RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
57 (3) 1292-1301, 2025
http://doi.org/10.54910/sabrao2025.57.3.40
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

SEAWEED EXTRACT EFFECT ON THE GROWTH AND YIELD-RELATED TRAITS OF ROSELLE (*HIBISCUS SABDARIFFA* L.)

A.H. RUMI* and M.H. JARALLAH

Department of Plant Production Technologies, Al-Furat Al-Awsat Technical University, Babylon, Iraq
*Corresponding author's emails: alroome.abdalkreem@atu.edu.iq
Email address of co-author: mrwa.jaralah.tcm@atu.edu.iq

SUMMARY

This research aimed to determine the effects of different levels of marine seaweed extract on growth and yield traits of Roselle (*Hibiscus sabdariffa* L.) cultivars (eggplant, red, white, and striped) and their six half diallel hybrids. The experiment layout was in a randomized complete block design with a factorial arrangement and three replications. The first factor included four cultivars and their semi-reciprocal hybrids, while the second factor comprised the foliar application of marine seaweed extract with three concentrations (0, 10, and 20 ml L^{-1}). The results showed the roselle cultivar eggplant surpassed all other cultivars and provided the highest values for the traits, i.e., plant height, leaf area, dry weight of nuts, nuts per plant, and seeds of nut (160.03 cm, 635.50 cm^2, 402.77 g $plant^{-1}$, 172.44 nuts $plant^{-1}$, and 28.69 seeds nut^{-1}, respectively). The marine seaweed extract with the strongest concentration (20 ml L^{-1}) also displayed better performance for the above traits (176.02 cm, 615.58 cm^2, 361.22 g $plant^{-1}$, 176.74 nuts $plant^{-1}$, and 25.80 seeds nut^{-1}, respectively).

Keywords: Roselle (*H. sabdariffa* L.), cultivars, seaweed extract, growth and yield traits

Key findings: The Roselle (*H. sabdariffa* L.) cultivar eggplant excelled all other cultivars for growth and yield traits. The marine seaweed with the strongest concentration (20 ml L^{-1}) also provided better performance for growth and yield traits in Roselle.

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is an important flowering, medicinal, and vegetable plant belonging to the family Malvaceae, widely grown in tropical and subtropical regions (Rabo *et al*., 2015). It is native to Africa, particularly the West Africa, and in the 16th and early 17th centuries, it spread widely to Asia and the West Indies, where it has since become

Communicating Editor: Dr. A.N. Farhood

Manuscript received: April 21, 2024; Accepted: October 08, 2024.

Citation: Rumi AH, Jarallah MH (2025). Seaweed extract effect on the growth and yield-related traits of Roselle (*Hibiscus sabdariffa* L.). *SABRAO J. Breed. Genet.* 57(3): 1292-1301. http://doi.org/10.54910/sabrao2025.57.3.40.

naturalized in many places. Its cup-shaped leaves are a major source of many medicinal substances, such as vitamin C, anthocyanins, and glucosides, i.e., hibasscin, tartaric, citric, and malic acids. Additionally, it is rich in the compound acid protocatechinic, which is an antioxidant and a considered treatment that suppresses the growth of cancer cells, as well as rich in essential oil content in seeds (Kiliic *et al.,* 2011). In Iraq, roselle cultivation is small-scale in the central and southern areas.

Studying various cultivars of roselle enhances one's understanding of the diversity of genetic characteristics, such as, color, size, flavor, and nutritional content. The genetic diversity allows the development of new cultivars with improved characteristics, such as pest resistance and improved productivity, as well as knowing the extent of their adaptation to different environmental conditions. Some roselle genotypes may show better adaptability to different environmental conditions, viz., high temperatures and drought, making them ideal for cultivation in areas with unique environmental conditions (Yagi *et al.,* 2023).

