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تمت الطباعة في مطبعة
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صدرت وقائع المؤتمر في شهر مارس ٢٠٢٥

٣٧٦	Rabab Majeed Abed Salam Rahim Yosif	Impact of biochare and mycorrhizal fungus Glomus sp. as biofertilizer on Phaseolus vulgaris plant growth	٢٠
٣٨٩	Mahmood Shakir Hashim Dhia Ahmed Taain	The role of seaweed extract in the management of the storage behavior of jujube fruits (Z. mauritiana Lam. Cv. Tufahi)	٢١
٣٩٩	Hind Abdel Hamid Rashid	Effect of Arginine and Tryptophan on Floral Growth Characteristics of Gladiolus	٢٢
٤١٤	Noor Refaat Fadhil Areej Atiyah Hussein (Ph.D.)	Detection of Hepatitis C Virus in patients with Thalassemia and Hemophilia in Diyala Governorate	٢٣
٤٢٤	Susan Duraid Ahmed, Abdalla khataybeh Rawan Salameh Al-Eroud	The Steering wheel on the subject of earth gravity between Al-Biruni and Newton: comparative study	٢٤
٤٣٦	Hassan Khasro Akram, Dimitrios G. Goulis, Omar Khasro Akram, Dania Ali Abdulkarim, Daniel José Franco, Efstratios M. Kolibianakis, Gesthimani Mintziori, Khasro Akram Othman Al- Najar	Sulforaphane's Impact on Metabolic and Hormonal Imbalances in PCOS: A Therapeutic Approach	٢٥
٤٥١	Raafat A. Oubida, Abdulhakeem A. Abdulameer, Abbas Kh. Abbas ^٣	IMPACT ON SUSTAINABLE SYSTEMS AND INTELLIGENT SECURITY SYSTEMS ONLINE SAFETY	٢٦
٤٧٣	Jumana F. Shallal, and Mohsin N.Hamzah and Ali H. Almukhtar	Experimental Investigation of Sloshing Effects on the Fuel Tank of a Boeing ٧٣٧-١٠٠ Wing Model	٢٨
٤٨٨	Abbas Khudhair Abbas, Abdulhakeem Amer, Raafat	Blockchain-Based Secure AI Systems	٢٩

The role of seaweed extract in the management of the storage behavior of jujube fruits (*Z. mauritiana* Lam. Cv. Tufahi)

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Abstract

The present study was conducted on the jujube fruits cv. Tufahi growing in one of the commercial orchards in the Al-Hartha region, Basrah governorate for the season ٢٠٢٢-٢٠٢٣, where nine trees were selected as similar as possible in terms of growth strength and age and had the same agricultural operations. The experiment included spraying trees with the seaweed extract 'agazone' at concentrations (٠, ١, ٢) mg.L⁻¹ for three times. The fruits were harvested at the maturity stage and the fruits of similar volume and undamaged were selected and packed in perforated polyethylene bags (٨ holes per bag, the diameter of the hole is ٤ mm). The bag expanded to ١ kg of fruit, then stored at a temperature of ٤°C for four weeks. The most important results showed the superiority of the treatment with the seaweed extract, especially the concentration of ٢ mg.L⁻¹, in reducing the percentage of decay and weight loss and maintaining the highest content of organic acids and vitamin C compared to the control treatment. The results indicated an increase in the percentage of decay and an increase in the fruit content of total soluble solids and total sugars with increasing storage period.

Keywords: Jujube fruits, Decay percentage, Weight loss, Vitamin C

Introduction

Ziziphus Spp. belongs to the Rhamanaceae family and the genus *Ziziphus*, which contains more than ١٠٠ species of plants that are evergreen trees and shrubs that grow in tropical, subtropical and temperate regions of the world (Williams, ٢٠٠٦). *Ziziphus* fruits have a high nutritional value due to their content of sugars, proteins, organic and amino acids, vitamins, fats, fibers and minerals. In Iraq, there are four main species of *Ziziphus*: *Z. nummularia* L. and *Z. jujuba* Lam. In addition to *Z. mauritiana* Lam and *Z. spina-christi*, which are the most widespread and economically important (Al-Rubaai, ١٩٨٨).

The jujube fruit is a drupe resulting from the development of a single ovary. The growth and development of jujube fruit can be divided into four stages: growth, maturation, ripening, and senescence (Pareek, ٢٠٠١).

