EFFECT OF GAS ENRICHMENT AND FOLIAR WITH ORGANIC NUTRIENTS ON YIELD QUALITY OF BROCCOLI UNDER HYDROPONIC SYSTEM

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ABSTRACT

A hydroponic experiment was carried out at the College of Agricultural Engineering Sciences - University of Baghdad during the fall season of 2019-2020 in order to improve the quality traits of broccoli grown hydroponically under the modified Nutrient Film Technique (NFT), using an internationally approved standard solution and alternative solution, the plant was enriched with ozone and the foliar application of organic nutrients. The Hydroponic study included two experiments with the standard solution (Cooper's solution) and the alternative solution (ABEER). Both experiments were implemented within the Nested Design with three replications, and both included the gas type in the main plot, which were oxygen and ozone, while the sub-plot occupied with the foliar application of organic nutrients. The foliar application included the coconut water with two concentrations of 50 and 100 ml. L^{-1} and moringa leaves extract with two concentrations of 2 and 4%, in addition to the control treatment. Results were revealed a significant effect of ozone enrichment and the foliar application of coconut water at a concentration of 100 ml L^{-1} in the standard and alternative solutions, as the chlorophyl content (41.34, and 51.59%) and the β-Carotene (37.35 and 27.78 %) respectively. While the treatment of ozone enrichment and the foliar application of moringa leaves extract 2% for both solutions recorded the highest percentage Indol-3-Carbinol (54.03 and 56.40%) and Sulforaphane (51.66 and 43.95 mg kg dry weight^{-1}) in the main heads respectively.

Keywords: oxygen, ozone, coconut water, moringa, soiless culture , sulforaphane, I3C,nitrate, low footprint .
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تأثير الاغناء بالغاز والرش بالمغذيات العضوية في جودة حاصل البروكلي تحت نظام الزراعة المائية

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المستخلص

نفذت التجربة المائية في كلية علوم الهندسة الزراعية – جامعة بغداد للموسم الخريفي 2019–2020 بهدف دراسة جودة المنتج للبروكلي المزروع مائيا تحت نظام فلم المحلول المغذي Nutrient Film Technique (NFT) المحور باستعمال محلول قياسي معتمد عالميا ومحلول بديل، ولتحسين صفات نوعية حاصل البروكولي تم الاغناء بالاوزون والرش بالمغذيات العضوية، وقد شملت الزراعة المائية تجربتي المحلول القياسي (محلول Cooper) والمحلول البديل (محلول ABEER) وقد نفذتا ضمن تصميم Nested Design وبثلاثة مكررات وضمت كلا منها في القطع الرئيسة نوعية الغاز المُجَهز الى المحلول المغذي، والذي ضم الاوكسجين والاوزون ثم وُزعت في القطع الثانوية الرش بالمغذيات العضوية وهي: ماء جوز الهند بتركيزين 50 و100 مل.لتر$^{-1}$ والرش بمستخلص اوراق المورنكا بتركيزين 2 و4% فضلا عن معاملة القياس، أظهرت النتائج تفوق معاملة الاغناء بالاوزون والرش بماء جوز الهند بالتركيز 100 مل لتر$^{-1}$ معنويا في تركيز الكلوروفيل (41.34 و 51.59%) والبيتاكاروتين (37.35 و 7.78%) على الترتيب فيما سجلت معاملة الاغناء بالاوزون والرش بمستخلص اوراق المورنكا2% ولكلا المحلولين اعلى نسبة زيادة في تركيز المركب الطبي Indol–3– Carbinol (54.03 و 56.40%) و اعلى محتوى لمركب Sulforaphane (51.66 و 43.95 ملغم كغم وزن جاف$^{-1}$) في القرص الرئيس على الترتيب .

الكلمات المفتاحية: الاوكسجين، الاوزون، ماء جوز الهند، المورنكا، الزراعة من دون تربة ، السالفورافان ، I3C، النترات، اسمدة ذات بصمة كاربونية منخفضة