Given its medicinal and economic value, it is entirely essential to extend its planting and carry out some studies to enhance its production. Among these factors, marine seaweed extract has a considerable impact by improving the soil properties and increasing the efficiency of the root system by absorbing sufficient amounts of water and nutrients. The quantity used is small and environmentally friendly. Increasing the concentration of the active substance also increases the absorbed nitrogen that enters the chlorophyll molecule, thus boosting the efficiency of photosynthesis. In roselle leaves, the different biochemicals like vitamin C, anthocyanins, auxins, cytokines, gibberellins, sugar, and vitamins B and A complex exist in a considerable quantity (Kadam *et al.,* 2013).

Biofertilizers accelerate side branches, thus increasing the number of flowers, the number of nuts, and the plant's total seeds and sepal leaves (Elansary *et al.,* 2016). The dissimilarity in genetic makeup of the different genotypes could have varied types of adaptation to different ambient conditions. The hybrids may also differ in their strength for the studied traits (El-Naim *et al*., 2017). Therefore, due to the lack of field studies, breeding, and improvement operations on the roselle crop, the presented study sought to identify the most productive cultivar and hybrid. It also aimed for the best concentration of seaweed extract and its interaction with roselle genotypes for growth and yield traits of roselle with the highest active ingredients.

MATERIALS AND METHODS

A field research began at the Research Station of AL-Mhanawia (A.S.) (30 km north of Al-Hilla), Iraq during the summer of 2021. It determined the impact of marine seaweed extract on the growth and yield traits of four genotypes and their semi-reciprocal hybrids of roselle with their bioactive compounds. The roselle genotype seeds' planting on a row with a 5-m length proceeded by placing 2–3 seeds with spacing of 50 cm and row spacing of 75 cm. Thus, the overall plant density was 26,666 plants ha^{-1}, with the field operations carried out as per the recommended package. Thinning transpired after two weeks of germination. The experimental land received fertilization with half the recommended nitrogen fertilizer (180 kg ha^{-1}) as urea (46% N), while adding half of the recommended phosphate fertilizer (160 kg ha^{-1}) as phosphorus pentoxide during soil preparation (Nasrallah, 2012). The rest of the crop service operations occurred whenever necessary.

Experiment design

The experiment layout in a randomized complete block design (RCBD) had a factorial arrangement of two factors and three replications. The first factor comprised 10 roselle genotypes, including four cultivars (eggplant, red, white, and striped) and their six half-diallel hybrids obtained from the Roselle Plant Development Project, Diwaniyah, Ministry of Agriculture, Iraq. The second factor was the three concentrations of marine seaweed extract (0, 10, and 20 ml L^{-1}) with symbols as A0, A1, and A2. The extract came from the dried marine (Tecamin Alga), and it contains various compounds (Table 1). The marine seaweed extract's foliar application succeeded with the help of a 16-liter backpack sprayer according to the concentrations as in the research plan, spraying three times for each concentration after 15, 30, and 45 days of germination. The spraying of marine seaweed extract on the leaves and stems continued until completely wet and during the first hours of dawn.

Upon crop maturity, carrying out the multiplication process among the four genotypes was according to the semi-reciprocal hybridization system, and the number of hybrids resulting was six half-diallel hybrids according to the law n(n-1)/2 (Griffing, 1956). At maturity, separate harvesting of the stalks of each genotype occurred, storing them in ideal warehouses until the following year. The seeds of the roselle four cultivars and their six semi-reciprocal hybrids reached planting in the second season of 2022.

Data recorded and analysis

The data recorded were on 10 randomly selected plants of roselle in each experimental unit for the traits, i.e., plant height (cm), leaf area (cm^2), dry weight of the plant (g $plant^{-1}$), nuts per plant (nuts $plant^{-1}$), and the number of seeds per nut (seeds nut^{-1}). All the recordings for various traits underwent the analysis of variance (ANOVA) as per the RCBD. Using the least significant difference ($LSD_{0.05}$) test helped compare and separate the means (Gomez and Gomez, 1984). All the statistical analyses' processing used the software GenStat12.