Agricultural researchers have turned to finding safe and environmentally friendly materials such as the use of seaweed extracts. Therefore, the use of biostimulants has increased in recent years and has become a common application in sustainable agriculture. Agazone is a natural liquid extract of the algae *Ascophthllum nodosum*, a brown seaweed belonging to the Fucaceae family, found in the northern coasts of Europe and the northeastern coasts of North America. It has been used for a long time as an organic fertilizer for many crops due to its content of major nutrients N, P, K and micronutrients (S, Cu, Fe, Zn). It also contains cytokines, auxins, gibberellins, organic acids, sugars, amino acids and proteins (Taain and Salman, ٢٠١٨).

Cold storage is one of the important methods at the present time that is used to preserve the quality of fruits for the longest possible period. Cold storage delays the ripening of fruits and thus reduces the speed of their deterioration and reaching senescence and leads to a reduction in the vital activity of fruits, especially the processes of respiration and ethylene production. It also works to limit the growth of pathogens, especially fungi (Al-sareh & Taain, ٢٠٢١).

The study was conducted with the aim of improving the storage capacity of the jujube fruits cv.Tufhi, and thus the possibility of extending the display of these fruits in fresh condition in local markets, in addition to improving the qualitative characteristics and reducing the decay of the fruits during storage.

Materials and methods

The current study was conducted in one of the private orchards in the Al-Hartha region, Basrah Governorate, for the agricultural season ٢٠٢٢-٢٠٢٣ on jujube trees cv.Tufahi. Nine trees were selected that were as similar as possible in terms of growth strength and age. The same agricultural operations were carried out on all trees, including irrigation, fertilization, fruit pruning, and pest control. The trees were sprayed three times in the early morning with the extract of the seaweed agazone. The first spray was on ٦/٤/٢٠٢٢, followed by the second and third sprays, with a time interval of ٣٠ days between each spray using a ٥-liter hand sprayer. The spray concentrations were (٠, ١, ٢) mg.L⁻¹.

Tween٢٠ was added at a concentration of ٠.٠١% as a spreading agent to reduce surface tension. The fruits were collected at the physiological maturity stage (yellow color) and after cleaning them from dust, they were packed in perforated polyethylene bags (٨ holes per bag, the diameter of the hole is ٤ mm). The bag expanded to ١ kg of fruits ,then stored at a temperature of ٤°C for four weeks. The following characteristics were estimated:

١. Decy percentage: was estimated as a percentage as follows.

$$\text{Decy percentage} = \frac{\text{Weight of damaged fruits in the package}}{\text{Total weight of fruits in the package}} \times ١٠٠$$

٤. Weight loss was calculated by observed the changes in fruits weight during the storage period using weight balance (Polegaev, ١٩٨٨).

٢. Total soluble solids (T.S.S.) were determined by using hand refractometer and the results were corrected to ٢٠ °C.

٣. Total titratable acidity (%) determined according to A.O.A.C. (١٩٩٠) by mashing five grams of fresh fruit pulp with ٢٠ ml of distilled water. The mixture was then filtered and (١٠

ml) was taken from it and titrated with sodium hydroxide NaOH (0.1 N) until reaching the equivalence point using Phenolphthalein indicator.

٥. Total sugars (%) of fruits were determined according to Lane and Eynon method outlined in A.O.A.C. (1990) by taking 0.5 g of dry fruit pulp from each replicate and adding 50 ml of distilled water to it. In order to extract the sugars, the mixture was placed in a water bath at a temperature of 70 °C for half an hour and the extract was filtered. Then, the clearing process was carried out using 3 ml of basic lead acetate (40%) and 3 ml of potassium oxalate. Then, the reducing sugars were estimated by titrating 50 ml of the filtrate after the clearing process with Fehling's solution A and B with using methylene blue dye. Another 50 ml of the cleared filtrate was taken and acid hydrolysis was carried out by adding five ml of concentrated hydrochloric acid to another 50 ml of the cleared filtrate and left for 24 hours. Then, the acidified solution was adjusted with 40% sodium hydroxide NaOH until reaching the equivalence point.

٦. Vitamin C (mg/100 g) determined according to A.O.A.C. (1990).

The experiment was designed as a factorial experiment consisting of two factors: the seaweed extract agazone and storage period using a completely randomized design (CRD). The difference between the treatments was tested using the Revised LSD test at a probability level of 0.05 (Al-Rawi and Khalaf Allah, 2000).

