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Response of Some Vegetative Growth Characteristics and Mineral Content of Albion Strawberry Plants to Spraying with Amino Acids, Ascorbic, and Naphthalene Acetic Acid

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ABSTRACT: The experiment was carried out inside the plastic house at the Agricultural Research and Experiment Station of the College of Agriculture, University of Kirkuk, Iraq. During the 2025/2026 growing season with the aim of showing the extent of the response of the vegetative growth characteristics and mineral content of strawberry plants of the Albion cultivars to foliar spraying with three concentrations of each of the amino acids (0, 4 and 8) ml L-1 and ascorbic acid (0, 150 and 300) mg L-1 and naphthalene acetic acid (0, 40 and 80) mg L-1. The plants were planted on 1/11/2026 on raised beds and the mulching process was carried out for the planting soil with black polyethylene nylon, alternately with a distance of 25 cm between plants, and sprayed with three sprays during the growing season starting from 1/12 with a difference of 30 days between sprays. The experiment was carried out according to a completely randomized block design for factorial experiments with three replicates and with 6 plants per experimental unit. The results showed that spraying with a concentration of 8 ml L-1 of amino acids significantly increased leaf area, number of leaves, chlorophyll content, nitrogen percentage, and carbohydrate content in the leaves, reaching (56.24 cm2, 15.09 leaves plant-1, 22.78 mg g-1 fresh weight, 3.483%, and 18.75%) respectively. Spraying with a concentration of 300 mg L-1 of ascorbic acid significantly affected leaf area, number of leaves, and chlorophyll and carbohydrate content, which reached (55.10 cm2, 14.65 leaves plant-1, 22.18 mg g-1 fresh weight, 18.46%) respectively. However, spraying with the growth regulator naphthalene acetic acid at a concentration of 80 mg L-1 significantly affected the number of leaves and the percentage of nitrogen, potassium, and carbohydrates in the leaves, which amounted to (14.69 leaves plant-1, 3.409%, 3.025%, and 18.29%) respectively. The bilateral and tertiary interactions between the concentrations of the factors included in the study had a significant effect on improving most of the studied Characteristics.

INTRODUCTION:

Strawberry is a perennial herbaceous plant and a small, widespread fruit, its name is derived from the Latin words "ragrans" and "fragrant" and its scientific name is *Fragaria ananassa* Duch., it is considered a fruit because it develops annual rings in the crown area, it belongs to the Rosaceae family and the Fragaria genus, which includes more than 45 species (Al-Saidi, 2000; Janick, 2005). Europe and North America are considered the original home of the strawberry, and its cultivation is widespread in Italy, Poland, the Netherlands, France, and Bulgaria between latitudes 28-60 north of the equator (Hancock, 1999). Strawberries are a source of several compounds important for human health, nutritionists place them at the forefront of foodstuffs compared to fruits and grains due to their significant nutritional benefits and positive effects on human health,

they also contain polyphenols, which help combat a range of diseases, including atherosclerosis, cardiovascular disease, neurological disorders, type 2 diabetes, cancer, and obesity (Giampieri *et al.*,2015; Hussein and Al-Doori, 2021).

Researchers have turned to finding modern technical methods and techniques for supplying plants with essential nutrients by spraying them on the foliage to reduce or eliminate obstacles that hinder the availability of elements in the soil, nutrient absorption begins through the leaves, with the nutrients being transferred from the leaf cell walls via the leaf surfaces, stomata, or both (Wittwer and Lansing, 2005). Amino acids are safer for the environment, humans, and animals, plants need amino acids primarily for growth and to increase yield in quantity and quality, adding amino acids through the leaves depends on the plant's needs and stage of growth, these are carboxylic acids containing one or more amino groups, the basic building block of proteins is the α–amino acid, in which the amino group is attached to the alpha carbon atom, which is the atom adjacent to the carboxylic group (Hussein and Al-Doori, 2025). Amino acids are the precursors to hormone formation and growth regulators, and they are also biostimulants, they stimulate growth and encourage plant development under unfavorable climatic conditions, furthermore, they have a chelating effect on macro and micronutrients when added to them, making nutrient absorption and transport within the plant easier (Shalazy, 1986; Dabrowski, 2008). In this area, Khairi (2015) found that spraying Summer Royal grape seedlings with the amino acid nutrient Terra-Sorb at a concentration of 4 ml L^{-1} resulted in a significant increase in leaf area and leaf content of chlorophyll, carbohydrates, and the macronutrient NPK in both study seasons compared to concentrations of 0 and 2 ml L^{-1}. Rzouki *et al.*, (2019) found that spraying fig seedlings of the c.v. Waziri with amino acids at a concentration of 8 mg L^{-1} significantly improved the vegetative and chemical growth characteristics of the seedlings compared to concentrations of 0 and 4 mg L^{-1}.

