Chapter 1
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Role of Spraying Biostimulators Agazone and Atonik for Improvement of Storage Ability of Egg Plant (*Solanum melongen* L.) Hybrids: Jawaher and Barcelona

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ABSTRACT

The present study was conducted by using biostimulators, especially agazone and atonik, in improving storage ability of eggplant fruits hybrids of Jawaher and Barcelona. The new orientation in agriculture is to move away from the use of chemical fertilizers, chemical growth regulators and pesticides of different kinds and composition, because of their toxic effects on human and animal organisms. The experiment was conducted in one of the greenhouses of the Agricultural Research Station, College of Agriculture, University of Basrah, during the growing season 2017-2018 in order to improve the storage behavior of eggplant fruits hybrids Jawaher and Barcelona. Agazone. Solutions of agazone with three concentrations (0, 1.5 and 3) ml L-1, and atonik with three concentrations (0, 0.5 and 1) ml L-1 were prepared and the plants were sprayed in the early morning four times. Fruit firmness determined by using fruit pressure instrument, the weight loss was calculated as a percentages, Vitamin C determined according to A.O.A.C. Results indicated that the percentage of weight loss and the percentage of total soluble solids increased while the fruit firmness and the amount of vitamin C decreased with an increment of storage periods. The lowest percentages of the weight loss and the highest percentage of total soluble solids were in fruits treated with 3 ml L^{-1} agazone. Barcelona fruits gave the highest fruit firmness, vitamin C, total soluble solids and the lowest percentage of weight loss compared to Jawaher fruits, so the study recommended that spraying eggplant plants with agazone at a concentration of 3 3 ml $L^{-1}$and atonik at a concentration of 1 ml L^{-1} for four times to improve the qualitative characteristics of the fruits when stored at 13°C for two weeks. Barcelona fruits gave the highest fruit firmness, vitamin C,

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total soluble solids and lowest percentage of weight loss compared to Jawaher during the two-week storage period, so for the purpose of organizing the display of the crop in the markets, it could be recommended for planting in unheated plastic house under the conditions of south of Iraq.

Keywords: Eggplant; agazone; atonik; total soluble solids.

1. INTRODUCTION

Biostimulants are a category of relatively new products of diverse formulations that positively affect a plant's vital processesof plant growth and developments and whose impact is usually more evident under stressful conditions [1]; Eggplant (*Solanum melongena* L.) is one of the most important vegetable crops in Iraq, which belongs to Solanaceae family of more than 75 species and 2,000 plant species spread around the world. India and China are the original home, growing wild since old time [2]. Eggplant is consumed in large quantities as it is eaten cooked, either by frying, boiling or grilling, and it is the main ingredient for some dishes such as makdous and others. There are also eggplant pickles and eggplant jam. There is still controversy over who determines the optimal volume of production that requires the producer to reach it by adhering to the optimal greenhouses that achieve the farmer's goals in minimizing production costs per unit of production [3].

Each 100 g of fresh eggplant fruit contains 92.4 g water, 1.2 g protein, 5.6 g carbs, 0.2 g fat, 0.9 g fiber and 25 calories [3a, 4]. Eggplant is known for its medicinal properties as it is used to treat many diseases such as asthma. It has also been found to have a high ability to rid the body of free radicals and protect against oxidation of fat [5]. Potassium salts found in the fruit are helping to release fluids from the body [6].

The new orientation in agriculture is to move away from the use of chemical fertilizers, chemical growth regulators and pesticides of different kinds and composition, because of their toxic effects on human and animal organisms. Therefore, researchers in agriculture have tended to find safer materials such as biostimulants [3a]. Agazone is a natural liquid extract of algae *Ascophyllum nodosum*, a brown seaweed belonging to the Fucaceae family, located on the northwestern coasts of Europe and the northeastern coasts of North America. It has long been used as organic fertilizer for many crop varieties because of its major nutrient content (NP; K, Mg; S; Mn; Cu; Fe; Zn;) It also contains cytokines, auxins, gibberellins, organic acids, sugars, amino acids and proteins. Atonik is a synthetic bio stmulator. The studies have the effect of encouraging vegetative growth and increasing the quality of the plant as it is used to increase the vital activities in the plant and without any toxicity or deformation of the plants used in it [7], and it is a substance free of collateral damage to humans or animals By the Environmental Protection Agency (EPA) [3a].

