Improving Fruit quality of Strawberry (*Fragaria* x *ananassa* Duch) Cv. Albion under different levels of Arginine, Brassinolide and Seaweed Application

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Abstract

The research was carried out in two distinct plastic greenhouses. The first location was at the University of Anbar, College of Agriculture first research station. The second location was in Heet city, Aldolab village during the growing season of 2022-2023, with the goal of investigating the effect of spraying with seaweed extract(2 and 4 ml L^{-1}), amino acid "arginine" (100 and 200 mg L^{-1}), and growth regulator brassinolide (0.05 and 0.10 mg L^{-1})on the quality of fruits of Albion strawberry plants under protected environment conditions. in addition to the control treatment of spraying with distilled water only for the three factors. A factorial experiment with three factors was conducted according to the randomized complete block design (RCBD). Spraying with seaweed extract, arginine and brassinolide had a significant effect on all the traits of the quality of the studied fruits, the concentrations of seaweed extract (4 ml L^{-1}), arginine (200 mg L^{-1}), and brassinolide (0.01 mg L^{-1}) contributed to the best results for the traits (percentage of total sugars, the ratio between sugars and acidity, total soluble solid, anthocyanin and ascorbic acid). The values were (7.34 and 6.59%, 6.83 and 6.64%, 7.11 and 6.35%), (20.61 and 14.60, 17.99 and 14.17, 18.66 and 13.39), (9.25 and 8.34%, 8.87 and 8.24%, 9.10 and 8.34%), (59.57 and 48.91 mg 100 g^{-1}, 53.81 and 43.02 mg 100 g^{-1}, 52.34 and 42.98 mg 100 g^{-1}), (50.95 and 57.73 mg 100 g^{-1}, 50.18 and 56.37 mg 100 g^{-1}, 50.39 and 55.96 mg 100 g^{-1}), for the two sites respectively. On the other hand, the above treatments led to lowering the ratios of total acidity in fruits at both sites were (0.38 and 0.48%, 0.40 and 0.49%, 0.40 and 0.51%), respectively.The interaction between the two and three factors had a significant effect on most of the studied traits depending on the type of trait studied.

Keywords: Strawberry, Seaweed extract, Arginine, Brassinolide, Yield quality.

Introduction

Strawberries *Fragaria* x *ananassa* Duch are popular fruits because they can adapt to different environmental conditions, have high nutritional value, and grow and produce quickly (26). Strawberry cultivation is currently spread in more than 63 countries. In 2021, the cultivated area was about 389,665 hectares, with a global production rate of about 9.1 million tons (10). In Iraq, strawberry cultivation is relatively recent. It is limited to scientific research stations, some home gardens, and small agricultural areas. The consumption of strawberries in Iraq is relatively low, and most of the strawberries consumed in Iraq are imported from neighboring countries(28).

Their fruits have a high nutritional and therapeutic value due to their content of nutrients, fiber, vitamins, proteins, carbohydrates, and phenolic compounds, including anthocyanins (12). It is worth noting that strawberry fruits are a good source of vitamin C (40-120 mg per 100 g of fruit), which is an antioxidant. Strawberries also have protective effects against heart disease, cardiovascular disease, cancer, hypertension, and other chronic diseases (13).

The strawberry plant demands abundant fertilizer due to its capacity to yield a substantial amount of fruit despite its small stature(11). Consequently, foliar fertilization emerges as a crucial strategy to address the insufficiency of essential elements and nutrients. This approach enhances the plant's efficiency in generating high-quality fruits meeting specific appearance criteria. Studies indicate that excessive reliance on chemical fertilizers can lead to environmental contamination and adverse impacts on both human and animal. Hence, the pursuit of alternatives to chemical fertilizers in plant nutrition has become imperative., including plant extracts (1 and 14) and amino acids (15), as well as the use of growth regulators such as brassinolides (29), which are safer for the environment, humans and animals.

Algae extracts are increasingly being used to improve plant growth, yield, and quality. They are used to produce chemical-free crops and are considered a significant organic source, with approximately 15 million tons being used annually in agriculture. They are effective in promoting plant growth even at low concentrations. Additionally, these extracts contain growth-promoting substances such as cytokinins, auxins, gibberellins, vitamins, and complex sugars. They also contain both micro and macro nutrients, amino acids, and organic acids. (3 and 22).