Ascorbic acid, or vitamin C, with the chemical formula $C_6H_8O_6$, is one of the essential components necessary in higher plants, which need it in small quantities to maintain their normal growth, it performs several functions within plant tissues, including reducing the effects of temperature and toxin stress, stimulating respiration and cell division, increasing the effectiveness of several enzymes, and participating in the electron transport system, it also protects chloroplasts from oxidation as an antioxidant, in addition to influencing flower sex, increasing seed germination rates and vegetative growth, and enhancing plant tolerance to excessive salinity (Oertli, 1987; Afzal *et al.*, 2006). In his study, Al-Dulaimi (2014) found that spraying fig seedlings of the c.v. Aswad Diyala with ascorbic acid at four concentrations (0, 25, 50 and 100) mg L^{-1} significantly improved the number of leaves, leaf area, and carbohydrate content of the leaves compared to the other concentrations used. Bilal *et al.*, (2022) found that spraying Starking Delicious apple trees with ascorbic acid at a concentration of 0.5 g L^{-1} resulted in a significant increase in the chlorophyll and NPK macronutrient content of the leaves compared to the control treatment.

Naphthalene acetic acid (NAA) is one of the auxins, which constitute the first and most important group of plant growth regulators, it has been and continues to be at the forefront of research and studies related to plant growth regulation, playing a crucial role in a wide range of plant growth and development processes, at the cellular level, it is involved in division, expansion, and development throughout the plant life cycle, at the level of the whole plant, it plays an important role in root formation, apical dominance, phototropism, and others, it also contributes to many physiological processes leading to plant growth and development, as it stimulates cell division and elongation, callus formation, root formation, lateral bud growth, apical dominance, parthenocarpic fruit formation, and increasing female flowers in plants characterized by a high percentage of male flowers (Guilfoyle *et al.*, 1998; Ozaga and Reinecke, 2003) In a study by Dawood (2010), it was found that spraying Hapil strawberry plants with a concentration of 20 mg L^{-1} of naphthalene acetic acid increased the leaf area to 95.38 cm^2, while concentrations of 10 and 20 mg L^{-1} significantly increased the total leaf chlorophyll content to (13.11 and 14.06) mg g^{-1} fresh weight, compared to the no-spray treatment. Paikra *et al.*, (2018) concluded in their study, which involved spraying strawberry plants of the Sabrina cultivar with naphthalene acid at six concentrations (0, 10, 20, 30, 40, 50) mg L^{-1}, that a concentration of 50 mg L^{-1} led to a significant increase in the number of leaves per plant, reaching 33.33 leaves $plant^{-1}$, compared to the other concentrations. The study aims to stimulate vegetative growth and increase the mineral content of the leaves of Albion strawberry plants by spraying with amino acids, ascorbic acid, and naphthalene acetic acid, and to find the best combination of the three factors involved in the study.

MATERIALS AND METHODS:

This experiment was carried out inside the plastic house at the Agricultural Research and Experiment Station of the College of Agriculture, University of Kirkuk, Iraq, during the 2025/2026 growing season. The strawberry seedlings of the Albion cultivars were brought from a licensed nursery in Sulaimani Governorate, Iraq, where they were stored in refrigerated

warehouses, uniform in size, and ready for planting. On November 1, 2025, the seedlings were planted alternately, 25 cm apart, on raised beds 60 cm wide and 25 cm high. The beds were equipped with a drip irrigation system, and a balanced 15:15:15 NPK fertilizer was manually applied once two days before planting. The planting the mulching process was carried out for the planting soil with black polyethylene nylon, and all recommended agricultural practices were carried out during the trial period, including irrigation, weeding, fertilization, and pest and disease control.

The experiment included the effect of spraying amino acids on a commercial product image (Bombardier) containing (free amino acids 16.6 g, total nitrogen 10.8 g, organic nitrogen 5.4 g) at three concentrations (0, 4 and 8) ml L^{-1}, ascorbic acid $C_6H_8O_6$ with a molecular weight of 176.13 at three concentrations (0, 150 and 300) mg L^{-1}, and naphthalene acetic acid at three concentrations (0, 40 and 80) mg L^{-1}. The seedlings were sprayed three times during the growing season, with a one-month interval between sprays, from December 1, 2025, to February 1, 2026, and with a one-day interval between each application. The spreading agent Tween-20 at a concentration of 0.01% was used with the spraying agents to reduce leaf surface tension. The experiment was designed according to the design of completely randomized blocks as a factorial experiment with three replicates and 6 plants per experimental unit, so the number of plants in one replicate was 162 plants and the total number of plants in the experiment was 486 plants. The data were statistically analyzed according to the ANOVA table using a computer, in accordance with the system (SAS, 2001) for analyzing agricultural experiments, and the means were compared using Duncan's Multiple Range test under a probability level of 0.05, as stated by (Roger and Hosted, 2003).

Study Characteristics: The following characteristics were studied at the end of the experiment on 1/5/2026.

1- Leaf area (cm^2): It was calculated according to what was mentioned by (Saieed, 1990) according to the following equation:

$$\text{Leaf area } (cm^2) = \frac{\text{large sheet area(cm)} \times \text{ Weight of cut part(g)}}{\text{Weight of large leaf(g)}}$$

2- Leaves number (leaf $plant^{-1}$): The number of leaves for five plants from each experimental unit was counted, and then the average was calculated.