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INTRODUCTION

In recent years there is global trend of consuming coulourful vegetables that high in nutritional value such as broccoli. *Brassica oleracea* var. Italica, which belongs to the Brassicaceae. As it considered one of the most promising vegetables and a source of valuable nutrients (14 and 12). Every 100 g of broccoli flowers contains 2.82 g protein, 0.37 g total fat, and 6.64 g carbohydrates (7). Consequently many researches in iraq oriented to enhance its yield and nutritional value (25, 26, 32, 34, 35) The Nutrient Film Technique (NFT) axial hydroponics system can change the face of the agricultural sector in crop production technology, which depends mainly and directly on the nutrient solution in which the roots of plants live directly and are quickly affected by solution's change (36). Over the past years, different types of nutrient solutions have been installed, which differ in their components and the proportions of these components in different countries of the world according to the different plant species, stage of growth, availability of materials and their prices. Gruda *et al.* (17) mentioned that the pioneering work in the field of the process of formulating and preparing nutrient solutions around the world has resulted from the structural formulas of nutrient solutions prepared by Hoagland and Arnon, which is called the general nutrient solution and is widely used for research purposes until today. The usefulness in the different ranges of nutrient concentrations in the solution is the provision of a wide range that can be used in the preparation of nutrient solutions, which led to the emergence of different formulas of solutions carrying different concentrations of nutrients and for the plant itself (16), that was depends mainly on the high susceptibility of the plant to Adapt in a wide range of concentrations of mineral nutrients, which is a natural behavior due to the plant living in different soils in terms of texture and chemical composition (6), Specialized research in food production and quality has gained great importance in recent years, especially when the world population is increasing. Guzel *et al.* (18) conducted a study of the cucumber crop and its content of mineral nutrients the after cultivation under the hydroponics and aquaponics techniques, which integrated plant growth with Koi carps fish farming, The results revealed that there were no significant differences between the two systems in the concentration of Ca and P in the plant, while a statistical difference was recorded in K and Mg. Also, the plants grown in Aquaponics were recorded a significant increment in their content of Cd, Cr, Fe, Ni, Pb and Zn. While the concentration of Mn, Cu and B nutrients and the content of chlorophyll were higher in hydroponic plants. Also, the plants in the two systems did not differ in terms of antioxidant activities. Dissolved oxygen depletion (DO) is one of the most important parameters of concern in any aquaculture system (19) and determines production and affects product quality (23). Ozone is considered more soluble in water up to thirteen times compared to oxygen at a temperature of 0-30 C°; since it is unstable, it is quickly turning back into oxygen, which leads to super saturation of oxygen in water can be reached quickly after it turns back into oxygen (11). Peng et al. (29) conducted an experiment on lettuce, in which local waste (Sludge city waste), ozonated and diluted to four levels, was used as a source of nutrient solution, as well as a modified Hawkland's solution as a comparator treatment in a hydroponics system. In numerous studies, it was discovered that the application of plant extracts improved reproductive indicators (2, 5), qualitative traits (21, 33), plant resistance (6) and yield (1, 4, 8). Moringa extract, which has been shown to be helpful in multiple research conducted, is one of the most significant extracts utilized (3).Similarly, in an effort to promote sustainability, employment of natural fertilizers with low-carbon footprint, like coconut water (0.46 kg CO_2/kg), which has been shown in numerous studies to be an efficient natural growth regulator (7, 24). This research was aimed to study the quality of the broccoli crop grown in two types of nutrient solutions and its content of mineral nutrients and medicinal compounds within hydroponics under the influence of ozone enrichment and the foliar application of plant extracts.

MATERIALS AND METHODS

This study was conducted at research station B at College of Agricultural Engineering Sciences - University of Baghdad during the

fall season of 2019-2020. Two experiments were implemented, the standard solution experiment and the alternative solution experiment, each of which included two separated systems, in a number of four in hydroponic systems, each of which contains a 1000 liters tank. The tank was buried in the ground containing the nutrient solution and a submersible pump to raise the solution into three plastic tubes 18 m long and 6 inches in diameter installed on iron supports and perforated with holes of 7 cm in diameter suitable for cultivation cups and ending with a tube with a diameter of 4 inches to collect the reflux solution and return it to the tank in a closed loop. The drainage holes were installed by raising them to a distance of 1/3 of the diameter of the cultivation tube so that part of the nutrient solution was kept in the cultivation tubes when the power was off. Thus, the NFT becomes modified, each tank was also equipped with an air pump to aerate the nutrient solution around the clock. A deionization device was installed in the main water source to provide deionized water. Reverse Osmosis (RO) is used in preparing the applied solutions in the experiment after passing it on a water meter to calculate the amount of water added to tanks continuously. Jassmina F1 hybrid broccoli seeds produced by DELTA SEEDS (D/S) were used in the experiment and the seedlings were transferred after reaching the appropriate size to the system on 9/16/2019 after being planted in plastic cups for hydroponics filled with perlite as an inactive medium, at planting distances of 30 cm between plants and 60 cm between one tube and another, then the nutrient solutions were pumped on 9/26/2019. Hydroponics included two experiments with the standard solution (Cooper's solution, 1979) Table 1 and the alternative solution (ABEER solution prepared from fertilizers available in the local markets that are inexpensive and easy to prepare) Table (2). It was implemented within the Nested Design and with three iterations, and each of them included in the main parts the first factor, which is the quality of the gas supplied to the nutrient solution, which is enriched with oxygen (O_2) and enriched with ozone (O_3) by means of an ozone generation device with a concentration of 3 g as an additional source of oxygen that works to generate and pump it into Feed tank at a rate of four times for half an hour during daylight hours (12 hours) and throughout the growing season, Then the levels of the second factor were distributed randomly within each replicate, which included the foliar application of organic nutrients, namely: Coconut water with two concentrations of 50, and 100 ml. L^{-1} (T_1 and T_2, respectively) and the foliar application of moringa leaves extract at two concentrations of 2 and 4% (T_3 and T_4, respectively) as well as the control treatment (T_0). The plants were sprayed three times during the season and once per each month.