Results and Discussion

١. Decay percentage

Table 1 showed the effect of spraying with the seaweed extract agazone, storage period and their interaction on decay percentage of jujube fruits cv. Tufahi. The results indicated that the percentage of decay increased with the advancement of storage periods, reaching 5.11%, and this may be due to the attack of the fruits by microorganisms, especially fungi and bacteria (Alsareh and Taain, 2018). The statistical analysis indicated the superiority of the treatment with the 3 mg.L⁻¹ seaweed extract agazone in reducing the percentage of decay (0.87%). As for the interaction between the two factors, it is clear that the highest percentage of decay was in the control fruits after four weeks of storage (8.32%), with a significant difference from the rest of the treatments.

Damage of all kinds is one of the most dangerous influencer that facing fruits after harvest. During packaging and storage, fruits are exposed to damage that varies depending on its causes. It may be the result of mechanical damage to which the fruits are exposed during packaging and storage, such as bruises or deformities resulting from pressing the fruits of each other inside the package, or the damage may be the result of physiological disorders, or as a result of the fruits advancing in ripening. Damage also results from infections with pathogenic microorganisms such as bacteria, fungi and yeasts (Taain, 2011, Taain *et al.* 2023).

The role of seaweed extract agazon in controlling fruit decay may be due to its content of auxins, gibberellins and cytokinins, and thus their role in reducing the rate of respiration of the fruits and their production of ethylene, as increasing the rate of respiration lead to the deterioration of the fruits. Auxins work to extend the storage period by preserving the stored food in the fruits. Gibberellins and cytokinins also play a role in reducing the rate of disease infections because of their effectiveness in reducing the rate of respiration and ethylene production and delaying the entry of fruits into the senescence. They also play a role in increasing the thickness of cell walls, which makes them more resistant to the microorganisms that decompose fruit tissues (Hopkins & Muner, 2008).

Basak (2008) indicated that treating apple trees with the sea extract Kelpak had a role in inhibiting the growth of fungi and bacteria, extending their storage life and maintaining their quality characteristics.

Table ١

The effect of application seaweed extract , storage period and their interaction on the decay percentage of fruits %

Seaweed extract (mg.L ⁻¹)	Storage period (day)			Means of seaweed extract	
١	٢	٣	٤		
٠	٠	٠	٤.١٢	٨.٣٣	٣.١١
١	٠	٣.٣	٦.٤		٢.٤٢
٢	٠	٠	١.١	٢.٤	٠.٨٧
Means of storage period	٠	٠	٢.٨٤	٥.٧١	
RLSD ٠.٠٥					
Seaweed extract ١.٥١	Storage period ٢.١١	Interaction ٤.١٣			

٢. Weight loss

Table ٢ showed the effect of spraying with the seaweed extract , storage period and their interaction on the percentage of weight loss of the fruits. The results indicated that the weight loss increased as the storage periods progressed, reaching ١.٨١ %. The statistical analysis indicated the superiority of spraying with the seaweed extract in reducing the weight loss of the fruits compared to the control treatment, which recorded the highest percentage of weight loss, reaching ١.٣٢%. As for the interaction between the treatment with the seaweed extract and storage period, It is clear that the highest percentage of weight loss was in the fruits of the control treatment after four weeks of storage ٢.٨٧% and with a significant difference from the rest of the treatments .

Weight loss can occur as a result of the loss of the stored food of the fruits due to their consumption by the respiration process or as a result of the loss in water content (Taain, ٢٠١١) as the fruits lose their water through evaporation from the surface of the fruit, and part of stored food consumed by the respiration process. After harvesting, there is a major problem of water loss, which leads to wilting, wrinkling and a significant decrease in weight.

The reason for the decrease in weight with the advancement of the storage period is the loss in the water content of the fruits with the continuation of the storage period, in addition to the decrease in the stored food due to the respiration process (Shirokov, ١٩٨٨; Taain *et al.* ٢٠١٧).