3- Leaf content of chlorophyll (mg g^{-1} fresh weight): It was calculated using the method of (Arnon, 1949) according to the following equation: Total Chlorophyll (mg L^{-1})= 20.2 A_{645} + 8.02 A_{663}

4- Percentage of macronutrients NPK and carbohydrates in leaves (%): Fully grown leaves were collected from different areas of 5 plants per experimental unit, washed several times with distilled water to remove any adhering dust, dried after being placed in perforated paper bags, then placed in an electric oven at a temperature of (70°C $\pm$5) for 48 hours, ground well, and 0.2 g of the dry samples were taken and digested using concentrated sulfuric acid H_2SO_4 and perchloric acid $HClO_4$ at a ratio of 1:4 ml each, respectively, according to what was mentioned in Johnson and Ullrich (1959), and the following elements were estimated:

- Leaf content of Nitrogen (%): Estimated using the Micro_Kjeldahl apparatus and according to the method reported by it (A.O.A.C., 1980)
- Leaf content of Phosphorus (%): Estimated by colorimetric method and reading light absorption at a wavelength of 410 nanometers using a Spectrophotometer type (100 1-v lab EMC) according to the method of Estefan *et al.*, (2013).
- Leaf content of Potassium (%): Estimated using a Flame Photometer (Elico CL-378) according to the method of Estefan *et al.*, (2013).
- Leaf content of carbohydrates (%): It was estimated using a Spectrophotometer, type (100 1-V lab EMC), at a wavelength of 490 nanometers, according to the Dubois *et al.,* (1956).

RESULTS AND DISCUSSION:

1_ Leaf area (cm^2): Table (1) shows that spraying strawberry plants of the Albion cultivars with amino acids at a concentration of 8 ml L^{-1} resulted in a significant increase and recorded the highest area of 56.24 cm^2, followed by a concentration of 4 ml L^{-1} which recorded 52.51 cm^2, while the control treatment recorded the lowest area of 46.45 cm^2. Spraying with a concentration of 300 mg L^{-1} of ascorbic acid had a significant effect on this trait, with the highest recorded area being 55.10 cm^2 and an increase of 14.48% compared to the control treatment. While the concentration of 80 mg L^{-1} of the growth regulator NAA recorded the highest area per leaf, reaching 52.34 cm^2, which did not differ significantly from the

concentration of 40 mg L^{-1}, which reached 52.59 cm^2, both of which significantly outperformed the control treatment, which recorded the lowest area of 50.28 cm^2.

The interaction between amino acids and ascorbic acid significantly affected the leaf area when the interaction treatment was applied with a concentration of 8 ml L^{-1} of amino acids and a concentration of 300 mg L^{-1} of ascorbic acid, which recorded the highest area of 62.13 cm^2, significantly surpassing the other interaction treatments, the control treatment recorded the lowest area of 41.96 cm^2. As for the interaction between amino acids and naphthalene, the interaction treatment with a concentration of 8 ml L^{-1} of amino acids and a concentration of 80 mg L^{-1} of NAA recorded the highest leaf area of 59.20 cm^2 and was significantly superior to the rest of the interactions, while the control treatment recorded the lowest area of 43.32 cm^2. The highest leaf area recorded was 56.69 cm^2 when 150 mg L^{-1} of ascorbic acid combined with 40 mg L^{-1} of NAA, while the lowest leaf area was 44.76 cm^2 when 150 mg L^{-1} of ascorbic acid combined with 0 mg L^{-1} of naphthalene acetic acid. As for the triple interaction between amino acids, ascorbic acid, and naphthalene acetic acid, spraying with a concentration of 8 ml L^{-1} of amino acids combined with a concentration of 300 mg L^{-1} of ascorbic acid and a concentration of 80 mg L^{-1} of NAA significantly outperformed the other triple interaction treatments and recorded the highest leaf area of 65.41 cm^2, while the interaction treatment recorded the lowest leaf area of 38.70 cm^2.

Table (1) Effect of spraying with Amino acids, Ascorbic acid, and Naphthalene acetic acid (NAA) on the Leaf area (cm^2) of the Strawberry plants c.v. Albion

Amino acids (ml L^{-1})	**Ascorbic acid (mg L^{-1})**	**NAA (mg L^{-1})**			**Amino acids × Ascorbic acid**
		0	40	80	
0	0	38.70 k	42.06 j	45.13 h-j	41.96 f
	150	45.30 h-j	51.81 ef	44.88 h-j	47.33 e
	300	45.95 hi	55.85 cd	48.38 gh	50.06 d
4	0	60.33 b	43.73 ij	44.28 ij	49.44 d
	150	45.03 h-j	63.08 ab	56.84 c	54.98 b
	300	60.14 b	45.28 h-j	53.94 c-e	53.12 bc
8	0	52.60 d-f	55.85 cd	50.49 fg	52.98 c
	150	43.94 ij	55.20 cd	61.71 b	53.62 bc
	300	60.51 b	60.46 b	65.41 a	62.13 a
	Amino acids				Average Amino acids
Amino acids × NAA	0	43.32 g	49.91 e	46.13 f	46.45 c
	4	55.16 c	50.69 de	51.68 de	52.51 b
	8	52.35 d	57.17 b	59.20 a	56.24 a
	Ascorbic acid				Average Ascorbic acid
Ascorbic acid × NAA	0	50.54 d	47.22 e	46.63 e	48.13 c
	150	44.76 f	56.69 a	54.47 bc	51.98 b
	300	55.53 a-c	53.86 c	55.91 ab	55.10 a
Average NAA		50.28 b	52.59 a	52.34 a	

Means not sharing the same letter (s) within each column for each are significantly different at 0.05 level of probability.