The organization of the supply of the fruits of this crop in the local markets and the increase in the duration of its presentation in fresh condition and high quality

of consumption requires the improvement of the storage ability of the fruits if we take into account the weakness of storage behavior of fruits because of the high water content and thus infected with the mold, especially gray mold, black mold and mildew [8] in addition to lose weight ,so the storage considers an active method used to try to keep the fruits fresh as long as possible and this process requires storing fruits at temperatures above 10 °C because the fruits sensitive to Chilling Injury [3a, 9].

The present study was conducted due to the lack of studies related to using biostimulants, especially agazone and atonik, in improving storage ability of eggplant fruits hybrids Jawaher and Barcelona.

2. MATERIALS AND METHODS

The experiment was carried out during the 2017-2018 season in one of the greenhouses of the Agricultural Research Station, Faculty of Agriculture, Basrah University, Karma Ali site, in order to study the effect of pre-harvest spraying agazone and atonik in storage ability of eggplant hybrids Jawaher and Barcelona grown in plastic greenhouses [3a].

The seedlings were planted in the plastic house on 12/10/2017 and all the processes using in the production of this crop grown in plastic greenhouses were conducted. Solutions of agazone with three concentrations (0, 1.5 and 3) ml L^{-1}, and atonik with three concentrations (0, 0.5 and 1) ml L^{-1} were prepared and the plants were sprayed in the early morning four times starting from 29/11 /2017, with a time interval of 30 days from the date of planting for the first spray and the operation returned after 14 days.

Fruits were harvested before reaching the maturity stage in the early morning and brought to the laboratory of storage technology [3a].

All the fruits were packed in perforated polyethylene bags (16 hole with a diameter of 5 mm per bag and weighed 2 kg per bag), and then stored at the temperature of 13°C.

Fruit firmness ($kg \cdot cm^{-1}$) determined by using fruit pressure instrument, the weight loss was calculated as a percentages, Vitamin C (mg / 100 g) determined according to A.O.A.C. [10]. Total soluble solids determined by using hand refractometer and the results were corrected to 20ºC.

Experiment was carried out as factorial experiment consisting of three factors: spraying with agazone and atonik, two hybrids of eggplant Jawaher and Barcelona and storage period, using Complete Rondomize Design (CRD) with 3 replicates [3a]. The results were statistically analyzed using the statistical program Genstat. The mean differences were compared by using the least significant difference (L.S.D) test at the probability level of 0.05 [11].

3. RESULTS AND DISCUSSION

3.1 Fruit Firmness (kg cm^{-1})

The results presented in Table 3 showed the effect of hybrids, spraying treatments with agazone and atonik and storage period and their interaction on fruit firmness (kg cm^{-1}) stored at 13°C [3a]. The results indicated that the fruit firmness increased with an increment of storage periods till reached 4.149 kg cm^{-1} after two weeks of storage. The highest amount of fruit firmness was in Barcelona fruits which recorded 3.741 kgcm^{-1}. As for the effect of spray treatments, results showed that the highest amount of fruit firmness was in fruits of with 3 ml L^{-1} agazone which recorded 4.149 kg cm^{-1} while the lowest amount of fruit firmness was in untreated fruits that gave 2.997 kg cm^{-1}.

The results also showed a significant interaction between hybrids and spraying treatments with agazone and atonik [3a]. The highest amount of fruit firmness was in the fruits of Barcelona plants sprayed with 3 ml L^{-1} agazone which was 4.378 kg cm^{-1} whereas the lowest amount of fruit firmness was in the untreated fruits of Jawaher plants that recorded 2.990 kg cm^{-1} .Results in the same line with results reported by Sousa et al. [12] on apple fruits cv. Gala, that reported the application of seaweed with high concentrations leads to an increase in the traits of fruit firmness and fruit weight.

The table also showed the significant interaction between the spraying treatments and the storage period. The highest amount of fruit firmness was in fruits of 3 ml L^{-1} agazone which was 5.005 kg cm^{-1} after two weeks of storage, while the lowest amount of fruit firmness was in untreated fruits after a week of storage which was2.413 kg cm^{-1} [3a]. As for the interaction between hybrids and storage periods, the results showed that the highest amount of fruit firmness was in Barcelona fruits after two weeks of storage which gave 4.234kg cm^{-1} while the lowest amount of fruit firmness was in Jawaher fruits after a week of storage which was3.019 kg cm^{-1}.

Regarding the interaction between hybrids, spraying treatments and storage periods, the highest amount of fruit firmness was in the fruits of Barcelona plants sprayed with 3 ml L^{-1} agazone after two weeks of storage which was 5.353 kg.cm^{-1}.

As previously mentioned, spraying of eggplant with agazone, increased the fruit firmness. that maybe due to the content of agazone from gibberellins and auxins which inhabited the activity of ethylene and thus, delayed the ripening of fruits [13].