Amino acids are natural chelating compounds with low molecular weights that are highly soluble in water and easily penetrate cell membranes, especially when sprayed on plants as nutrient solutions. They can therefore directly or indirectly affect the physiological activities that contribute to the formation of basic compounds such as carbohydrates, proteins, fats, vitamins, and others (4). Amino acids also contribute to increased pollen germination and pollen tube growth, which increases the percentage of fruit set (24). They also play an important role in improving vegetative growth and plant health, which increases their resistance to disease, pests, and stress (21).

Brassinolides are environmentally friendly plant growth regulators that play a role in plant growth and development. They affect cell division and contribute to plant growth. Initial studies have focused on their ability to stimulate cell elongation and increase cell size (30). They are also very effective in stimulating the growth of young green tissues (16). Brassinolides have good applications in flower growth (5). (9) reported that brassinolide is a natural compound that is widely distributed in many plants. It has a high biological activity in very low concentrations, and its activity is ten thousand times stronger than the plant growth regulator (IAA). This leads to a high increase in the fruit set rate due to its important role in stabilizing newly formed flowers. (17) confirmed that brassinolide stimulates the production of DNA, RNA, and different proteins, nitrogen fixation, and the distribution of manufactured materials to plant organs. This leads to an increase in fruit weight and size, which in turn reflects positively on the overall yield of plants. The study aims to assess the impact of foliar nutrition with arginine, brassinolide and seaweed extract application on enhancing the quality of fruits of Albion variety strawberry plants.

Materials and Methods

Experiment site

The experiment was conducted in a greenhouse at two sites: the first location was at the University of Anbar, College of Agriculture, first research station, and the second site was at the Heet city, Aldolab village, during the growing season 2022-2023, with the aim of investigating the impact of spraying with seaweed extract, amino acid (arginine), and growth regulator (Brassinolide) on the quality of fruits of Albion strawberry saplings under protected environment conditions. Table (1) shows some of the chemical and physical properties of the soil at the two sites.

Factors used in the Experiment

The following factors were studied during the experiment:

1- Spraying with seaweed extract (A) at three concentrations: A0 (spraying with distilled water), A2 (2 ml L^{-1}), and A3 (4 ml L^{-1}). The seaweed extract (Alcygol Ca) It is manufactured by a company (Agronutrition in France), it is composed of (CaO 22.5%, N 15.4%, MgO 3%, B 0.14%, Cu 0.04%, Fe 0.04%, Zn 0.04%).

2- Spraying with the amino acid "arginine" (B). It is manufactured by a company (Avonchem in UK), it used at three concentrations: B0 (spraying with distilled water), B1 (100 mg L^{-1}), and B2 (200 mg L^{-1}).

3- Spraying with the growth regulator brassinolide (C) at three concentrations: C0 (spraying with distilled water), C1 (0.05 mg L^{-1}), and C2 (0.10 mg L^{-1}).

A 16-liters sprayer were used to spray the plants until they were completely wet. Liquid soap was added as a dispersant at a rate of 0.1 ml L^{-1} to reduce the surface tension of the spray solution molecules, which allows the plants to absorb the maximum amount of the sprayed solutions. The plants were treated five times on the following dates: November 20, December 20, January 1, February 2, and March 3. The spraying operations were carried out in the early morning after a moveable barrier was built to prevent the spray solutions from being transferred between treatments.

Experimental design

A factor factorial experiment was conducted according to a randomized complete block design (RCBD). The experiment consisted of 27 treatments, which were distributed in three blocks, with five plants per experimental unit. This resulted in a total of 405 plants per site. The data were statistically analyzed, and the means were compared using the least significant difference (LSD) test at the 5% level of significance (6). The data were analyzed using the Genstat program. The following traits have been studied in the fruits:

1. Total sugars (%): The total sugar percent was determined from the filtered juice using (18). It was done by taking 1 ml of the filtered juice by pipette and the volume completed to 200 ml and mixed. 1 ml of filtered juice in a glass conical flask, 1 ml of phenol (concentration 5%) was added and then 5 ml of concentrated sulfuric acid 98% with continuous hand shaking of the mixture until light color appeared. The mixture was left to cool down, and then the light absorption was measured using the light spectrogram type EMCLAB at wavelength of 490 nm. The standard solutions of glucose were prepared to make standard curve and locate the readings.