2. LEAVES NUMBER (LEAF PLANT^{-1}):

The results shown in Table (2) show that spraying strawberry plants of the Albion cultivars with amino acids at a concentration of 8 ml L^{-1} led to a significant increase in the number of leaves of the plants, reaching 15.09 leaf plant^{-1}, with an increase rate of 11.78% over the control treatment. Spraying with a concentration of 300 mg L^{-1} of ascorbic acid resulted in the highest number of leaves, reaching 14.65 leaf plant^{-1}, significantly outperforming other concentrations and showing a 3.09% increase over the control treatment. The concentration of 80 mg L^{-1} of NAA had a significant effect on this trait, as it recorded the highest rate of 14.69 leaf plant^{-1} compared to the control treatment, which recorded the lowest rate of 13.71 leaf plant^{-1}.

The interaction of the study factors significantly affected the number of leaves trait. Spraying with 8 ml L^{-1} of amino acids in conjunction with spraying with 300 mg L^{-1} of ascorbic acid resulted in the highest average, significantly surpassing the other interactions, reaching 15.79 leaf plant^{-1}. Conversely, the control treatment of amino acids in conjunction with 150 mg L^{-1} of ascorbic acid resulted in the lowest average, at 13.09 leaf plant^{-1}. While the 8 ml L^{-1} amino acid concentration combined with 80 mg L^{-1} NAA concentration recorded the highest rate of 15.81 leaf plant^{-1}, significantly outperforming the other interactions, the control treatment recorded the lowest rate of 12.49 leaf plant^{-1}. While spraying with a concentration of 0 mg L^{-1} of ascorbic acid combined with spraying with a concentration of 80 mg L^{-1} of NAA recorded the highest rate of 15.11 leaf plant^{-1}, while a concentration of 150 mg L^{-1} of ascorbic acid combined with a concentration of 0 of NAA recorded the lowest rate of 12.87 leaf plant^{-1}. The three-way interaction between the factors had a clear significant effect on increasing the number of leaves of strawberry plants, as spraying with a concentration of 8 ml L^{-1} of amino acids, combined with spraying with a concentration of 300 mg L^{-1} of ascorbic acid and spraying with a concentration of 80 mg L^{-1} of NAA, recorded the highest rate for this trait, reaching 16.42 leaf plant^{-1}, significantly superior to the other interactions, while the control treatment recorded the lowest rates, reaching 11.72 leaf plant^{-1}.

Table (2) Effect of spraying with Amino acids, Ascorbic acid, and Naphthalene acetic acid (NAA) on the leaves number (leaf plant^{-1}) of the Strawberry plants c.v. Albion

Amino acids (ml L^{-1})	**Ascorbic acid (mg L^{-1})**	**NAA (mg L^{-1})**			**Amino acids × Ascorbic acid**
		0	40	80	
0	0	11.72 k	15.00 b-e	15.20 b-d	13.97 de
	150	12.09 jk	13.53 f-i	13.64 f-i	13.09 f
	300	13.65 f-i	13.30 g-i	13.36 g-i	13.44 ef
4	0	13.20 hi	12.77 ij	14.47 c-f	13.48 ef
	150	13.13 hi	14.50 e-h	13.13 hi	13.44 ef
	300	15.52 ab	13.67 f-i	15.00 b-e	14.73 bc
8	0	15.13 b-d	14.71 b-e	15.67 ab	15.17 b
	150	13.38 g-i	14.27 d-g	15.33 bc	14.33 cd
	300	15.53 ab	15.40 bc	16.42 a	15.79 a
	Amino acids				Average Amino acids
Amino acids × NAA	0	12.49 f	13.94 de	14.07 d	13.50 c
	4	13.95 de	13.49 e	14.20 cd	13.88 b
	8	14.68 bc	14.79 b	15.81 a	15.09 a
	Ascorbic acid				Average Ascorbic acid

Ascorbic acid × NAA	0	13.35 c	14.16 b	15.11 a	14.21 b
	150	12.87 c	13.95 b	14.04 b	13.62 c
	300	14.90 a	14.12 b	14.93 a	14.65 a
Average NAA		13.71 c	14.08 b	14.69 a	

Means not sharing the same letter (s) within each column for each are significantly different at 0.05 level of probability.

3. LEAF CONTENT OF CHLOROPHYLL (MG G^{-1} FRESH WEIGHT):

Table (3) shows that spraying with a concentration of 8 ml L^{-1} of amino acids led to a significant increase in the leaf content of chlorophyll, reaching 22.78 mg g^{-1} fresh weight, representing an increase of 9.88% compared to the control treatment. Spraying with a concentration of 300 mg L^{-1} of ascorbic acid recorded the highest chlorophyll content of 22.18 mg g^{-1} fresh weight, significantly superior to the control treatment and a concentration of 150 mg L^{-1}, which recorded the lowest content of 21.07 mg g^{-1} fresh weight. The concentrations of 40 and 80 mg L^{-1} of NAA significantly affected this characteristic, reaching (21.79 and 21.86) mg g^{-1} fresh weight respectively, compared to the control treatment which reached 20.80 mg g^{-1} fresh weight.