RESULTS AND DISCUSSION

Plant height

For plant height, the roselle cultivar eggplant excelled by giving the tallest value (160.03 cm), whereas the cultivar striped showed the lowest value for the said trait (81.07 cm), and the increase was 49.34% (Table 2). The presented results were greatly analogous to past findings, and this could be due to differences in the genetic makeup of the genotypes and their interaction with environmental influences (Majeed and Ali, 2011; Kreem and Ihsan, 2015).

The marine seaweed extract (20 ml L^{-1}) showed the highest average for plant height (176.02 cm) compared with the control treatment (no marine seaweed applied) (73.50 cm), and a considerable increase in plant height appeared (58.23%) (Table 2). This increase could refer to spraying seaweed extract, which provides the roselle plant with necessary nutrients, especially nitrogen, crucial in building the amino acid tryptophan, a considered basic substance of auxin. Auxin plays an important role in increasing cell elongation and, thus, increasing the plant height, as well as the level of nucleic acids, RNA, and DNA to boost proteins' formation and stimulate cell division. Moreover, the direct involvement of some elements in the synthesis of several vital compounds, such as cytokinins, enhances the process of photosynthesis and stimulates cell growth (Ahuja *et al.,* 2020).

As for the bilateral interaction between the four genotypes and the marine seaweed extract, the combination of roselle cultivar eggplant and marine seaweed extract (20 ml L^{-1}) was superior by giving it the tallest plant height (251.96 cm). Meanwhile, the genotype with the control treatment (A0) showed the shortest value for the said trait (59.89 cm), with an increase in the characteristic amounting to 100% (Table 2). As for the interaction between the hybrid roselle and the marine seaweed extract, the combination of hybrid 1 × 2 and A2 revealed the uppermost plant height (228.78 cm), while the hybrid 3 × 4 with A0 (control) showed the least value (60.09 cm), thus achieving an increase of 73.73%.

The superiority of the hybrid 1 × 2 with A0 gave the highest hybrid strength of 24.75%, while the hybrid 3 × 4 showed the lowest value (-3.37%) (Table 3). With marine seaweed (A1), the hybrid 1 × 2 outperformed by giving the highest values (46.63%), while the hybrid 2 × 3 revealed the lowest value for hybrid strength (2.52%). At A2 level, the hybrid 1 × 2 outdone by giving the utmost value (136.12%), while the hybrid 2 × 3

Table 1. Components of marine seaweed (Tecamin Alga) used in the experiment.

Name	Ratio (%)
Dried seaweed	16
Organic substance	13
Total nitrogen	1
Total phosphorus	0.5
Total potassium	2
Amino acids	1.5

Table 2. Effect of cultivars, seaweed extract, and their interactions on the plant height of Roselle.

Seaweed extract / Compositions	A0	A1	A2	Means (cm)
Eggplant (1)	86.21	141.92	251.96	160.03
White (2)	71.33	113.73	193.53	126.19
Red (3)	64.49	80.54	147.14	97.40
Striped (4)	59.89	72.39	100.93	81.07
1*2	98.27	165.93	228.78	147.66
1*3	82.24	138.39	209.89	133.84
1*4	79.39	112.64	188.94	119.32
2*3	69.33	99.49	173.40	110.07
2*4	68.80	95.40	150.33	96.17
3*4	60.09	80.44	127.35	85.96
Means (cm)	73.50	99.78	176.02	

Table 3. Hybrid vigor (%) of semi-reciprocal crosses of Roselle under the influence of seaweed extract for plant height.