Table 1. Salts that used on the preparation of standard nutrient solution and elements concentration in it (Cooper solution 79)

Salt type	Chemical structure	The weight $g.L^{-1}$	Element type	Concentration of the element $mg.L^{-1}$
	Stock A			
Calcium nitrate	$Ca(NO3)_2.4H_2O$	1003	Nitrogen	119
			Calcium	170
Chelated Iron	EDDHSA	79	Iron	12
	Stock B			
Potassium dihydrogen phosphate	KH_2PO_4	263	Phosphorus	60
			Potassium	75
Potassium nitrate	KNO_3	583	Potassium	225
			Nitrogen	81
Magnesium sulfate	$MgSO_4.7H_2O$	513	Magnesium	50
Manganese sulfate	$MnSO_4.H_2O$	6.1	Manganese	2
Boric acid	H_3BO_3	1.7	Boron	0.3
Copper sulfate	$CuSO_4.5H_2O$	0.39	Copper	0.1
Ammonium heptamolybdate	$(NH_4)_6Mo_7O_{24}.4H_2O$	0.37	Molybdenum	0.2
Zinc sulfate	$ZnSO_4.7H_2O$	0.44	Zinc	0.1

Table 2. Fertilizer that used on the preparation of alternative nutrient solution (ABEER) and its' elements concentrations

Fertilizer type	The weight g.L^{-1}	Element type	Concentration of the element mg.L^{-1}
		Vegetative growth stage	
30- 10- 10 +10 Neutral ammonium citrate	0.75	Total Nitrogen	225
		P_2O_5	75
		K_2O	75
		SO_3	75
Disper Complex GS	0.25	Fe-EDDHSA	12.5
		Mn -EDTA	10
		Zn-EDTA	1.5
		MgO -EDTA	5
		Cu -EDTA	1.25
		B	1.75
		Mo	0.75
Disper Mg	0.341	MgO	42
Disper Ca	1g L^{-1} sprinkled on the plant every 15 days throughout the growing season.		
		Flower growth stage	
20 -20 -20 Neutral ammonium citrate	0.75	N-NH_4	150
		P_2O_5	150
		K_2O	150
Disper Complex GS	0.25	Fe-EDDHSA	12.5
		Mn -EDTA	10
		Zn-EDTA	1.5
		MgO -EDTA	5
		Cu -EDTA	1.25
		B	1.75
		Mo	0.75
Disper Mg	0.341	MgO	45
Disper Ca	1g L^{-1} sprinkled on the plant every 15 days throughout the growing season.		

the sample was randomly taken for each treatment, and the main head of the selected plants were taken, the nitrogen content of the heads was estimated using the Kjeldahl, the phosphorous was estimated by ammonium molybdate and ascorbic acid using a spectrophotometer at a wavelength of 620 nm, and the content of the heads of K, Ca, Mg, Fe, Zn, Mn, and Cu Using the Atomic Absorption Device. Boron was estimated using the Carmin pigment and to estimate the total chlorophyll content of the heads , the pigment was extracted according to the Goodwin method, and the percentage of protein was calculated according to the Dalali and Al-Hakim method. And Nitrate (mg. 100g dry weight^{-1}) was estimated using the method of Cataldo et al. , Also Joslyn method was used to estimate the percentage of total carbohydrates, and (22) method to calculate the percentage of total dissolved solids (T.S.S) . while β-carotene was extracted according to the method of Nagata and Yamashita. Folic acid concentration (100 µg^{-1}) was also estimated according to the method of Ruengsitagoon and Hattanat (31). The main head juice filtrate was calibrated with a dye (2,6, Dichlorophenol Indophenols) to calculate the concentration of Ascorbic acid (V.C) (mg. 100 g fresh weight). The Davies method was applied to extract Total Carotenoids (mg 100 g fresh weight^{-1}) from the main head using a high-performance liquid chromatography (HPLC) device. Indol-3-Carbonel (mg 100 g fresh weight^{-1}) was estimated according to Li et al. (25), and Sulforaphane (mg 100 g fresh weight^{-1}) according to Li et al. (26) in the main disc of hydraulically grown broccoli plants.

RESULTS AND DISCUSSION

1- Chemical indicators of the main heads of broccoli plants: The results in Table (3) reveal that the plants grown in both solutions under the ozone (O_3) enrichment had a significant increment in the percentage of N, P, K, Ca and Mg in the main heads and in its content of Fe, B and chlorophyll reached 4.790, 0.725, 2.636, 1.050, 0.370%, 79.95, 23.60 mg. kg^{-1} and 112.30 mg.100g fresh weight^{-1}, respectively, in the standard solution, and 4.828, 0.668, 2.345, 0.840, 0.394 %, 87.03, 24.56 mg. kg^{-1}, and 133.03 mg.100g fresh weight^{-1}, respectively, in the alternative