Spraying with 8 ml L^{-1} of amino acids combined with 300 mg L^{-1} of ascorbic acid resulted in the highest chlorophyll content, reaching 24.33 mg g^{-1} fresh weight, significantly surpassing the other interaction treatments, the control treatment recorded the lowest content, at 20.12 mg g^{-1} fresh weight. While the interaction treatment with a concentration of 8 ml L^{-1} of amino acids and a concentration of 80 mg L^{-1} of NAA significantly affected the same trait, recording the highest content of 23.88 mg g^{-1} fresh weight, surpassing the other interactions, the control treatment recorded the lowest content of 19.86 mg g^{-1} fresh weight. The highest concentration (23.07 mg g^{-1} fresh weight) was recorded at 300 mg L^{-1} ascorbic acid combined with 80 mg L^{-1} NAA, while the lowest concentration (20.33 mg L^{-1} fresh weight) was recorded at 150 mg L^{-1} ascorbic acid combined with 0 mg L^{-1} NAA. The triple interaction with a concentration of 8 ml L^{-1} of amino acid, a concentration of 300 mg L^{-1} of ascorbic acid, and a concentration of 80 mg L^{-1} of NAA significantly affected the leaf content of chlorophyll, reaching 26.14 mg g^{-1} fresh weight, compared to the other triple interaction treatments, the control treatment recorded the lowest content, reaching 18.42 mg g^{-1} fresh weight.

Table (3) Effect of spraying with Amino acids, Ascorbic acid, and Naphthalene acetic acid (NAA) on the leaf content of chlorophyll (mg g^{-1} fresh weight) of the Strawberry plants c.v. Albion

Amino acids (ml L^{-1})	**Ascorbic acid (mg L^{-1})**	**NAA (mg L^{-1})**			**Amino acids × Ascorbic acid**
		0	40	80	
0	0	18.42 k	19.28 jk	22.68 c-e	20.12 e
	150	19.65 ij	21.63 fg	19.49 j	20.26 e
	300	21.52 fg	22.03 e-g	21.85 e-g	21.79 c
4	0	21.30 gh	21.56 fg	20.52 hi	21.13 d
	150	22.04 e-g	22.50 d-f	19.36 j	21.30 cd
	300	19.49 j	20.52 hi	21.22 gh	20.41 e
8	0	23.17 cd	21.89 e-g	22.00 e-g	22.35 b
	150	19.31 jk	22.16 e-g	23.51 c	21.66 c
	300	22.35 d-f	24.49 b	26.14 a	24.33 a
	Amino acids				Average Amino acids
Amino acids	0	19.86 f	20.98 d	21.34 cd	20.73 b

×	4	20.94 d	21.53 c	20.37 e	20.95 b
NAA	8	21.61 c	22.85 b	23.88 a	22.78 a
	Ascorbic acid				Average Ascorbic acid
Ascorbic acid	0	20.96 d	20.91 d	21.74 c	21.20 b
×	150	20.33 e	22.09 bc	20.79 de	21.07 b
NAA	300	21.12 d	22.35 b	23.07 a	22.18 a
Average NAA		20.80 b	21.79 a	21.86 a	

Means not sharing the same letter (s) within each column for each are significantly different at 0.05 level of probability.

4. LEAF CONTENT OF NITROGEN (%):

Table (4) shows a significant increase in the percentage of nitrogen in the leaves of Albion strawberry plants when sprayed with a concentration of 8 ml L^{-1} of amino acids, as the highest percentage was recorded at 3.483%, followed by a concentration of 4 ml L^{-1}, which recorded 3.232%, and then the control treatment, which recorded the lowest percentage at 3.142%. Spraying with a concentration of 300 mg L^{-1} of ascorbic acid recorded the highest nitrogen content in the leaves, reaching 3.420%, and the lowest content was recorded in the control treatment, which recorded a content of 3.139%. As for the effect of spraying with the growth regulator NAA, it was significantly superior at a concentration of 80 mg L^{-1}, and the highest nitrogen percentage was recorded at 3.409%, while the lowest percentage was recorded at a concentration of 40 mg L^{-1} at 3.207%.

The dual interaction between amino acids at a concentration of 8 ml L^{-1} and a concentration of 300 mg L^{-1} of ascorbic acid recorded the highest percentage of nitrogen in the leaves, reaching 3.795%, while the control treatment recorded the lowest percentage, reaching 2.572%. The highest recorded interaction was 3.628% with a concentration of 8 ml L^{-1} of amino acids and a concentration of 80 mg L^{-1} of NAA, while the lowest recorded interaction was 2.978%. As for the interaction between ascorbic acid and naphthalene, a concentration of 300 mg L^{-1} of ascorbic acid interacting with a concentration of 80 mg L^{-1} of NAA recorded the highest nitrogen percentage, reaching 3.646%, while the control treatment recorded the lowest percentages, reaching 3.007%. As for the triple interaction between the factors involved in the study, spraying with a concentration of 8 ml L^{-1} of amino acids combined with a concentration of 300 mg L^{-1} of ascorbic acid and a concentration of 80 mg L^{-1} of NAA recorded the highest percentage, reaching 4.156%, while the control treatment recorded the lowest percentage, reaching 2.237%.