Seaweed extract / Hybrids	A0	A1	A2
1*2	24.75	46.63	136.12
1*3	9.14	24.41	5.17
1*4	8.67	5.12	7.06
2*3	2.09	2.52	1.80
2*4	4.86	2.51	2.10
3*4	-3.37	5.20	2.67

displayed the least value of hybrid strength (1.80%). The best interaction of the roselle hybrids and the levels of marine seaweed extract emerged for the combination of 1 × 2 with A2, providing the maximum hybrid strength (136.12%). The lowest strength occurred with the combination of hybrid 4 × 3 with the control treatment (A0).

Leaf area

For leaf area, the roselle cultivar eggplant was superior and showed the broadest leaf area (635.50 cm^2), whereas the cultivar striped provided the lowest average (418.21 cm^2), and the increase was 34.19% (Table 4). The reason could be the differences in genetic structures of the roselle genotypes and the interaction of the genotypes with the environmental conditions (Wang *et al.,* 2016).

The marine seaweed concentration (A2) revealed the widest leaf area (615.58 cm^2) compared with the control treatment (439.80 cm^2), indicating an increase of 26.13% (Table 4). This could refer to the addition of marine seaweed to the roselle

Table 4. Effect of cultivars, seaweed extract, and their interactions on the leaves per plant in Roselle.

Seaweed extract / Compositions	A0	A1	A2	Means (leaf plant^{-1})
Eggplant (1)	501.53	611.57	793.40	635.50
White (2)	450.89	497.78	636.49	526.38
Red (3)	410.66	452.30	521.27	461.41
Striped (4)	380.44	417.87	456.34	418.21
1*2	490.35	596.65	737.71	608.23
1*3	467.76	520.43	679.74	555.98
1*4	444.52	511.87	640.89	532.42
2*3	444.45	501.30	600.18	515.31
2*4	411.17	465.95	576.97	484.70
3*4	399.21	431.62	510.81	447.21
Means (leaf plant^{-1})	439.80	500.74	615.58	

Table 5. Hybrid vigor (%) of semi-reciprocal crosses of Roselle under the influence of seaweed extract for leaves per plant.

Seaweed extract / Hybrids	A0	A1	A2
1*2	2.96	6.48	3.18
1*3	2.36	- 2.16	3.40
1*4	-9.19	1.19	2.56
2*3	3.17	5.52	3.76
2*4	-1.08	1.77	5.59
3*4	0.92	-0.79	4.52

plant, as it contains prime elements, such as nitrogen, critical in the formation of leaf buds, enhancing leaf area. In addition, the phosphorus, potassium, and minor elements, such as calcium, iron, manganese, and magnesium, as well as amino acids that produce a specific protein, cause an increase in the activity of meristematic cells. This also points to the microelements contained in marine seaweed, like zinc, which encourages the growth and increase in the cell division and leaf formation (Khan *et al.,* 2009).

The hybrid 2 × 3 showed the maximum hybrid strength at marine seaweed extract level A0 (3.17%), while hybrid 1 × 4 gave the minimum values (-9.19%) (Table 5). At A1 level, hybrid 1 × 2 gave the ultimate hybrid strength (6.48%), while hybrid 1 × 3 displayed the lowest value of hybrid strength (-2.16%). At A2 level, hybrid 2 × 4 outperformed by giving the highest hybrid strength (5.59%), and hybrid 1 × 4 appeared with the least value of hybrid strength. As for the interaction between two factors, it was notable that the highest value of the hybrid strength was 6.48% given by the combination of hybrid 2 × 1 with A1 level. Meanwhile, the lowest hybrid strength (-9.19%) resulted in the combination of hybrid 4 × 1 with the control treatment (A0).

Nuts dry weight per plant

The roselle cultivar eggplant showed the best performance over other genotypes for nuts dry weight per plant (402.77 g plant^{-1}), whereas the cultivar striped exhibited the least value for the said trait (213.87 g plant^{-1}) (Table 6). Thus, an increment in the dried weight of nuts was 46.90%. This difference could be due to the genetic makeup among the genotypes, as well as, the nature of their adaptation to the existing environmental conditions (Al-Moussawi, 2015; Al-Taie, 2017). Roselle hybrids also revealed considerable differences for the studied trait. Hybrid 1 × 4 excelled all other hybrids by getting the premiere nuts dry weight per plant (371.38 g plant^{-1}), whereas hybrid 3 × 4 gave the less value for the said trait (230.16 g plant^{-1}), indicating the increase of around 38.02% in the said trait.