solution, compared to plants enriched with oxygen, which recorded 4.674, 0.657, 2.470, 0.935, 0.357%, 74.41, 21.38 mg. kg^{-1} and 108.54 mg.100g fresh $weight^{-1}$, respectively, in the standard solution, and 4.734, 0.643, 2.249, 0.817, 0.374%, 78.88, 23.58 mg. kg^{-1}, and 111.53 mg.100g fresh $weight^{-1}$, respectively, in the alternate solution, while the ozone enrichment did not significantly affect the concentration of Zn in the main flower head of growing plants in both standard and alternative solutions. Also, the plants grown in the standard solution under the ozone (O_3) enrichment recorded the highest concentrations of Mn and Cu reached 10.41 and 5.16 mg kg^{-1}, respectively, compared to the plants that were enriched with oxygen (O_2), which recorded 9.57 and 3.97 mg kg^{-1}, respectively, while the gas enrichment treatment did not significantly affect these two characteristics of the plants growing in the alternative solution. The foliar application of organic nutrients has significantly affected the chemical traits of the main head of broccoli grown under hydroponic conditions. As the application of coconut water 100 $ml.L^{-1}$ (T_2) recorded a significant increase in the percentage of N, P, K, and Ca in the main flowering head and their content of Fe, Zn, and chlorophyll for the plants grown in both solutions, which reached 4.910, 0.734, 2.648, 1.025%, 86.16, 84.54 mg. kg^{-1} and 119.87 mg.100g fresh $weight^{-1}$, respectively, in the standard solution, and 4.935, 0.713, 2.373, 89.09, and 86.10 mg kg-1 and 136.97 mg 100g fresh $weight^{-1}$, respectively, in the alternate solution. While the lowest content was recorded by the control treatment (T_0), which amounted to 4.525, 0.635, 2.299, 0.930%, 68.81 and 61.95 mg. kg^{-1} 92.05 mg 100g fresh $weight^{-1}$, respectively, in the standard solution, and 4.595, 0.614, 2.262, 0.743%, 73.25 and 70.55 mg kg^{-1} and 108.17 mg 100g fresh $weight^{-1}$, respectively in the alternate solution. While the foliar application of moringa 2% (T_3) recorded a significant increase in the percentage of Mg in flowering head and its content of Mn and Cu for broccoli grown in the standard solution, which amounted to 0.377%, 10.50, and 4.980 $mg.kg^{-1}$, respectively, compared to the lowest content recorded by the control treatment (T_0) reached 0.350%, 9.13, and 4.130 mg kg^{-1}, respectively. While in the alternative solution, the foliar application of coconut water 100 ml L^{-1} (T_2) produced a significant increase in Mg and Mn in the flowering head amounted to 0.422% and 17.12 mg kg^{-1}, respectively, compared to the control treatment (T_0), which recorded 0.365% and 14.30 mg kg^{-1}, respectively. While the foliar application treatment of moringa 4% (T_4) was recorded the highest content of Cu in the head of broccoli grown under the alternative solution reached 5.380 mg kg^{-1}, while the lowest concentration was recorded by the control treatment (T_0), reached 3.380 mg kg^{-1}. Also, the foliar application treatments of organic nutrient have significantly affected the concentration of B in broccoli head grown in both solutions. As the foliar application of coconut water 100 ml L^{-1} (T_2) produced a significant increase in this characteristic for plants growing in the standard solution, which amounted to 24.35 mg kg^{-1}, while the lowest concentration was in the heads of the control treatment plants (T_0), which recorded 21.10 mg kg^{-1}, while in the alternative solution, the foliar application of moringa leaves extract 2% (T_3) recorded a significant increase in this parameter, reached 25.56 mg kg^{-1}. While the lowest concentration was in the control treatment (T_0), which were recorded 21.96 mg kg^{-1}. The interaction between the two studied factors of gas enrichment and the foliar application with organic nutrients had a significant effect on the chemical traits of the main heads of broccoli plants. The treatment of ozone enrichment and the foliar application of 2% moringa leaf extract (O_3T_3) revealed a significant increase in plants grown in standard solutions in the percentage of N and Mg in the main head, reaching 4.950. and 0.386%, respectively, while the lowest percentage was recorded by the control treatment (O_2T_0), reached 4.420 and 0.346%, respectively. The plants grown in the alternative solution were significantly recorded the highest values at the treatment of (O_2T_2) reached 4.940 and 0.437%, respectively, compared to the control treatment (O_2T_0) which recorded the lowest values reached 4.510 and 0.353%, respectively. The treatment of ozone enrichment and the foliar application of coconut water 100 ml. L^{-1} (O_3T_2) revealed a