Table (4) Effect of spraying with Amino acids, Ascorbic acid, and Naphthalene acetic acid (NAA) on the leaf content of Nitrogen (%) of the Strawberry plants c.v. Albion

Amino acids (ml L^{-1})	**Ascorbic acid (mg L^{-1})**	**NAA (mg L^{-1})**			**Amino acids × Ascorbic acid**
		0	40	80	
0	0	2.237 k	2.433 jk	3.044 f-i	2.572 e
	150	3.683 a-e	3.767 a-d	3.405 c-h	3.618 ab
	300	3.013 f-i	3.377 c-h	3.321 c-h	3.237 c
4	0	3.433 b-g	2.679 i-k	3.212 d-i	3.108 cd
	150	3.377 c-h	3.349 c-h	3.352 c-h	3.359 bc
	300	3.153 e-i	3.072 f-i	3.461 b-f	3.229 c
8	0	3.349 c-h	3.991 ab	3.879 a-c	3.739 a
	150	3.072 f-i	2.819 h-j	2.848 g-j	2.913 d

	300	3.851 a-c	3.377 c-h	4.156 a	3.795 a
	Amino acids				Average Amino acids
Amino acids × NAA	0	2.978 d	3.193 b-d	3.257 b-d	3.142 b
	4	3.321 a-c	3.034 cd	3.342 a-c	3.232 b
	8	3.424 ab	3.396 ab	3.628 a	3.483 a
	Ascorbic acid				Average Ascorbic acid
Ascorbic acid × NAA	0	3.007 d	3.035 cd	3.378 ab	3.139 b
	150	3.377 ab	3.312 b-d	3.202 b-d	3.297 ab
	300	3.339 a-c	3.276 b-d	3.646 a	3.420 a
Average NAA		3.241 b	3.207 b	3.409 a	

Means not sharing the same letter (s) within each column for each are significantly different at 0.05 level of probability.

5. LEAF CONTENT OF PHOSPHORUS (%)

The results of the statistical analysis in Table (5) showed that the percentage of phosphorus in the leaves was not significantly affected by spraying with amino acids and ascorbic acid, but rather caused an increase in the percentage of phosphorus at a concentration of 8 ml L^{-1} of amino acids, which recorded the highest percentage, reaching 0.251%, while the control treatment recorded the lowest percentage, reaching 0.219%. The highest concentration of ascorbic acid (0.255%) was recorded at 300 mg L^{-1}, while the lowest concentration was recorded at 0.227% in the control treatment. As for spraying with naphthalene acetic acid, it achieved a significant increase at a concentration of 80 mg L^{-1}, which reached 0.256%, and it did not differ significantly from a concentration of 40 mg L^{-1}, which reached 0.238%, and both of which significantly outperformed the control treatment, which reached 0.222%.

The interaction between amino acids and ascorbic acid led to the highest phosphorus content in the leaves at a concentration of 4 ml L^{-1} of amino acids, interacting with a concentration of 300 mg L^{-1} of ascorbic acid, which reached 0.269%, and the lowest content in the control treatment, which reached 0.204%.The interaction treatment with 8 ml L^{-1} of amino acids and 80 mg L^{-1} of NAA recorded the highest phosphorus content at 0.299%, while the lowest content was recorded in the control treatment with 0 ml L^{-1} of amino acids combined with 80 mg L^{-1} of NAA, both of which recorded 0.210%. The interaction between ascorbic acid and naphthalene concentrations did not significantly affect the percentage of phosphorus in the leaves. Spraying with a concentration of 8 ml L^{-1} of amino acids combined with a concentration of 300 mg L^{-1} of ascorbic acid and a concentration of 80 mg L^{-1} of naphthalene acetic acid recorded the highest percentage of phosphorus, which reached 0.324%, while the lowest percentage was recorded in the control treatment, which reached 0.191%.

Table (5) Effect of spraying with Amino acids, Ascorbic acid, and Naphthalene acetic acid (NAA) on the leaf content of Phosphorus (%) of the Strawberry plants c.v. Albion

Amino acids (ml L^{-1})	**Ascorbic acid (mg L^{-1})**	**NAA (mg L^{-1})**			**Amino acids × Ascorbic acid**
		0	40	80	
0	0	0.191 b	0.226 ab	0.197 b	0.204 b
	150	0.203 b	0.221 ab	0.229 ab	0.218 ab
	300	0.238 ab	0.261 ab	0.204 b	0.234 ab
4	0	0.212 ab	0.220 ab	0.269 ab	0.234 ab
	150	0.215 ab	0.261 ab	0.223 ab	0.233 ab

	300	0.274 ab	0.253 ab	0.281 ab	0.269 a
8	0	0.217 ab	0.226 ab	0.287 ab	0.243 ab
	150	0.243 ab	0.218 ab	0.285 ab	0.249 ab
	300	0.203 b	0.259 ab	0.324 a	0.262 ab
	Amino acids				Average Amino acids
Amino acids × NAA	0	0.210 b	0.236 b	0.210 b	0.219 a
	4	0.234 b	0.245 ab	0.258 ab	0.246 a
	8	0.221 b	0.234 b	0.299 a	0.251 a
	Ascorbic acid				Average Ascorbic acid
Ascorbic acid × NAA	0	0.207 a	0.224 a	0.251 a	0.227 a
	150	0.220 a	0.233 a	0.246 a	0.233 a
	300	0.238 a	0.257 a	0.269 a	0.255 a
Average NAA		0.222 b	0.238 ab	0.256 a	

Means not sharing the same letter (s) within each column for each are significantly different at 0.05 level of probability.