As for the impact of marine seaweed extract on the trait, the marine seaweed extract 20 ml L^{-1} (A2) was distinct by giving the highest ratio (352.12 g plant^{-1}) versus the control treatment (A0). It provided the least average (247.68 g plant^{-1}), incurring an increase of 29.66%. This can be an attribute to the macro- and micronutrient elements contained in the marine seaweed extract, which directly manifested in photosynthesis and enzyme activity, and thus, an increase in protein, eventually enhancing vegetative growth (Tables 2 and 3). It led to an increment in yield characteristics, including the dry weight of the nuts.

In the interaction of both factors (genetic composition by seaweed extract), the combination of cultivar eggplant and marine seaweed (A2) excelled, demonstrating the highest average (487.23 g plant^{-1}). However, the cultivar striped with A0 showed the least nuts dry weight per plant (188.60 g plant^{-1}), recording an increase of 61.29%. For the interaction between the roselle hybrids and marine seaweed extract, the combination of hybrid 4 × 1 and A2 revealed the topmost value for the said trait (441.39 g plant^{-1}). Although, the combination of hybrid 4 × 3 and A0 gave the least ratio (220.52 g plant^{-1}), with an increase of 56.83% in nuts dry weight per plant.

In the strength of different hybrids as per marine seaweed extract, hybrid 2 × 3 (21.97%) was superior in performance, and hybrid 1 × 2 showed the least strength (0.86%) (Table 7). The marine seaweed level (A1) and hybrid 1 × 4 provided the highest ratio for hybrid vigor, whereas hybrid 1 × 2 presented the lowest ratio for hybrid vigor with

Table 6. Effect of cultivars, seaweed extract, and their interactions on the nuts dry weight in Roselle.

Seaweed extract / Compositions	A0	A1	A2	Means (g plant^{-1})
Eggplant (1)	337.49	383.59	487.23	402.77
White (2)	244.62	310.89	364.55	306.68
Red (3)	218.17	250.74	290.34	253.08
Striped (4)	188.60	210.66	242.37	213.87
1*2	293.58	355.49	439.48	362.85
1*3	289.34	334.84	395.81	339.99
1*4	301.99	370.76	441.39	371.38
2*3	282.24	310.17	361.38	317.93
2*4	260.25	287.75	311.87	286.62
3*4	220.52	244.19	277.79	247.50
Means (g plant^{-1})	263.68	305.90	361.22	

Table 7. Hybrid vigor (%) of semi-reciprocal crosses of Roselle under the influence of seaweed extract for nuts dry weight.

Seaweed extract / Hybrids	A0	A1	A2
1*2	0.86	2.37	3.19
1*3	4.39	5.57	1.80
1*4	14.80	24.78	20.99
2*3	21.97	10.45	10.25
2*4	20.14	10.34	2.77
3*4	8.43	5.84	4.29

the same level of marine seaweed. As for level A2, hybrid 1 × 4 outperformed by giving the ultimate hybrid vigor (20.99%), and hybrid 1 × 3 indicated the lowest strength (1.80%).

Nuts per plant

For nuts per plant, the roselle cultivar eggplant bested the rest of the genotypes by showing the most value for this trait (172.44 nuts plant^{-1}). However, the cultivar striped revealed the lowest value (93.56 nuts plant^{-1}), thus, showing an increase of 14.9% (Table 8). Majeed and Ali (2011) also reported the differences in the genetic makeup of the genotypes for the binding of nucleotides to RNA. In the same table, hybrid 1 × 2 excelled all other studied hybrids by giving the highest value (164.78 nuts plant^{-1}), whereas hybrid 3 × 4 enunciated the least value (95.61 nuts plant^{-1}), with an increase of 41.97%.