3.2 Weight Loss percentage

Date presented in Table 2 showed the effect of hybrids, spraying treatments with agazone and atonik and storage period and their interactions on the percentage of weight loss of eggplant fruits cvs [3a]. Jawaher and Barcelona stored at 13°C.

The results indicated that the percentage of weight loss increased by increasing the storage period reached 8.842% after two weeks of storage. Jawaher hybrid fruits recorded the highest percentage of weight loss compared to the fruits of the Barcelona hybrid, which gave the lowest percentage of weight loss, amounting to 6.490% and this is may be due to the genetic differences between the two hybrids [14]. As for the effect of spraying treatments, the lowest percentage of weight loss was in fruits treated with 3 ml L^{-1} agazone which reached 3.399% with significant difference with the rest treatments [3a]. The results of the same table, mentioned that the lowest percentage of weight loss was in the fruits treated with agazone and atonik compared to the untreated fruits. This may be due to the fact that these substances contain some elements, especially calcium, which decreased the percentage of weight loss because of calcium increases cell wall strength and reduces the decomposition of pectin and wax layer surrounding the fruit epidermis, which leads to reduce the evaporation of water content of fruits [15].

The results of the same table showed a significant difference between hybrids and the spraying treatments. The lowest percentage of weight loss was in fruits of Barcelona hybrid sprayed with 3 ml L^{-1} agazone which was 3.211% while, the highest percentage of weight loss was in untreated fruits of Jawaher hybrid which reached 9.673% [3a].

Regarding to the correlations between hybrids and storage periods and the correlations between spraying treatments and storage period, the lowest weight loss percentages (4.402%, 2.293%) were in Barcelona hybrid and in untreated fruits after two weeks of storage respectively [3a].

In regard to triple interaction, the weight loss percentages was in the fruits of Jawaher hybrid sprayed with 3 ml L^{-1} agazone after one weeks of storage which was 2.273%.

As previously mentioned, spraying with agazone and atonik, reduced the weight loss percentage of eggplant. The effect of agazone and atonik on the reduction of weight loss may be due to the fact that they contain auxins, cytokines and gibberellins, which have a role in inhibiting the production of ethylene gas, reducing the respiration rate of fruits, maintain the permeability of cellular membranes and reduce the loss of food stored in fruits [3a, 16].

As for the effect of the storage period, the results indicated to an increase in the percentage of weight loss by increasing storage period. This is due to the reduction of weight of the fruits as the storage period progresses, resulting in loss of the water content of fruits while the storage period continues, as well as the consumption of the food stored in the fruit as a result of respiration process. These finding are in the accordance with those previously reported by Taain et al. [14] for Super Maramond tomato cultivar and Taain and Hamza [17] for olive fruits.

Table 1. Effect of hybrids, spraying agazone and atonik, storage period and the interaction among them on fruit firmness (kg cm^{-1}) of eggplant fruits stored at 13 ° C

hybrids	Treatments (ml. L^{-1})	Storage period (week)		hybrids × treatments
		1	**2**	
Jawaher	control 0	2.423	3.557	2.990
	agazone 1.5	3.197	4.142	3.653
	agazone 3	3.450	5.005	4.053
	atonik 0.5	2.857	3.737	3.297
	atonik 1	3.170	4.267	3.713
	control 0	2.403	3.603	3.003
Barcelona	agazone 1.5	3.150	4.173	3.662
	agazone 3	3.403	5.353	4.378
	atonik 0.5	2.903	3.763	3.333
	atonik 1	3.270	4.277	3.773
				Means of hybrids
hybrids ×	Jawaher	**3.019**	**4.063**	**3.430**

storage period						
	Barcelona	3.026		4.234		3.741
						Means of treatments
treatments× storage period	Control 0	2.413		3.580		2.997
	agazone 1.5	3.173		4.142		3.657
	agazone 3	3.427		5.005		4.216
	atonik 0.5	2.880		3.750		3.315
	atonik 1	3.220		4.267		3.743
Means of storage period		3.023		4.149		
RLSD 0.05						
hybrids	treatments	storage period	hybrids× treatments	hybrids× storage period	treatments× storage period	hybrids× treatments× storage period
0.1583	**0.2502**	**0.1583**	**0.3539**	**0.2238**	**0.3539**	**0.5005**

Table 2. Effect of hybrids, spraying agazone and atonik, storage period and the interaction among them on fruit weight loss (%) of eggplant fruits stored at 13 ° C.