2. Total acidity (%):TA was calculated by taking a certain volume of the same filtered juice for the determination of (TSS) and correcting it with the base NaoH of standardized (0.1N) and using 2 drops of phenonphthalein indication only on the basis of citric acid as the predominant acid in Strawberry (23).

3. sugars/acidity ratio: Calculated by dividing the values of the total sugars by the values of the total acidity of the fruits.

4. Total soluble solid (%): The total soluble solids percent was measured using Hand refractor meter. Ten homogenized and mature fruits were cut into slices for each experimental unit. The slices were blended in electric blender for 2-3 minutes, and then the juice was filtered using cotton rag. The reading was recorded from the device to represent the (TSS) in the fruit juice.

5. Anthocyanin (mg 100 g^{-1}): Anthocyanins were extracted from the fresh fruits using alcoholic hydrochloric acid (Alcoholic HCl) consisting of 95% as ethyl alcohol and HCl (1.5 standards) at a ratio of 85:15 by taking 1 g of the mixed soft fruits and dissolving them in 20 ml of acidified alcohol Leave it for 24 hours at room temperature, then filter it with (watman No.1) filter paper. Then the estimation was done using EMC lab v1 100 Spectrophotometer at wavelength of 535 nm as reported in (23).

6. Ascorbic acid (mg 100 g^{-1}): Ascorbic acid (Vitamin C) in fruit juice was estimated according to the method mentioned by (25), using Oxalic acid at a concentration of 2% as a preservative solution and correcting with pigment (2,6-Dichlorophenol Indophenol, Ascorbic acid, alone is able to reduce this pigment by changing from blue in the basic medium to pink in the acid medium.

Table 1. Some chemical and physical properties of soil for two sites.

First location (first research station)						
P Av. mg Kg^{-1}	Total N %	$CaCO_3$ g Kg^{-1}	Bulk density g cm^{-3}	O.M %	EC ds m^{-1}	pH
1.27	0.31	122.46	1.48	1.83	3.65	7.74
Cl^- Mq L^{-1}	$HCO3^=$ Mq L^{-1}	$CO_3^=$ Mq L^{-1}	Na^+ Mq L^{-1}	Mg^{++} Mq L^{-1}	Ca^{++} Mq L^{-1}	K Av. mg Kg^{-1}
52.41	4.23	Nil	0.85	39.56	44.92	136.63
		Texture	Clay	Silt	Sand	$SO_4^=$

			g Kg^{-1}	g Kg^{-1}	g Kg^{-1}	Mq L^{-1}
		Sandy Clay Loam	241.4	166.3	592.3	27.40
Second location (Aldolab village)						
P Av. mg Kg^{-1}	Total N %	$CaCO_3$ g Kg^{-1}	Bulk density g cm^{-3}	O.M %	EC ds m^{-1}	pH
1.13	0.47	153.61	1.32	2.18	2.94	7.54
Cl^- Mq L^{-1}	$HCO3^=$ Mq L^{-1}	$CO_3^=$ Mq L^{-1}	Na^+ Mq L^{-1}	Mg^{++} Mq L^{-1}	Ca^{++} Mq L^{-1}	K Av. mg Kg^{-1}
37.25	3.78	Nil	0.69	51.82	32.26	93.70
		Texture	Clay g Kg^{-1}	Silt g Kg^{-1}	Sand g Kg^{-1}	$SO_4^=$ Mq L^{-1}
		Sandy Clay Loam	352.6	137.0	510.4	27.40

Results and Discussion

Total sugars Percentage

The results indicate that spraying with seaweed extract, arginine, and brassinolide all contributed to significant differences in the total sugars of 'Albion' strawberry fruits (Table 2). Treatments (A2, B2, and C2) gave the highest percentages of 7.34 and 6.59%, 6.83 and 6.64%, 7.11 and 6.35% at sites 1 and 2, respectively. The lowest values were found in the no-spray treatments (A0, B0, and C0), reaching 5.98 and 5.44%, 6.29 and 5.56%, 6.02 and 5.88% at sites 1 and 2, respectively. The two-way interaction between algae extract and growth regulator at both sites, had a significant effect especially at the treatments (A2C1) at the first site, and (A2C2) at the second site were gave the highest value 8.04 and 7.40%, respectively. The interaction between amino acid and growth regulator at second site, had a significant effect especially at the treatment (B2C1) was gave the highest percentage 6.92%. The three-way interaction had a significant effect on the trait at both sites. Treatment (A2B2C1) at the first site, and treatment (A2B1C2) at the second site was gave the highest value, reaching 8.78 and 7.92%, respectively. The control treatment (A0B0C0) gave the lowest value 4.97 and 4.65% at sites 1 and 2, respectively.