The marine seaweed extract 20 ml L^{-1} (A2) was remarkable with the most number of nuts per plant (174.74 nuts plant^{-1}), whereas the comparison treatment gave the least value (67.76 nuts plant^{-1}). A recorded increase of 61.22% existed in the said trait. This may be due to the strongest concentration of the marine seaweed extract, which provided more nutritional elements such as nitrogen. These nutrients increase the vegetative growth by enhancing the branching, leaf area, flowers, and the percentage of nodes, causing a rise in nuts per plant. Past studies also established that marine seaweed foliar application also improved vegetative growth and yield traits of okra (Al-Tahafy *et al.,* 2016).

In the interaction of green seaweed extract with roselle hybrids, the combination of eggplant cultivar with A2 level provided the maximum number of nuts per plant (272.10 nuts plant^{-1}) (Table 8). However, the treatment A0 × striped cultivar granted the minimum average (52.92 nuts plant^{-1}), indicating an increase of 80.55%. As for the impact of marine seaweed extract on the roselle hybrids, the combination of hybrid 2 × 1 with A2 showed the highest value (256.24 nuts plant^{-1}), while the combination of hybrid 4 × 3 with A0 (control) exhibited the least average value (55.95 nuts plant^{-1}), thus, achieving an increase of 78.16%.

The roselle hybrid 2 × 4 displayed superiority by giving the utmost value of the hybrid strength (5.99%) with the A0 level of the seaweed extract. Meanwhile, hybrid 1 × 4 gave the lowest value of hybrid strength with the same level of marine seaweed (Table 9). At seaweed level A1, hybrid 1 × 4 excelled other genotypes by revealing the highest hybrid strength (17.61%), with the least strength observed in hybrid 3 × 4 (2.94%). At marine seaweed level A2, hybrid 1 × 3 excelled by granting the maximum value (6.65%), while hybrid 1 × 4 provided the lowest value of hybrid strength (-5.57%).

Table 8. Effect of cultivars, seaweed extract, and their interactions on the nuts per plant in Roselle.

Seaweed extract / Compositions	A0	A1	A2	Means (nuts plant^{-1})
Eggplant (1)	85.70	159.54	272.10	172.44
White (2)	71.42	143.50	212.87	142.59
Red (3)	60.66	120.39	180.62	120.55
Striped (4)	52.92	96.56	131.21	93.56
1*2	80.67	157.43	256.24	164.78
1*3	73.93	145.65	241.42	132.14
1*4	69.92	150.60	190.41	136.97
2*3	68.60	140.95	200.89	136.14
2*4	65.90	131.11	177.49	124.83
3*4	57.95	111.66	149.24	106.28
Means (nuts plant^{-1})	69.76	135.74	176.74	

Table 9. Hybrid vigor (%) of semi-reciprocal crosses of Roselle under the influence of seaweed extract for the nuts per plant.

Seaweed extract / Hybrids	A0	A1	A2
1*2	2.68	3.90	5.67
1*3	1.02	4.06	6.65
1*4	0.88	17.61	- 5.57
2*3	3.87	6.82	2.10
2*4	5.99	9.23	3.16
3*4	2.04	2.94	- 4.27

Table 10. Effect of cultivars, seaweed extract, and their interactions on the seeds per nut in Roselle.