6. LEAF CONTENT OF POTASSIUM (%):

The results in Table (6) showed that spraying with a concentration of 8 ml L^{-1} of amino acids significantly outperformed and recorded the highest leaf content of potassium of strawberry plants, which reached 2.983%, with an increase of 4.59% over the control treatment. Spraying with different concentrations of ascorbic acid did not show a significant increase in the leaf content of potassium, while spraying with a concentration of 80 mg L^{-1} of NAA significantly outperformed the other concentrations and recorded the highest percentage of 3.025% and an increase of 7.12% over the control treatment.

The dual interaction treatment of 8 ml L^{-1} of amino acids and 300 mg L^{-1} of ascorbic acid showed a significant advantage in this trait, recording the highest percentage at 3.105%, the lowest percentage was recorded in the interaction treatment of 0 ml L^{-1} of amino acids and 150 mg L^{-1} of ascorbic acid, which reached 2.798%. However, the interaction between amino acids at a concentration of 8 ml L^{-1} and naphthalene acetic acid at a concentration of 80 mg L^{-1} recorded the highest leaf content of potassium, reaching 3.127%, and the lowest percentage in the control treatment, which reached 2.765%. Spraying with a concentration of 300 mg L^{-1} of ascorbic acid combined with a concentration of 80 mg L^{-1} of NAA recorded the highest percentage of 3.105%, while the control treatment recorded the lowest percentage of 2.805%. The triple interaction treatment with a concentration of 8 ml L^{-1} of amino acids, a concentration of 300 mg L^{-1} of ascorbic acid, and a concentration of 80 mg L^{-1} of NAA recorded the highest percentage of potassium in the leaves, reaching 3.378%, while the control treatment recorded the lowest percentages, reaching 2.613%.

Table (6) Effect of spraying with Amino acids, Ascorbic acid, and Naphthalene acetic acid (NAA)) on the leaf content of Potassium (%) of the Strawberry plants c.v. Albion

Amino acids (ml L^{-1})	**Ascorbic acid (mg L^{-1})**	**NAA (mg L^{-1})**			**Amino acids × Ascorbic acid**
		0	40	80	
0	0	2.613 e	3.024 a-c	2.957 b-e	2.865 b
	150	2.758 c-e	2.625 de	3.012 bc	2.798 b
	300	2.924 b-e	2.914 b-e	2.836 c-e	2.891 b
4	0	2.934 b-e	2.891 c-e	2.936 b-e	2.920 ab

	150	2.791 c-e	3.046 a-c	3.002 b-d	2.946 ab
	300	2.781 c-e	2.847 c-e	3.101 a-c	2.909 ab
8	0	2.869 c-e	2.858 c-e	3.279 ab	3.002 ab
	150	2.891 c-e	2.903 b-e	2.724 c-e	2.839 b
	300	2.858 c-e	3.079 a-c	3.378 a	3.105 a
	Amino acids				Average Amino acids
Amino acids × NAA	0	2.765 c	2.854 bc	2.935 a-c	2.851 b
	4	2.835 bc	2.928 a-c	3.013 ab	2.926 ab
	8	2.873 bc	2.947 a-c	3.127 a	2.982 a
	Ascorbic acid				Average Ascorbic acid
Ascorbic acid × NAA	0	2.805 c	2.924 a-c	3.057 ab	2.929 a
	150	2.813 c	2.858 bc	2.913 a-c	2.861 a
	300	2.855 bc	2.947 a-c	3.105 a	2.969 a
Average NAA		2.824 b	2.909 b	3.025 a	

Means not sharing the same letter (s) within each column for each are significantly different at 0.05 level of probability.

7. LEAF CONTENT OF CARBOHYDRATES

(%): The leaf content of carbohydrates of Albion strawberry plants was significantly affected by spraying with different concentrations of amino acids, ascorbic acid, and naphthalene acetic acid. Table (7) shows that spraying with a concentration of 8 ml L^{-1} of amino acids recorded the highest percentage, significantly exceeding the other concentrations, reaching 18.75%, this was followed by a concentration of 4 ml L^{-1}, which reached 16.78%, and then the control treatment, which recorded the lowest percentage at 16.33%. Spraying with a concentration of 300 mg L^{-1} of ascorbic acid was significantly superior, reaching 18.46%, with an increase of 11.81% compared to the control treatment. Spraying with naphthalene acetic acid at a concentration of 80 mg L^{-1} resulted in a significant improvement in this trait, recording the highest percentage at 18.29% and the lowest percentage at a concentration of 40 mg L^{-1} at 16.48%.