From the above results, we find that spraying with agazon reduced the weight loss of fruits . The reason may be due to the fact that the agazon contains auxins, cytokinins and gibberellins, which play a role in inhibiting the production of ethylene gas and maintaining the permeability of cell membranes by controlling the transfer of materials across the membranes (Wang *et al.* ١٩٩٦). The role of auxins in reducing weight loss is highlighted by reducing the rate of respiration, which is a cause of the consumption of nutrients stored in the fruits and thus their weight decreases. Gibberellins and cytokinins also work to inhibit the effectiveness of ethylene, regulate the permeability of cell membranes, and reduce the rate of respiration, thus reducing the percentage of weight loss (Kumar and Gutap, ١٩٨٧; Hopkins & Muner, ٢٠٠٨).

Table ٢

The effect of application seaweed extract , storage period and their interaction on weight loss of fruits %

Seaweed extract (mg.L ⁻¹)	Storage period (day)			Means of seaweed extract
	١	٢	٣	
٠	٠.١١	٠.٧٧	١.٥٤	٢.٨٧
١	٠.٠٠	٠.١٦	٠.٦٥	١.٤٢
٢	٠.٠٠	٠.١٢	٠.٤٣	١.١٣
Means of storage period	٠.٠٤	٠.٣٥	٠.٨٧	١.٨١
RLSD ٠.٠٥				
Seaweed extract	٠.٧٩			
Storage period		١.٥١		
Interaction			٢.٦٧	

٣. Total soluble solids

Results of table ٣ showed an increase in the total soluble solids of the fruits as the storage periods progressed. This may be due to the decrease in the water content of the fruits with the progress of the storage periods. As well known, there is an inverse relationship between the content of the fruits of total soluble solids and their content of water (Burton, ١٩٨٢). It is

also noted from the aforementioned table that control treatment (0 mg.L^{-1}) recorded the highest percentage of the total soluble solids 16.60% which significantly outperformed the rest of the treatments. The interaction between the seaweed extract and the storage period, had significant effect ,as the highest percentage of total soluble solids was in control treatment after four weeks of storage (17.00%), with a non-significant difference from the control treatment after three weeks of storage (16.80%), and with a significant difference from the rest of the treatments.

Fruits treated with the seaweed extract gave the lowest percentge of total soluble solids compared to the fruits of the control treatment, this may be due to the role of seaweed extract in delaying fruit ripening, as it is known that the percentage of total soluble solids increases with the continued advancement of fruit ripening. the advancement of fruit ripening leads to an increase in the accumulation of total soluble solids because jujue fruits considered as climatic fruits (Desouki *et al.*, ٢٠٠١).

Table ٣

The effect of application seaweed extract , storage period and their interaction on the total soluble solids of fruits %

Seaweed extract (mg.L ⁻¹)	Storage period (day)			Means of seaweed extract	
١	٢	٣	٤		
٠	١٦.٢٠	١٦.٥٠	١٦.٨٠	١٧.٠٠	١٦.٦٠
١	١٦.٠٠	١٦.٢٠	١٦.٤٠	١٦.٥٠	١٦.٢٠
٢	١٦.٠٠	١٦.٠٠	١٦.٢٠	١٦.٤٠	١٦.١٥
Means of storage period	١٦.٦٥	١٦.٢٣	١٦.٤٦	١٦.٦٣	
RLSD ٠.٠٥					
Seaweed extract ٠.٣٧	Storage period ٠.٢٢		Interaction ٠.٢٨		

٤. Total titratable acidity

Reselts presented in table ٣ indicated the effect of spraying with seaweed extract, storage period and their interaction on the percentage of total titratable acidity of jujube fruits. The results showed a decrease in the percentage of total titratable acidity of the fruits as the storage periods increased. This may be due to their consumption by respiration process or conversion to sugars (Alsareh and Taain, ٢٠١٨). It is also noted that the content of organic acids in the fruits treated with seaweed extract was higher compared to the fruits of the

control treatment. Regarding to the interaction between seaweed extract treatments and storage periods was not significant.

The presence of macro and micro elements ,gibberellins and cytokinins in the seaweed extract causes an increase in the efficiency of photosynthesis, which provides the largest amount of manufactured food to the fruits and increases their content of chemical components such as organic acids (Stern, ٢٠٠٨). This result is consistent with Taain and Salman (٢٠١٨) on eggplant fruits treated with agazone and stored at ١٣°C.