Seaweed extract / Compositions	A0	A1	A2	Means (seeds nut^{-1})
Eggplant (1)	20.18	29.20	36.69	28.69
White (2)	18.59	25.79	36.33	24.90
Red (3)	17.54	21.75	23.43	20.90
Striped (4)	16.55	18.01	20.66	18.40
1*2	21.60	26.98	35.44	24.34
1*3	20.27	25.62	32.58	22.42
1*4	19.99	23.84	30.89	20.84
2*3	18.87	23.89	28.10	20.45
2*4	17.83	22.69	26.87	19.76
3*4	17.53	20.55	22.09	19.16
Means (seeds nut^{-1})	18.13	22.03	25.80	21.31

Seeds per nut

For seeds per nut, the roselle cultivar eggplant led and produced the most number of seeds per nut (28.69 seeds nut^{-1}), whereas the striped genotype granted the least value for the said trait (18.40 seeds nut^{-1}). Thus, the increase was 35.86% (Table 10). Hybrid 1 × 2 also excelled all other hybrids by granting the highest number of seeds per nut (24.34 seeds nut^{-1}), while hybrid 3 × 4 disclosed the least value (19.16 seeds nut^{-1}); hence, the increase was 21.28%. Past studies also explained the reason for the enhancement in the number of seeds, which might be due to different okra genotypes and their interaction with environmental conditions (Matar, 2010).

As for different levels of seaweed extract, the marine seaweed level A2 outperformed the other two levels by providing the maximum number of seeds per nut (25.80 seeds nut^{-1}) compared with the control treatment (18.13 seeds nut^{-1}) (Table 10). Al-Nuaimi (2000) also stated that the cause for the increment in the seeds per nut refers to the addition of seaweed extract, which contained nutritional elements, especially nitrogen, improving growth and yield traits. Through the process of photosynthesis, the transfer of these materials from the source to the downstream (the nuts and their contents) hastens, and the number of nuts and seeds per nut rises.

The interaction between roselle genotypes and marine seaweed levels revealed the combination of cultivar eggplant and A2 was superior by giving the most number of seeds per nut (36.69 seeds nut^{-1}). Conversely, the genotype with A0 showed the least average for the said trait (16.54 seeds nut^{-1}), with an increase of 54.91% (Table 10). The combination of hybrid 2 × 1 with A2 excelled the rest of the combinations and displayed the highest value (30.44 seeds nut^{-1}), while the

Table 11. Hybrid vigor (%) of semi-reciprocal crosses of the Roselle under the influence of seaweed extract for seeds per nut.

Seaweed extract / Compositions	A0	A1	A2
1*2	8.65	10.16	5.75
1*3	7.47	0.58	8.38
1*4	8.87	1.01	7.74
2*3	4.48	0.50	4.53
2*4	1.53	3.60	5.41
3*4	2.87	3.37	0.22

combination of hybrid 4 × 3 and A0 (control) indicated the less average for the said trait (16.93 seeds nut^{-1}), with an increase of 44.38%.

In case of hybrids' strength, hybrid 1 × 4 at marine seaweed level A0 showed the maximum value of strength (8.87%), while hybrid 2 × 4 disclosed the minimum strength (1.53%) (Table 11). At seaweed extract level A1, hybrid 1 × 2 excelled in the strength (10.16%), whereas hybrid 2 × 3 recorded the least value (0.50%). At level A2, hybrid 1 × 3 outperformed other combinations and boasted the highest hybrid strength (8.38%), while hybrid 3 × 4 shared the least strength (0.22%).

CONCLUSIONS

The results enunciated that the genetic makeup of the roselle genotypes plays an important role in its growth and production characteristics. The use of marine seaweed extract has vividly affected most growth and yield traits of roselle.

REFERENCES

Ahuja I, Dauksas E, Remme JF, Richardsen R, Løes AK (2020). Fish and fish waste-based fertilizers in organic farming–with status in Norway: A review. *Waste Manag*. 115: 95-112.

Al-Moussawi HG (2015). The effect of spraying with two types of foliar fertilizers on growth and yield of some medically effective ingredients in two types of Roselle. Master's Thesis, Department of Life Sciences, College of Science for Girls, University of Babylon, Iraq. pp. 92.

Al-Nuaimi SN (2000). Principles of Plant Nutrition. Mosul University Publishing Press. College of Agriculture and Forestry. University of Al-Mosul, Iraq. pp. 722.