Table 2. Effect of Spray with Seaweed Extract, Arginine, and Brassinolide on the Total Sugars (%) in the Fruits of Albion Strawberry Plants

Arginine (B)	**Brassinolide (C)**	**First site (Research Station) Sea weed extract (A)**				**Second site (Aldolab) Sea weed extract (A)**			
		A0	**A1**	**A2**	**B×C**	**A0**	**A1**	**A2**	**B×C**
	C0	4.97	5.34	7.15	5.82	4.65	5.42	6.89	5.62
B0	**C1**	5.09	6.40	7.43	6.31	5.13	5.65	5.42	5.40
	C2	6.25	7.45	6.52	6.74	4.95	5.08	6.96	5.66
	C0	5.91	6.52	5.68	6.04	5.27	6.78	5.29	5.78
B1	**C1**	6.47	5.76	7.89	6.71	5.19	5.87	5.34	5.47
	C2	6.21	7.39	8.42	6.34	5.78	6.16	7.92	6.62
	C0	5.86	5.73	7.07	6.22	5.81	6.29	6.61	6.24
B2	**C1**	6.35	5.96	8.78	7.03	6.37	6.84	7.56	6.92
	C2	6.72	7.87	7.13	7.24	5.86	7.10	7.32	6.76

					Mean B				**Mean B**
A×B	**B0**	5.44	6.40	7.03	6.29	4.88	5.38	6.42	5.56
	B1	6.20	6.55	7.33	6.69	5.42	6.27	6.18	5.96
	B2	6.31	6.52	7.66	6.83	6.01	6.74	7.17	6.64
					Mean C				**Mean C**
A×C	**C0**	5.58	5.86	6.63	6.02	5.21	6.16	6.26	5.88
	C1	5.97	6.04	8.04	6.68	5.56	6.12	6.11	5.93
	C2	6.39	7.57	7.36	7.11	5.53	6.11	7.40	6.35
Mean A		5.98	6.49	7.34		5.44	6.13	6.59	

LSD 5%

	A	**B**	**C**	**A×B**	**A×C**	**B×C**	**A×B×C**
First site	0.36	0.36	0.36	NS	0.63	NS	1.09
Second site	0.40	0.40	0.40	NS	0.68	0.68	1.18

Total Acidity Percentage

The results in (Table 3) show that spraying with seaweed extract; amino acid (arginine), and growth regulator (brassinosteroid) had a significant effect on the percentage of total acidity. Treatments (A2, B2, and C2) gave the lowest values, reaching 0.38 and 0.48%, 0.40 and 0.49%, 0.40 and 0.51% at sites 1 and 2, respectively, compared to treatments (A0, B0, and C0), which had the highest values of 0.48 and 0.59% 0.46 and 0.59%, 0.47 and 0.57% at sites 1 and 2, respectively.

The results showed significant Effect of dual interaction between algae extract and amino acid at two sites, especially at treatments amino acid (A2C2) and (A2C1) at the first site and (A2C2) at the second site, which achieved the lowest percentage of 0.34, 0.34 and 0.43%, respectively. In contrast, the interaction between amino acid and growth regulator show a significant effect on this trait at second site of study, especially at treatment (B2C2), which gave the lowest value of 0.35 and 0.45%, respectively. On the other hand, the three-way interaction had a significant effect at 1 site with the treatment (A2B2C1) achieved lowest percentage of 0.28%, while treatment (A0B0C0) gave the highest percentage of 0.52%.