significant increment in the plants grown with the standard solution in the percentage of P in the main head and recorded 0.849%. While the treatment of oxygen enrichment and the foliar application of coconut water 100 ml L^{-1} (O_2T_2) was significantly recorded the highest values in the alternative solution for the same capacity reached 0.778%, compared to the control treatment (O_2T_0), which recorded the lowest values reached 0.608% in the standard solution and 0.582% in the alternative solution. Also, the treatment of ozone enrichment and the foliar application of coconut water 100 ml L^{-1} (O_3T_2) recorded a significant increase in the percentage K, Ca, and total chlorophyll concentration in the main head of growing plants in both solutions, as it reached 2.759 and 1.086% and 120.85 mg 100 g fresh $weight^{-1}$ respectively in standard solution, and 2.435, 0.944%, and 140.27 mg 100g fresh $weight^{-1}$, respectively, in the alternate solution, compared to the lowest values recorded by the control treatment (O_2T_0), reached 2.208, 0.888%, and 85.50 mg 100 g fresh $weight^{-1}$, respectively, in the standard solution, and 2.214, 0.722% and 92.53 mg 100g fresh $weight^{-1}$ respectively in the alternate solution. The treatment of ozone enrichment and the foliar application of coconut water 100 ml L^{-1} (O_3T_2) has significantly affected the concentration of Fe and B in the main flower head of plants growing with the standard solution, as the concentration reached 94.80 and 24.90 mg kg^{-1}, respectively, in comparison to the lowest concentration which recorded by the control treatment (O_2T_0) and reached 68.70 and 20.06 mg kg^{-1}, respectively. As for the plants grown in the alternative solution, the treatment of ozone enrichment and the foliar application of moringa 2% (O_3T_3), which had a concentration in heads of 92.80 and 26.83 mg kg^{-1}, respectively, compared to the control treatment (O_2T_0), which amounted to 68.90 and 21.50 mg kg^{-1}, respectively. The application of oxygen enrichment and the foliar application of moringa 2% (O_2T_3) revealed a significant increase in the concentration of Zn in the main head under standard solution reached 92.50 mg kg^{-1}, and the lowest concentration of Zn was recorded in the control treatment (O_2T_0) reached 60.00 mg kg^{-1}. The treatment of oxygen enrichment and the foliar application of coconut water 100 ml L^{-1} (O_2T_2) recorded a significant increase in the concentration of Mn in the main heads of plants grown under the alternative solution, reaching 17.35 mg kg^{-1}, compared to the lowest concentration recorded by the control treatment (O_2T_0), reaching 14.30 mg kg^{-1}, while the interaction between the two factors did not significantly affect the concentration of Zn in the main head of plants growing in the alternative solution and the concentration of Mn in the main head of plants growing in the standard solution. The treatment of ozone enrichment and the foliar application of moringa 2% (O_3T_3) recorded a significant increase in the concentration of Cu in the main head of plants growing with the standard solution, reaching 5.830 mg kg^{-1}, compared to the lowest concentration was in the treatment of oxygen enrichment and the foliar application of moringa 4% (O_2T_4), reaching 3.630 mg kg^{-1}, which did not differ significantly from the control treatment (O_2T_0), which recorded 4.06 mg kg^{-1}, respectively, while in the alternative solution, enrichment with ozone and the foliar application of moringa 4% (O_3T_4) gave a significant values, which amounted to 5.560 mg kg^{-1}, compared to the lowest concentration that was in the control treatment (O_2T_0) which produced 3.300 mg kg^{-1}.

Table 3. Effect of gas enrichment and spraying with organic nutrients on the chemical analyzes of the main flower heads of broccoli plants growing in two types of nutrient solutions for the fall season 2019-2020