hybrids	Treatments (ml .L^{-1})	Storage period (week)		hybrids × treatments
		1	2	
Jawaher	control 0	7.033	12.313	9.673
	agazone 1.5	4.110	9.203	6.657
	agazone 3	2.273	4.900	3.587
	atonik 0.5	5.823	10.570	8.197
	atonik 1	3.500	7.433	5.467
	control 0	6.987	12.353	9.670
Barcelona	agazone 1.5	4.040	9.370	6.705
	agazone 3	2.312	4.110	3.211
	atonik 0.5	5.400	10.557	7.978
	atonik 1	3.273	7.610	5.442
				Means of hybrids

hybrids × storage period	Jawaher	4.548		8.884		6.827
	Barcelona	4.402		8.800		6.490
						Means of treatments
treatments× storage period	Control 0	7.010		12.333		9.672
	agazone 1.5	4.075		9.287		6.681
	agazone 3	2.293		4.505		3.399
	atonik 0.5	5.612		10.563		8.088
	atonik 1	3.387		7.522		5.454
Means of storage period		4.475		8.842		
RLSD 0.05						
hybrids	treatments	storage period	hybrids× treatments	hybrids× storage period	treatments× storage period	hybrids× treatments× storage period
0.1835	0.2902	0.1835	0.4104	0.2596	0.4104	0.5804

3.3 Vitamin C (mg 100 g^{-1})

Table 3 showed the effect of hybrids, spraying treatments with agazone and atonik and storage period and their interactions on the amount of vitamin C for eggplant fruits stored at 13°C [3a]. The results indicated that the amount of vitamin C decreased with the continuation of storage period reached 4.29 mg. 100 g^{-1} after two weeks of storage. Results showed that there were no significant effect of spraying treatments with agazone and atonik on the amount of vitamin C. The highest percentage of amount of vitamin C was in Barcelona fruits which recorded 4.87% as compared with in Jawaher fruits, which may be due to genetic differences between the two hybrids [18].

In regard to binary interactions, there were significant differences between factorial treatments, the highest value of vitamin C was in Barcelona fruits sprayed with 1.5 ml L^{-1} agazone which recorded 5.08mg 100 g^{-1} [3a]. The lowest amount of vitamin C was in Jawaher fruits sprayed with 1.5 ml L^{-1} agazone, which reached 3.76 mg 100 g^{-1}. The table also showed the significance of the interaction between the spraying treatments and the storage period. The highest vitamin C value was in the fruits of the 3 ml L^{-1} agazone sprayed after a week of storage, which was 5.40 mg 100 g^{-1}, while the lowest value of vitamin C was in fruits of 0.5 ml L^{-1} atonik sprayed after two weeks of storage, which was 4.12 mg 100 g^{-1}.

The highest value of vitamin C in Barcelona fruits after a week of storage which was 5.08mg 100 g^{-1}. The lowest value of vitamin C was in Jawaher fruits after two weeks of storage, which amounted to 4.18mg 100 g^{-1} [3a].

In regard to triple interaction, the highest value of vitamin C was in Jawaher fruits sprayed with 3 ml L^{-1} agazone after a week of storage which amounted 5.50 18 mg 100 g^{-1}, whereas the lowest amount of vitamin C was in was in Jawaher fruits sprayed with 1.5 ml L^{-1} agazone after two weeks of storage, which amounted to 3.42 mg 100 g^{-1}.

The reason for decreasing vitamin C with the continuation of storage period may be due to the continuation of vital processes and increment the activity of ascorbase and oxidase with the continuation of storage period led to the oxidation of vitamin C to dehydroascorbic acid. This is in agreement with Taain [15] for jujube fruits cv. Tufahi and Fadala et al. [19] for tomato fruits.

3.4 Percentage of Total Soluble Solids (T.S.S)

Results presented in Table 4 showed that the percentage of total soluble solids increased up to 6.81% after two weeks of storage [3a]. The increment in the percentage of total soluble solids may be due to the reduction of moisture content of fruits with the continuation of storage periods, as the storage period progresses, the lower moisture content of the fruit increases the concentration of the cell juice of the fruit and thus increases the percentage of soluble solids [20]. The obtained results are in agreements with Taain [21] for date palm fruits cv. Barhi.