Table ٤

The effect of application seaweed extract , storage period and their interaction on the total titratable acidity of fruits(%)

Seaweed extract (mg.L ⁻¹)	Storage period (day)				Means of seaweed extract
	١	٢	٣	٤	
٠	٠.٠٦٢	٠.٠٥٥	٠.٠٥١	٠.٠٤٥	٠.٠٥٣
١	٠.١٢٥	٠.١٢١	٠.١١٥	٠.١١١	٠.١١٨
٢	٠.١٢٥	٠.١٢١	٠.١١٥	٠.١١١	٠.١١٨
Means of storage period	٠.١٠٤	٠.٠٩٩	٠.٠٩٣	٠.٠٨٩	
RLSD ٠.٠٥					
Seaweed extract	٠.٠١١	Storage period	٠.٠٦١	Interaction	NS

٥. Total sugars (%)

It is noted from table ٤ that the highest percentage of total sugars was in the control fruits, recording ١٤.٧٠%, with a significant difference from the rest of the treatments. As for the lowest percentage of sugars, it was in the treatment with ٢ mg.L⁻¹ seaweed extract, which gave ١٤.٢٧, with a non-significant difference from the treatment with ١ mg.L⁻¹ seaweed extract. The same table indicated an increase in the percentage of total sugars with the continuation of the storage period until it reached the highest percentage after four weeks of storage ١٤.٧٦%.

It is noted that the pattern of change in the total sugar content of the fruits matches the pattern of change in the total soluble solids, of which sugars constitute an important part. The reason for the decrease in the total sugar content of the fruits treated with seaweed extract

may be due to the role of these treatments in delaying the ripening of the fruits treated with them (Taa'in and Salman ,٢٠١٨).

Table ٥

The effect of application seaweed extract , storage period and their interaction on the total sugars of fruits %

Seaweed extract (mg.L ⁻¹)	Storage period (day)			Means of seaweed extract
١	٢	٣	٤	
٠	١٤.١٢	١٤.٥٢	١٤.٨٢	١٥.٣٣
١	١٤.٠٢	١٤.٢٢	١٤.٤٦	١٤.٥٥
٢	١٤.١١	١٤.١٩	١٤.٣٧	١٤.٤١
Means of storage period	١٤.٠٨	١٤.٣١	١٤.٣٨	١٤.٧٦
RLSD ٠.٠٥				
Seaweed extract ٠.٣٢		Storage period ٠.٣١	Interaction ٠.٤٩	

٦. Vitamin C

The table ٦ indicated the superiority of the spraying treatment with seaweed extract compared to the control treatment in the effect on the fruit content of vitamin C, as the concentration of ٢ mg.L⁻¹ recorded the highest value ١٥٦.٣٠ mg.١٠٠gm⁻¹ with no significant difference from the concentration of ١ mg.L⁻¹, while the concentration of ٠ mg.L⁻¹ gave the lowest value. The results of the table showed that the amount of vitamin C decreases the longer the storage period until it reaches ٩٦.٦٣ mg.١٠٠gm⁻¹.

the decrease in the amount of vitamin C in the fruits with the extension of the storage period may be due to its oxidation and transformation into the compound dehydro ascorbic acid by the action of the enzymes Oxidase and Ascorbase . This is consistent with what was mentioned by Taa'in *et al.* (٢٠١٧) regarding tomato fruits that the amount of vitamin C in the fruits decreases with the continuation of the storage period.

Table ٥

The effect of application seaweed extract , storage period and their interaction on vitamin C of fruits %

Seaweed extract (mg.L ⁻¹)	Storage period (day)			Means of seaweed extract
١	٢	٣	٤	
٠	١٤٢.٣٢	١٣٥.٧٧	١٢٢.١٢	١١٠.٠٥
١	١٦٦.١٦	١٥٧.١٧	١٤٨.٨٧	١٣٥.٠٦
٢	١٦٨.٣٦	١٦١.٦٦	١٥٣.٧٦	١٤١.٤٢
Means of storage period	١٥٨.٩٥	١٥١.٥٣	١٤١.٥٨	٩٦.٦٣
RLSD ٠.٠٥				
Seaweed extract ١٩.١٣	Storage period ١٦.٦٦		Interaction ٢٨.٣٥	

Conclusions

In conclusion, the results obtained in the present work clearly indicated that the treatment with the seaweed extract, especially the concentration of ٢ mg.L⁻¹ improved the qualitative parameters of jujube fruits cv. Tufahi during storage, by reducing the percentage of decay and weight loss and maintaining the highest content of organic acids and vitamin C compared to the control treatment.

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