Treatments	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu	B	chlorophyll mg.100g^{-1} fresh weight
			%					mg.kg^{-1}			
Standard nutrient solution (Cooper solution 79)											
O_2	4.674	0.657	2.470	0.935	0.357	74.41	72.20	9.57	3.97	21.38	108.54
O_3	4.790	0.725	2.636	1.050	0.370	79.95	72.00	10.41	5.16	23.60	112.30
L.S.D.5%	0.052	0.022	0.018	0.015	0.003	2.37	N.S	0.40	0.43	0.42	1.64
T_0	4.525	0.635	2.299	0.930	0.350	68.81	61.95	9.13	4.13	21.10	92.05
T_1	4.655	0.709	2.630	1.004	0.361	74.10	66.25	10.29	4.61	22.57	112.83
T_2	4.910	0.734	2.648	1.025	0.372	86.16	84.54	10.35	4.86	24.35	119.87
T_3	4.810	0.674	2.643	1.005	0.377	85.73	83.75	10.50	4.98	22.34	116.08
T_4	4.760	0.701	2.544	0.999	0.358	71.12	64.02	9.70	4.26	22.10	111.27
L.S.D.5%	0.055	0.045	0.029	0.011	0.006	3.40	2.67	0.47	0.42	0.46	2.63
O_2 T_0	4.420	0.608	2.208	0.888	0.346	68.70	60.00	8.83	4.06	20.06	85.50
O_2 T_1	4.630	0.680	2.536	0.942	0.364	69.30	65.00	10.23	4.13	21.00	110.56
O_2 T_2	4.930	0.620	2.538	0.962	0.361	77.53	82.13	9.60	3.93	23.80	118.88
O_2 T_3	4.670	0.652	2.570	0.945	0.368	83.30	92.50	9.90	4.13	21.25	114.55
O_2 T_4	4.720	0.725	2.500	0.935	0.348	73.25	61.40	9.30	3.63	20.80	113.22
O_3 T_0	4.630	0.663	2.391	0.972	0.355	68.93	63.90	9.43	4.20	22.15	98.60
O_3 T_1	4.680	0.739	2.725	1.067	0.359	78.90	67.50	10.35	5.10	24.15	115.10
O_3 T_2	4.890	0.849	2.759	1.086	0.383	94.80	86.96	11.10	5.79	24.90	120.85
O_3 T_3	4.950	0.696	2.717	1.065	0.386	88.16	75.00	11.10	5.83	23.43	117.62
O_3 T_4	4.800	0.678	2.588	1.063	0.369	68.99	66.65	10.10	4.90	23.40	109.33
L.S.D $_{0.05}$	0.080	0.059	0.039	0.018	0.008	4.60	3.89	N.S	0.62	0.66	3.50
Alternative nutrient solution (ABEER)											
O_2	4.734	0.643	2.249	0.817	0.374	78.88	81.34	16.15	4.40	23.58	111.53
O_3	4.828	0.668	2.345	0.840	0.394	87.03	80.16	15.76	4.45	24.56	133.03
L.S.D $_{0.05}$	0.025	0.012	0.014	0.011	0.007	1.50	N.S	N.S	N.S	0.42	8.21
T_0	4.595	0.614	2.262	0.743	0.365	73.25	70.55	14.30	3.38	21.96	108.17
T_1	4.760	0.629	2.268	0.809	0.371	80.45	75.23	15.55	3.69	22.50	117.04
T_2	4.935	0.713	2.373	0.906	0.422	89.09	86.10	17.12	5.25	25.36	136.97
T_3	4.880	0.665	2.307	0.886	0.378	89.93	87.50	16.88	4.45	25.56	127.91
T_4	4.735	0.658	2.276	0.800	0.383	82.05	84.37	15.91	5.38	24.97	121.31
L.S.D $_{0.05}$	0.061	0.012	0.010	0.009	0.008	1.40	3.05	0.19	0.32	0.23	6.55
O_2 T_0	4.510	0.582	2.214	0.722	0.353	68.90	70.00	14.30	3.30	21.50	92.53
O_2 T_1	4.640	0.596	2.223	0.813	0.357	74.70	74.06	15.60	3.63	21.80	102.55
O_2 T_2	4.940	0.778	2.311	0.869	0.437	86.16	87.50	17.35	5.00	24.56	133.66
O_2 T_3	4.850	0.650	2.269	0.848	0.363	87.06	88.90	17.20	4.90	24.30	121.54
O_2 T_4	4.730	0.612	2.229	0.836	0.362	77.60	86.25	16.30	5.20	25.75	107.36
O_3 T_0	4.680	0.647	2.311	0.764	0.378	77.60	71.10	14.30	3.46	22.43	123.81
O_3 T_1	4.880	0.662	2.313	0.805	0.386	86.20	76.40	15.51	3.75	23.20	131.53
O_3 T_2	4.930	0.648	2.435	0.9444	0.408	92.03	84.70	16.90	5.50	26.16	140.27
O_3 T_3	4.910	0.680	2.346	0.924	0.393	92.80	86.10	16.56	4.00	26.83	134.28
O_3 T_4	4.740	0.704	2.323	0.764	0.405	86.50	82.50	15.53	5.56	24.20	135.27
L.S.D $_{0.05}$	0.079	0.017	0.017	0.014	0.011	2.09	N.S	0.35	0.55	0.45	10.33

This increases in the concentration of nutrients in broccoli heads that growing in the standard solution when enriched with ozone can be due to the role of this treatment in providing oxygen, which is one of the most important requirements for healthy growth and increasing its concentration in the solution properly over time, which reached 6 mg O_2. L^{-1}, where the oxygen taken from the plant participates in the process of respiration in the