Table 3. Effect of Spray with Seaweed Extract, Arginine, and Brassinolide on the Total Acidity (%) of Albion Strawberry Plants

Arginine (B)	**Brassinolide (C)**	**First site (Research Station) Sea weed extract (A)**				**Second site (Aldolab) Sea weed extract (A)**			
		A0	**A1**	**A2**	**B×C**	**A0**	**A1**	**A2**	**B×C**
B0	**C0**	0.52	0.46	0.44	0.48	0.68	0.63	0.56	0.62
	C1	0.50	0.45	0.42	0.46	0.61	0.54	0.49	0.55
	C2	0.48	0.48	0.40	0.45	0.63	0.62	0.57	0.60
B1	**C0**	0.51	0.40	0.48	0.47	0.59	0.58	0.53	0.57
	C1	0.45	0.47	0.32	0.41	0.64	0.52	0.56	0.57
	C2	0.49	0.38	0.31	0.39	0.52	0.54	0.38	0.48
B2	**C0**	0.47	0.48	0.43	0.46	0.54	0.55	0.46	0.52
	C1	0.44	0.46	0.28	0.39	0.62	0.48	0.42	0.51
	C2	0.41	0.33	0.32	0.35	0.50	0.51	0.35	0.45

					Mean B				**Mean B**
	B0	0.50	0.47	0.42	0.46	0.64	0.59	0.54	0.59
A×B	**B1**	0.48	0.42	0.37	0.42	0.58	0.55	0.49	0.54
	B2	0.44	0.42	0.35	0.40	0.55	0.51	0.41	0.49
					Mean C				**Mean C**
	C0	0.50	0.45	0.45	0.47	0.60	0.59	0.52	0.57
A×C	**C1**	0.47	0.46	0.34	0.42	0.62	0.51	0.49	0.54
	C2	0.46	0.40	0.34	0.40	0.55	0.55	0.43	0.51
Mean A		0.48	0.44	0.38		0.59	0.55	0.48	

LSD 5%

	A	B	C	A×B	A×C	B×C	A×B×C
First site	0.02	0.02	0.02	NS	0.04	NS	0.07
Second site	0.03	0.03	0.03	NS	0.05	0.05	NS

The ratio between sugars and acidity

The results show that spraying with the three study factors had a significant effect on the ratio between sugars and acidity of fruits of 'Albion' strawberry fruits (Table 4). Treatment (A2) gave the highest values of 20.61 and 14.60 at sites 1 and 2, respectively. The highest values for amino acid treatments were found at treatment (B2) for two sites, reaching 17.99 and 14.17, respectively. The highest values for spraying with growth regulator were 18.66 and 13.39 at treatment (C2) and at both sites 1 and 2, respectively. On the other hand, the lowest values were found in the treatments (A0, B0, and C0), which had the lowest values of 12.79 and 9.37, 13.91 and 9.58, 13.13 and 10.58 at sites 1 and 2, respectively. The two-way interaction between algae extract and amino acid had no significant effect at both sites. The two-way interaction between algae extract and growth regulator had a significant effect at both sites, especially at treatments (A2C1) at 1 site and (A2C2) at 2 site, reaching 24.74 and 18.66, respectively. The two-way interaction between amino acid and growth regulator had a significant effect at both sites, especially at treatment (B2C2), which reached a value of 20.82 and 16.17, respectively. The three-way interaction had a significant effect at first site, especially at treatment (A2B2C1) that giving the highest value, reaching 31.29, while treatment (A0B0C0) gave the lowest number, at 9.56.

Table 4. Effect of Spray with Seaweed Extract, Arginine, and Brassinolide on the Ratio Between Sugars and Acidity of Fruits of Albion Strawberry Plants

Arginine (B)	Brassinolide (C)	First site (Research Station)				Second site (Aldolab)			
		Sea weed extract (A)			B×C	Sea weed extract (A)			B×C
		A0	A1	A2		A0	A1	A2	
	C0	9.56	11.61	16.45	12.54	6.70	8.62	12.32	9.21
B0	**C1**	10.11	14.14	17.64	13.97	8.44	10.57	11.13	10.05
	C2	13.29	15.53	16.88	15.23	7.92	8.22	12.29	9.47
	C0	11.67	16.44	11.74	13.28	9.18	11.63	10.20	10.33
B1	**C1**	14.28	12.28	25.34	17.30	8.14	11.36	9.61	9.70
	C2	12.76	19.50	27.56	19.94	11.16	11.47	20.97	14.53
	C0	12.36	11.89	16.46	13.57	10.78	11.51	14.27	12.19
B2	**C1**	14.44	13.06	31.29	19.60	10.30	14.21	17.93	14.15
	C2	16.63	23.70	22.12	20.82	11.70	14.09	22.71	16.17

