses regarding the percentage of anthocyanins in Roselle plant.

average genotype	Z 20	Z 10	Z0	Zeolite genotype
0.338	0.366	0.480	0.170	Eggplant 1
0.194	0.197	0.245	0.141	Red 2
0.242	0.261	0.315	0.150	White 3
0.175	0.176	0.211	0.137	striped 4
0.345	0.372	0.486	0.178	)1*2(
0.332	0.325	0.481	0.189	1*3
0.317	0.379	0.391	0.181	1*4
0.221	0.243	0.262	0.155	2*3
0.201	0.200	0.259	0.144	2*4
0.246	0.269	0.322	0.149	3*4
	0.278	0.345	0.159	average Zeolite
	interaction = 0.09	Zeolite 0.06	cultivar = 0.040	L S D

As for the hybrid strength (Table 17), it was shown that the highest hybrid strength was 39.85% given by the hybrid (1 .

Table (17) Hybrid vigor of semi-reciprocal hybrids based on anthocyanin content in Roselle plant

Z 20	Z 10	Z 0	Zeolite hybrid
32.38	34.25	14.83	1*2
3.83	21.15	18.12	1*3
39.85	13.33	18.30	1*4
6.11	- 6.42	6.89	2*3
7.52	13.59	3.59	2*4
23.39	22.43	4.19	3*4
			S E

As for the gene action (Table 18), the percentage of heritability in the broad sense was studied, and its highest percentage was at the second level, reaching 85.71%, while the lowest percentage of heritability in the broad sense was at the first level for zeolite, amounting to 72.22%, while the percentage of heritability in the narrow sense was higher at the level Fertilization with zeolite reached 28.57% at the second level (Z10), while the heritability rate in the narrow sense gave the lowest percentages at the first level (Z0) amounting to 16.66%. As for the average degree of dominance, it gave the highest value at the first level (Z0) amounting to 2.58, while the lowest values it gave At the third level (Z 20) it reached 1.88.

Table (18) Broad and narrow heritability rates and the average degree of dominance for different levels of zeolite rate for the trait of anthocyanin content in Roselle plants.

20 ton.ha-1	10 ton.ha-1	0ton.ha-1	Zeolite / Genetic action
78.12	85.71	72.22	Broad sense

			heritability
28.12	28.57	16.66	Narrow heritability rate
1.88	2.00	2.58	Average degree of dominance

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