oxidation of sugars and other substances into CO_2 and H_2O with the release of the energy required for plant growth and development, which loses a small part of it in the form of heat. However, the greatest part is preserved by living cells as energy-rich compounds, such as ATP, which are used in various vital processes, including the absorption of water and nutrients and their transport within the plant (9). In addition to the role of ozone enrichment in the continuous regulation of the pH of the solution and the increase in the nutrients availability, which directly affected the absorption of nutrients and then transported to the storage parts represented by the floral discs in broccoli, which indicates that this treatment was effective to the extent that it was able to secure the plant's need for Nutrients required for vegetative growth and formation of flowering heads. Hence, the increase in its content of these nutrients, while the increase in the concentration of nutrients in the growing broccoli discs in the alternative solution when enriched with ozone may be due to the role of this ozone in exposing the plant to a kind of stress as a result of lowering the pH of the solution over time, and the provision of conditions somewhat similar to cultivation in acidic soils, which was reflected in the relative reduction of vegetative growth, so the plant adapted to it in growth over time. As stress leads to inhibition of growth in the upper parts of the plant, followed by a reduction in the average cell division and elongation and enzyme activity. As well as reducing the uptake of nutrients from the roots and their transfer to the vegetative parts (37) with the transfer of a large part of the nutrients absorbed to the reproductive parts. The fact that the pink discs are the beginning of those parts, as the final result was an increase in their concentration of nutrients. The concentration of nutrients increased in the floral discs of broccoli plants growing in both solutions under the foliar application organic nutrients from various sources, which can be complementary or increase the effectiveness of nutrition through the roots. This increase may be due to the direct application of these nutrients through foliar method, which led to an increase in their absorption and then an increase in their concentration in plant tissues, or it may explain the behavior of these treatments according to the positive roles played by their components. Coconut water and moringa extract, with both concentrations, include several nutrients that qualify them for a significant effect on the process of carbon metabolism and improving vegetative and root growth. Which increased the roots absorption of nutrients, and reflected positively on their content in vegetative growth, and thus to the storage parts, which are the flowering discs of the plant (Table 3). The increase in the concentration of chlorophyll in the heads under ozone enrichment may be attributed to the increase in the concentration of nutrients in the heads (Table 3) and its role in the concentration of the pigment, as the nitrogen is a main part of protein and chloroplast (28). Phosphorus also participates with nitrogen in the formation of vital plant membranes, including the chloroplast membrane, as well as the role of phosphorus in the process of building energy compounds. And then the organic compounds, especially the proteins that are included in the structural structure of the chlorophyll molecule, while potassium is included as a cofactor in the formation of the pigment (30), through the activated calcium of some enzyme systems that are related to the synthesis of chlorophyll, and this was reflected on chlorophyll pigment (13 and 2) In addition to Fe, which contributes in the formation of chlorophyll, due to its direct impact on the formation of amino acids, carbohydrates, and energy compounds, and boron, which contributes in nutrients transformation (27). The increase in the concentration of chlorophyll in the discs in both solutions under the foliar application coconut water may be due to the behavior of this treatment similar to cytokinins, which increase the activity of the enzyme NADH-protochorophyllid reductase, which is used in the biosynthesis of chlorophyll. As well as its role in extending the life of leaves by delaying the decomposition and loss of chlorophyll (38) by inhibiting the activity of the enzyme Chlorophyllase responsible for the degradation of chlorophyll pigment (10 and 15). CK also plays an important role in the differentiation of Etioplasts and their transformation into chloroplasts, then their division and increase in

chloroplast numbers (20). The extract also contains amino acids and nitrogen, which have an important role in activating carbon metabolism, raising its efficiency, and activating the formation of chlorophyll (3). The studied pigments increase in the discs in both solutions under the interaction between gas enrichment and the foliar application of nutrient can be due to their complementary role in improving the plant content of nutrients, which was reflected in their manufacture.