					Mean B				**Mean B**
A×B	**B0**	10.98	13.76	16.99	13.91	7.68	9.14	11.91	9.58
	B1	12.91	16.07	21.55	16.84	9.49	11.48	13.59	11.52
	B2	14.48	16.22	23.29	17.99	10.93	13.27	18.31	14.17
					Mean C				**Mean C**
A×C	**C0**	11.20	13.31	14.88	13.13	8.89	10.59	12.26	10.58
	C1	12.94	13.16	24.76	16.95	8.96	12.05	12.89	11.30
	C2	14.23	19.58	22.19	18.66	10.26	11.26	18.66	13.39
Mean A		12.79	15.35	20.61		9.37	11.30	14.60	

LSD 5%

	A	B	C	A×B	A×C	B×C	A×B×C
First site	1.43	1.43	1.43	NS	2.47	2.47	4.28
Second site	1.20	1.20	1.20	NS	2.08	2.08	NS

Total soluble solid (%)

The results indicate that spraying with seaweed extract, arginine, and brassinolide all contributed to significant differences in the total soluble solids of 'Albion' strawberry fruits (Table 5). Treatments (A2, B2, and C2) gave the highest percentages of 9.25 and 8.34%, 8.87 and 8.24%, 9.10 and 8.13% at sites 1 and 2, respectively. The lowest values were found in the no-spray treatments (A0, B0, and C0), reaching 8.03 and 7.18%, 8.25 and 7.21%, 8.05 and 7.38% , respectively. The two-way interaction between algae extract and amino acid at both sites, had a significant effect especially at the treatment (A2B2) at both sites, were gave the highest value 9.80 and 9.34%, respectively. the interaction between algae extract and growth regulator at both sites, had a significant effect especially at the treatment (A2C1) at 1 site, and (A2C2) at 2 site were gave the highest percentage 10.00 and 8.87%. The three-way interaction had a significant effect on the trait at 1 site, treatment (A2B2C1) at the 1 site was gave the highest value, reaching 10.87%. The control treatment (A0B0C0) gave the lowest value 6.92%.

Table 5. Effect of Spray with Seaweed Extract, Arginine, and Brassinolide on Percentage of Total Soluble Solids of Fruits of Albion Strawberry Plants

Arginine (B)	**Brassinolide (C)**	**First site (Research Station)**				**Second site (Aldolab)**			
		Sea weed extract (A)			**B×C**	**Sea weed extract (A)**			**B×C**
		A0	**A1**	**A2**		**A0**	**A1**	**A2**	
B0	**C0**	6.92	7.25	8.97	7.71	6.25	7.90	7.26	7.14
	C1	7.23	8.50	9.28	8.34	6.61	6.62	7.64	6.96
	C2	7.86	9.76	8.43	8.68	7.63	6.83	8.16	7.54
B1	**C0**	8.19	8.45	7.58	8.07	6.82	8.10	7.55	7.49
	C1	8.04	7.66	9.84	8.52	7.14	7.25	7.87	7.42
	C2	8.82	9.21	9.76	9.26	7.56	8.34	8.57	8.16
B2	**C0**	8.34	7.84	8.93	8.37	7.02	7.35	8.21	7.53
	C1	8.22	7.53	10.87	8.87	7.72	7.80	9.94	8.49
	C2	8.68	9.78	9.61	9.36	7.87	8.37	9.88	8.71
					Mean B				**Mean B**
A×B	**B0**	7.34	8.51	8.89	8.25	6.83	7.12	7.69	7.21
	B1	8.35	8.44	9.06	8.62	7.17	7.90	8.00	7.69
	B2	8.41	8.38	9.80	8.87	7.54	7.84	9.34	8.24
					Mean C				**Mean C**

	C0	7.82	7.85	8.49	8.05	6.69	7.78	7.67	7.38
A×C	C1	7.83	7.90	10.00	8.58	7.16	7.23	8.48	7.62
	C2	8.45	9.58	9.27	9.10	7.68	7.85	8.87	8.13
Mean A		8.03	8.44	9.25		7.18	7.62	8.34	

LSD 5%	A	B	C	A×B	A×C	B×C	A×B×C
First site	0.39	0.39	0.39	0.67	0.67	NS	1.16
Second site	0.37	0.37	0.37	0.65	0.65	NS	NS

Anthocyanin (mg 100 g^{-1})