The dual interaction treatment with a concentration of 8 ml L^{-1} of amino acids and a concentration of 300 mg L^{-1} of ascorbic acid recorded the highest leaf content of carbohydrates, reaching 20.11%, significantly surpassing the other interaction treatments, the lowest percentage was recorded in the control treatment, which reached 15.54%. The interaction with a concentration of 8 ml L^{-1} of amino acids and a concentration of 80 mg L^{-1} of NAA was significantly superior, recording the highest percentage of 20.21%, while the control treatment recorded the lowest percentage of 15.91%. The interaction with a concentration of 300 mg L^{-1} of ascorbic acid and a concentration of 80 mg L^{-1} of NAA recorded the highest percentage of 20.69%, significantly superior to the other interaction treatments, while the lowest percentage was in the control treatment, which reached 15.28%. Spraying with a concentration of 8 ml L^{-1} of amino acids combined with spraying with a concentration of 300 mg L^{-1} of ascorbic acid and a concentration of 80 mg L^{-1} of NAA resulted in the highest percentage of carbohydrates in the leaves, reaching 23.64%, with a significant advantage over the other three interaction treatments, while the lowest percentages were in the interaction treatment, which reached 13.57%.

Table (7) Effect of spraying with Amino acids, Ascorbic acid, and Naphthalene acetic acid (NAA) on the leaf content of carbohydrates (%) of the Strawberry plants c.v. Albion

Amino acids (ml L^{-1})	**Ascorbic acid (mg L^{-1})**	**NAA (mg L^{-1})**			**Amino acids × Ascorbic acid**
		0	40	80	

0	0	13.57 j	16.13 gh	16.92 e-h	15.54 d
	150	18.29 c-e	14.37 ij	15.44 hi	16.04 d
	300	15.87 h	17.41 d-g	18.92 cd	17.40 c
4	0	15.75 hi	15.46 hi	17.65 d-f	16.29 d
	150	16.69 f-h	16.34 f-h	15.52 hi	16.18 d
	300	17.53 d-g	16.61 f-h	19.49 bc	17.88 bc
8	0	16.53 f-h	18.17 c-e	18.37 c-e	17.69 bc
	150	20.65 b	16.07 gh	18.61 cd	18.44 b
	300	18.89 cd	17.79 d-f	23.64 a	20.11 a
	Amino acids				Average Amino acids
Amino acids × NAA	0	15.91 e	15.97 e	17.09 cd	16.33 c
	4	16.66 de	16.14 e	17.56 c	16.78 b
	8	18.69 b	17.34 cd	20.21 a	18.75 a
	Ascorbic acid				Average Ascorbic acid
Ascorbic acid × NAA	0	15.28 e	16.59 d	17.65 c	16.51 b
	150	18.54 b	15.59 e	16.52 d	16.89 b
	300	17.43 c	17.27 cd	20.69 a	18.46 a
Average NAA		17.09 b	16.48 c	18.29 a	

Means not sharing the same letter (s) within each column for each are significantly different at 0.05 level of probability.

The reason for the improvement in vegetative growth characteristics (Tables 1-3) when spraying with amino acids is that they are responsible for enhancing the protein content of cells and stimulating cell division, plant pigments, and natural hormones such as gibberellins and indoleacetic acid, they are also a primary nitrogen source in building proteins and enzymes and supplying energy that promotes vegetative and root growth (Forsum, 2016) Amino acids also stimulate the synthesis of chlorophyll pigment in leaves, which improves plant growth by increasing photosynthesis, furthermore, amino acids have a direct effect on enzymatic activity, accelerating the absorption and transport of nutrients within the plant, or an indirect effect that accelerates nutrient absorption and transport, thereby increasing carbon synthesis (Chen and Chen, 2004) This is reflected in an increase in the nutrient content of the leaves (Tables 4-7). These results are consistent with Khairi (2015) and Rzouki *et al.*, (2019).

The improvement in growth characteristics resulting from spraying with ascorbic acid may be attributed to the acid's positive role in protecting the living components of cells from the harmful effects of temperature and photo oxidation, and its stimulation of cell division, as well as its importance in the electron transport chain and the regulation of photosynthesis (Galli, 2013) this is reflected in the increase in leaf area (Table 1), which in turn leads to an increase in the products of photosynthesis, which leads to an increase in the number of leaves and their chlorophyll content (Tables 2 and 3). Ascorbic acid also plays a role in increasing the activity and efficiency of vital processes, photo-oxidation processes, and ATP energy transfer (Galli, 2013), which positively encourages an increase in nutrient concentration in leaves (Tables 4, 5, 6, 7). These results are consistent with Al-Dulaimi (2014), Bilal *et al.*, (2022), and Al-Doori and Hussein (2024). As a result of the role of auxins in building proteins and enzymes specific to the process of cell division and elongation, which led to an increase in osmotic pressure inside them, and then the absorption of a quantity of water and nutrients, and this was reflected positively in plant growth, encouraging vegetative growth and increasing the formation of leaf primordia and thus its leaf area. In addition, leaves treated with auxins become a center for collecting nutrients, which helps to increase the vital activities in them (Abdul,

1987) this explains the improvement in vegetative growth and mineral content of leaves when sprayed with naphthalene acetic acid (Tables 1-7). These results are consistent with Dawood (2010), Paikra *et al*., (2018), Al-Doori *et al.,* (2020), and Hussein *et al*., (2021).

CONCLUSION:

From the results in the tables above, we conclude that spraying Albion strawberry plants with a concentration of 8 ml L^{-1} of amino acids (in the form of free amino acids), 300 mg L^{-1} of ascorbic acid, and 80 mg L^{-1} of the growth regulator naphthalene acetic acid significantly improved vegetative growth characteristics and leaf nitrogen and carbohydrate content, which may positively impact yield improvement.

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