Al-Tahafy SA, Abdel-Majeed AAL, Kazem RK, Hussein LM (2016). Effect of adding agricultural sulfur and spraying with marine seaweed extract on the growth and yield of okra plant, Al-Husseinawiyah cultivar. *Al-Furat J. Agric. Sci.* 8 (2): 93-99.

Al-Taie ASH (2017). The effect of salicylic acid and marine seaweed extract on growth and yield of Roselle varieties and their content of some effective medicinal compounds. Master's Thesis. Al-Furat Al-Awsat Technical University, Musayyib Technical College, Babylon, Iraq. pp. 115.

Elansary HO, Skalicka-Woźniak K, King IW (2016). Enhancing stress growth traits as well as phytochemical and antioxidant contents of Spiraea and Pittosporum under seaweed extract treatments. *Plant Physiol. Biochem.* 105: 310-320.

El-Naim AM, Ahmed AI, Ibrahim KA, Suliman AM, Babikir ES (2017). Effects of nitrogen and bio-fertilizers on growth and yield of roselle (*Hibiscus sabdariffa* L.). *Int. J. Agric. For.* 7(6): 145-150.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research. John Wiley and Sons, Inc., 2nd Ed. New York, USA. pp. 157.

Griffing B (1956). Concept of general and specific combining ability in relation to diallel cross system. *Aust. J. Biol. Set*. 9: 462-493.

Kadam SU, Tiwari BK, O'Donnell CP (2013). Application of novel extraction technologies for bioactives from marine seaweed*. J. Agric. Food Chem.* 61(20): 4667-4675.

Khan W, Rayirath UP, Subramanian S, Jithesh MN, Rayorath P, Hodges DM, Prithiviraj B (2009). Seaweed extracts as biostimulants of plant growth and development. *J. Plant Growth Regul.* 28: 386-399.

Kiliic CS, Aslan S, Kartal M, Coskun M (2011). Fatty acid composition of *Hibiscus trionum* L. Malvaceae. *Rec. Nat. Prod.* 5(1): 65-69.

Kreem HK, Ihsan SA (2015). The effect of cultivars and spray the compound fertilizer (NPK) in growth and yield in Roselle and the content of some active compounds in Roselle (*Hibiscus sabdariffa* L.). *Al-Furat J. Agric. Sci*. 7(4): 30-37.et

Majeed KA, Ali AS (2011). Effect of foliar application of NPK on some growth characters of two cultivars of Roselle (*Hibiscus sabdariffa* L.). *Am. J. Plant Physiol*. 6(4): 220-227.

Matar KA (2010). The effect of cultivar and level of phosphate fertilization on plant growth and yield of Okra. *Kerbala Univ. Sci. J.* 8(2): 210-214.

Nasrallah AY (2012). Medicinal Plants, First Edition. Informed by Dar Al-Hekma Printing Publishing and Distribution, Faculty of Agriculture, Baghdad University, Iraq. pp. 315.

Rabo SA, Mustapha BS, Simon AB, Hamma IL (2015). Influence of NP fertilizer on the performance of Roselle (*Hibiscus sabdariffa* L.) in Samaru Zaria. *Niger. J. Agric. Food Environ*. 11(3): 6l-64.

Wang J, Cao X, Ferchaud V, Qi Y, Jiang H, Tang F, Chin KL (2016). Variations in chemical fingerprints and major flavonoid contents from the leaves of thirty-one accessions of *Hibiscus sabdariffa* L. *Biomed. Chromatogr*. 30(6): 880-887.

Yagi S, Uba AI, Sinan KI, Piatti D, Sagratini G, Caprioli G, Zengin G (2023). Comparative study on the chemical profile, antioxidant activity, and enzyme inhibition capacity of red and white *Hibiscus sabdariffa* variety Calyces. *ACS omega*. 8(45): 42511-42521.