The results indicate that spraying with algae extract, arginine, and brassinosteroid had a significant effect on fruit content of Anthocyanin for 'Albion' strawberry saplings (Table 6). Treatments (A2, B2, and C2) reached the highest levels at both sites, reaching 59.57 and 48.91 mg 100 g^{-1}, 53.81 and 43.02 mg 100 g^{-1}, 52.34 and 42.98 mg 100 g^{-1}, respectively, compared to treatments (A0, B0, and C0), which gave the lowest values of 40.82 and 35.24 mg 100 g^{-1}, 46.73 and 37.87 mg 100 g^{-1}, 48.27 and 40.23 mg 100 g^{-1}, at both sites 1 and 2, respectively. The interaction between algae extract and amino acid at site 2, and algae extract and growth regulator at 1 site , and amino acid and growth regulator at 1 site had a significant effect, especially at treatments (A2B1), (A2C1) and (B2C2) at values of 52.02, 61.45 and 58.06 mg 100 g^{-1}, respectively. The three-way interaction had a significant effect, with treatment (A2B2C2) at site 2 achieving the highest rate of 58.75 mg 100 g^{-1}, while treatment (A0B0C0) gave the lowest value of 31.60 mg 100 g^{-1}.

Table 6. Effect of Spray with Seaweed Extract, Arginine, and Brassinolide on fruit content of Anthocyanin (mg 100 g^{-1}) of Albion Strawberry Plants

Arginine (B)	Brassinolide (C)	First site (Research Station)				Second site (Aldolab)			
		Sea weed extract (A)			B×C	Sea weed extract (A)			B×C
		A0	A1	A2		A0	A1	A2	
	C0	34.38	47.52	53.24	45.04	31.60	34.26	43.91	36.59
B0	C1	37.80	44.13	56.17	46.03	35.17	38.72	39.73	37.87
	C2	36.72	52.27	58.33	49.11	34.93	37.13	45.36	39.14
	C0	39.10	48.79	54.25	47.38	34.28	39.61	50.80	41.56
B1	C1	43.72	45.95	67.48	52.38	37.21	37.52	53.48	42.74
	C2	39.54	52.87	57.16	49.85	35.06	45.09	51.78	43.98
	C0	42.94	50.75	63.52	52.40	37.78	41.67	48.14	42.53
B2	C1	44.09	48.06	60.71	50.95	35.54	38.26	48.26	40.69
	C2	49.15	59.78	65.27	58.06	35.56	43.20	58.75	45.84
					Mean B				Mean B
	B0	36.30	47.97	55.91	46.73	33.90	36.70	43.00	37.87
A×B	B1	40.78	49.20	59.63	49.87	35.51	40.74	52.02	42.76
	B2	45.39	52.86	63.16	53.81	36.29	41.05	51.72	43.02
					Mean C				Mean C
	C0	38.80	49.02	57.00	48.27	34.55	38.52	47.62	40.23
A×C	C1	41.87	46.04	61.45	49.79	35.97	38.17	47.16	40.43
	C2	41.80	54.97	60.25	52.34	35.18	41.81	51.96	42.98

Mean A	40.82	50.01	59.57		35.24	39.50	48.91	

LSD 5%

	A	**B**	**C**	**A×B**	**A×C**	**B×C**	**A×B×C**
First site	2.48	2.48	2.48	NS	4.29	4.29	NS
Second site	1.89	1.89	1.89	3.28	NS	NS	5.68

Ascorbic acid (mg 100 g^{-1})

The results in Table 7 show that spraying with the three study factors individually had a significant effect on the fruit content of Ascorbic acid of 'Albion' strawberry. Treatments (A2, B2, and C2) gave the highest values of 50.95 and 57.73 mg 100 g^{-1}, 50.18 and 56.37 mg 100 g^{-1}, 50.39 and 55.96 mg 100 g^{-1} at both sites 1 and 2, respectively. The lowest values was found in treatments (A0, B0 and C0), which reached 44.00 and 50.36 mg 100 g^{-1}, 46.15 and 50.31 mg 100 g^{-1}, 46.78 and 51.12 mg 100 g^{-1} at both sites 1 and 2, respectively. The interaction between algae extract and amino acid at both sites had a significant effect especially at treatments (A2B1) at the site 1, (A2B2) at the site 2, which reached values of 53.02 and 59.09 mg 100 g^{-1}, respectively. The interaction between algae extract and growth regulator had a significant effect only in the second site, especially at treatment (B2C2), which reached a value of 60.41 mg 100 g^{-1}. On the other hand, there was no significant effect of the interaction between amino acid and growth regulator and also three-way interaction on the trait.