Table 3. Effect of hybrids, spraying agazone and atonik, storage period and the interaction among them on vit. C (mg 100 g^{-1}) of eggplant fruits stored at 13 ° C

hybrids	Treatments (ml $.L^{-1}$)	Storage period (week)		hybrids × treatments
		1	2	
Jawaher	control 0	5.00	4.60	4.80
	agazone 1.5	4.10	3.42	3.76
	agazone 3	5.50	4.43	4.96
	atonik 0.5	5.46	4.30	4.88
	atonik 1	4.96	4.16	4.56
Barcelona	control 0	4.96	4.66	4.81
	agazone 1.5	5.26	4.90	5.08
	agazone 3	5.30	4.18	4.74
	atonik 0.5	4.66	3.94	4.30
	atonik 1	5.23	4.33	4.78

						Means of hybrids
hybrids × storage period	Jawaher	5.00		4.18		4.46
	Barcelona	5.08		4.40		4.87
						Means of treatments
treatments× storage period	Control 0	4.98		4.63		4.80
	agazone 1.5	4.68		4.16		4.42
	agazone 3	5.40		4.30		4.85
	atonik 0.5	5.06		4.12		4.59
	atonik 1	5.10		4.24		4.67
Means of storage period		5.04		4.29		
RLSD 0.05						
hybrids	**treatments**	**storage period**	**hybrids× treatments**	**hybrids× storage period**	**treatments× storage period**	**hybrids× treatments× storage period**
0.393	**N.S**	**0.393**	**0.879**	**0.556**	**0.879**	**1.244**

Table 4. Effect of spraying with licorice extract, postharvest treatments and storage period on TSS (%) of eggplant fruits stored at 13°C

hybrids	Treatments (ml .L^{-1})	Storage period (week)		hybrids × treatments
		1	2	
Jawaher	control 0	4.74	5.20	4.97
	agazone 1.5	6.18	7.14	6.66
	agazone 3	6.84	7.37	7.11
	atonik 0.5	6.03	6.71	6.37
	atonik 1	6.26	7.15	6.71
Barcelona	control 0	4.56	5.55	5.06
	agazone 1.5	6.32	7.19	6.75
	agazone 3	6.72	6.79	7.15
	atonik 0.5	5.91	7.01	6.46
	atonik 1	6.30	7.24	6.77

						Means of hybrids
hybrids × storage period	Jawaher	**6.01**		6.71		6.25
	Barcelona	5.96		6.91		6.55
						Means of treatments
treatments× storage period	Control 0	4.65		5.37		5.01
	agazone 1.5	6.25		7.16		6.71
	agazone 3	6.78		7.48		7.13
	atonik 0.5	5.97		6.86		6.41
	atonik 1	6.28		7.19		6.74
Means of storage period		5.99		6.81		
RLSD 0.05						
hybrids	**treatments**	**storage period**	**hybrids× treatments**	**hybrids× storage period**	**treatments× storage period**	**hybrids× treatments× storage period**
0.146	**0.232**	**0.146**	**0.328**	**0.207**	**0.328**	**0.464**

The highest percentage of TSS was in Barcelona fruits which recorded 6.55% with significant differences with Jawaher fruits which recorded the lowest percentage (6.25%) of TSS. In regard to the spraying treatments, the highest percentage of TSS was in fruits with 3 ml L^{-1} agazone which gave 7.13% [3a]. The agazone content of gibberellins and cytokines increased the area of leaves and thus led to increase the efficiency of photosynthesis, which provides the largest amount of food produced to fruits with increase the content of chemical components [22]. The obtained results are in agreement with Maliki [23] on eggplants and Zodape et al. [24] on tomatoes.

In regard to binary interactions, the highest percentage of TSS was in fruits of Barcelona hybrid plants sprayed with 3 ml L^{-1} agazone which gave 7.15%, while the lowest percentage of TSS was in untreated Jawaher fruits which gave 4.97%. The highest percentage of TSS was recorded in fruits with 3 ml L^{-1} agazone which gave7.48% after two weeks of storage, while the lowest percentage of TSS was in control fruits after one week of storage which recorded 4.65%.

In regard to triple interaction, the highest percentage of TSS was in fruits of Barcelona hybrid plants sprayed with 3 ml L^{-1} agazone after two weeks of fruits, which amounted to 7.59% [3a].

4. CONCLUSIONS

In conclusion, the results obtained in the present work clearly indicated to the role of spraying agazone and atonik in improving storage ability of eggplant fruits hybrids Jawaher and Barcelona stored at 13°C for four weeks. Obtained results indicated that the lowest percentages of the weight loss and the highest percentage of total soluble solids were in fruits treated with 3 ml L^{-1} agazone [3a]. Barcelona fruits gave the highest fruit firmness, vitamin C, total soluble solids and lowest percentage of weight loss compared to Jawaher during the two-week storage period, so for the purpose of organizing the display of the crop in the markets, it could be recommended for planting in unheated plastic house under the conditions of south of Iraq.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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