Table 7. Effect of Spray with Seaweed Extract, Arginine, and Brassinolide on fruit content of Ascorbic Acid (mg 100 g^{-1}) of Albion Strawberry Plants

Arginine (B)	**Brassinolide (C)**	**First site (Research Station)**				**Second site (Aldolab)**			
		Sea weed extract (A)			**B×C**	**Sea weed extract (A)**			**B×C**
		A0	**A1**	**A2**		**A0**	**A1**	**A2**	
B0	**C0**	38.21	48.57	50.28	45.69	43.66	46.77	56.24	48.89
	C1	38.32	45.14	47.52	43.66	44.35	51.12	55.67	50.38
	C2	43.85	52.60	50.87	49.11	47.50	46.16	61.32	51.66
B1	**C0**	41.12	46.43	51.97	46.51	46.33	49.09	56.27	50.56
	C1	44.42	50.38	53.75	49.51	50.13	57.75	55.19	54.36
	C2	44.80	51.54	53.34	49.89	62.59	53.10	57.62	57.77
B2	**C0**	48.09	48.82	47.52	48.14	50.82	52.92	58.00	53.91
	C1	46.28	53.91	50.48	50.22	53.96	59.26	57.01	56.74
	C2	50.89	52.79	52.81	52.16	53.94	59.12	62.28	58.44
					Mean B	**Mean B**			
A×B	**B0**	40.13	48.77	49.56	46.15	45.17	48.02	57.74	50.31
	B1	43.45	49.45	53.02	48.64	53.02	53.31	56.36	54.23
	B2	48.42	51.84	50.27	50.18	52.91	57.10	59.09	56.37
					Mean C	**Mean C**			
A×C	**C0**	42.47	47.94	49.92	46.78	46.94	49.59	56.84	51.12
	C1	43.01	49.81	50.58	47.80	49.48	56.04	55.96	53.83
	C2	46.51	52.31	52.34	50.39	54.68	52.79	60.41	55.96
Mean A		44.00	50.02	50.95		50.36	52.81	57.73	

LSD 5%

	A	B	C	A×B	A×C	B×C	A×B×C
First site	2.28	2.28	2.28	3.95	NS	NS	NS
Second site	2.59	2.59	2.59	4.49	4.49	NS	NS

The seaweed extract's high concentration of macro- and micronutrients (N, Ca, Mg, B, Cu, Fe, and Zn) can be credited with the enhancing of quality of fruits that resulted from spraying (2 and 7). Amino acids that are formed as a direct result of nitrogen, most of the critical plant processes that contribute to faster development rates depend on it (20 and 27). It contributes to the production of chlorophyll (8). The production of chlorophyll consumes 70% of the nitrogen found in leaves (19), It ultimately helps to boost the pace of photosynthesis, which in turn causes an increase in the amount of carbohydrates, pigments and vitamin C. The amino acid (arginine)'s function as a fruit quality which is necessary for the synthesis of proteins and enzymes crucial for physiological processes, especially the processes of growth, division, and expansion of plant cells, can be used to explain the increase in fruit components. This is due to the fact that arginine is immediately absorbed into the guard cells through the stomata. Additionally, arginine enhances chlorophyll pigments, which improves photosynthesis efficiency and raises the amount of carbohydrates generated. the growth regulator BR stimulates the mechanisms that lead to cell elongation and division. Therefore, cell elongation and division may be the cause of the increase in vegetative growth brought on by the addition of BR (17). It might also be as a result of its control over the movement, distribution, and metabolism of the photosynthetic byproducts in the various plant parts, Additionally, it promotes the uptake of minerals and their utilization in the vegetative component which improvement of quantitative characteristics.

Conflict of interest

The authors declare no conflict of interest.

Conclusion

After reviewing the results of the research, it can be concluded that the strawberry plants, cultivar Albion, responded to foliar feeding with Seaweed extract, Arginine, and Brassinolide. The concentrations of seaweed extract (4 ml L^{-1}), arginine (200 mg L^{-1}), and brassinolide (0.01 mg L^{-1}) contributed to the best results for the traits, Therefore, we recommend spraying strawberry plants with the study factors that contribute to improving the quality of fruits.

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