2- Yield quality parameters

The results of Table 4 show the superiority of the growing plants in both solutions when enriched with ozone (O_3) in the percentage of protein and the concentration of total carotenoids, I3C and sulforaphane in the main head, which amounted to 29.93% and 9.94 mg 100g fresh weight^{-1} and 68.59 and 33.43 mg kg weight Dry^{-1} sequentially in standard solution, and 30.17% and 9.99 mg 100g^{-1} fresh weight and 75.28 and 31.82 mg kg dry weight^{-1} respectively in the alternate solution, compared to plants that were enriched with oxygen (O_2), which were reached 29.21% and 9.62 mg 100g fresh weight^{-1} and 54.39 and 23.36 mg kg dry weight^{-1} , respectively, in the standard solution, and 29.58% and 7.68 mg 100g^{-1} fresh weight and 59.38 and 23.01 mg kg dry weight^{-1} respectively in the alternate solution, While the plants grown under both solutions when enriched with oxygen (O_2) in reducing the concentration of nitrates in the main heads, which amounted to 39.29 and 36.89 mg 100 g dry weight^{-1} in the standard and alternative solutions, respectively, compared to plants that were enriched with ozone (O_3), which were reached 56.57 and 56.32 mg 100 g dry weight^{-1} in the standard and alternative solutions, respectively. While the plants grown under the standard solution when enriched with ozone (O_3) in the percentage of carbohydrates in the main head, which amounted to 6.69%, compared to plants enriched with oxygen (O_2), reached 6.18%. Gas enrichment treatment did not affect the percentage of carbohydrates in the heads of plants growing in the alternative solution, it also did not affect the percentage of soluble in the main head of broccoli plants grown in both standard and alternative solutions, respectively. And in the concentration of β-carotene, V.B9 and Vit. C in the discs of plants growing in the standard solution. While the growing plants excelled in the alternative solution when enriched with ozone (O_3) in the concentration of the dye and vitamins in the main head, which amounted to 5.72 mg 100 g fresh weight^{-1}, 80.45 µg 100 g fresh weight^{-1} and 106.98 mg 100 g fresh weight^{-1}, respectively. Compared to plants enriched with oxygen (O_2), it was 5.09 mg 100 g fresh weight-1, 76.28 mg 100 g fresh weight^{-1}, and 98.65 mg 100 g fresh weight^{-1}, respectively. The foliar application of organic nutrients was significantly affected yield quality parameters of broccoli plants grown in both solutions, as the application of coconut water 100 ml L^{-1} (T_2) resulted in a significant increase in the percentage of protein, the concentration of nitrates, the percentage of carbohydrates, TSS, the concentration of β-carotene and Vitamin C in the main heads, which amounted to 30.68% and 42.62 mg 100 g dry weight^{-1} and 6.67 and 9.10%, 6.60 and 110.80 mg 100g fresh weight^{-1}, respectively, in the standard solution, and 30.84% and 43.50 mg 100g dry weight^{-1} and 6.58, 8.87%, 5.71 and 109.69 mg 100g dry weight^{-1} respectively in the alternate solution, compared to the lowest value in the heads of standard treatment plants (T_0), which recorded 28.28% and 54.15 mg 100g dry weight^{-1} and 6.10 and 7.83% and 4.90 and 86.80 mg 100g fresh weight^{-1}, respectively, in the standard solution, and 28.71% and 49.50 mg 100g dry weight^{-1} and 6.02, 7.53%, 5.02 and 88.30 mg 100g dry weight^{-1} respectively in the alternative solution, While the foliar application of moringa 2% (T_3) recorded a significant increase in the concentration of vitamin B9 and I3C for the growing plant head in both solutions, which amounted to 87.08 mg 100 g fresh weight^{-1} and 68.76 mg kg dry weight^{-1}, respectively, in the standard solution, and 94.01 mg 100g fresh weight^{-1} and 76.90 mg kg dry weight^{-1} respectively in the alternate solution, compared to the lowest concentration in the heads of standard treatment plants (T_0), which amounted to 66.62 mg 100 g fresh weight^{-1} and 56.52 mg 100g fresh weight^{-1}, respectively, in the standard solution, and 66.17 mg 100g fresh weight^{-1} and 57.57 mg 100g fresh weight^{-}

[1]respectively in the alternate solution. The foliar application of moringa 4% (T_4) has significantly increased the concentration of total carotenoids of heads in the standard solution, which amounted to 10.66 mg 100 g fresh weight^{-1}, while the lowest concentration of the pigment was in the heads of plants of standard treatment (T_0), which amounted to 8.71 mg 100 g fresh weight^{-1}. As for the plants growing in the alternative solution, the foliar application of moringa 2% (T_3) produced the highest concentration of total carotenoids in the heads, which amounted to 9.53 mg 100 g fresh weight^{-1}, while the lowest concentration of the pigment was in the heads of plants of standard treatment (T_0), which amounted to 8.05 mg 100 g fresh weight^{-1}, The foliar application of organic nutrients also has a significant increase in the concentration of sulforaphane in the heads of broccoli plants growing in both solutions, as the foliar application of coconut water 100 ml L^{-1} (T_2) led to a significant increase in this characteristic, which amounted to 42.14 mg kg dry weight^{-1} in the plants of the standard solution. Also, the foliar application of moringa 2% (T_3) resulted in a significant increase in this characteristic, which amounted to 36.58 mg kg dry weight^{-1} in the plants of the alternative solution, while the lowest concentration of the compound was in the measurement treatment (T_0) in the standard and alternative solution, which amounted to 13.02 and 13.20 mg 100 g weight^{-1} respectively. The interaction treatments of gas enrichment and foliar application of organic nutrients had a significant effect on most of the quality traits of the yield of broccoli plants grown hydroponically, as the O_3T_3 treatment showed a significant increase in the percentage of protein in the heads with the standard solution, which recorded 30.93%, and the lowest percentage of protein in the measurement treatment (O_2T_0) reached 27.62%, as for the alternative solution, the oxygen enrichment treatment and spraying with coconut water 100 ml L^{-1} (O_2T_2) were significantly increased, with the highest rate of 30.87%, compared to the lowest percentage of protein in the measured treatment heads (O_2T_0), which recorded 28.18%, While the treatment of oxygen enrichment and the foliar application of coconut water 100 ml L^{-1} (O_2T_2) showed significant differences in reducing nitrates in plant heads grown with standard solution and recorded 35.25 mg 100 g^{-1} fresh weight. The highest concentration of nitrates in the heads was recorded by the treatments of (O_3T_0) and (O_3T_1), in which the concentration was 62.50 and 61.10 mg 100 g dry weight^{-1}, respectively, as for the plants growing in the alternative solution, the treatment of oxygen enrichment and spraying with moringa 2% (O_2T_3) was significantly increased in reducing nitrates and recorded 35.50 mg 100 g dry weight^{-1}. While the highest concentration of nitrates in the heads of the two treatments (O_3T_0) and (O_3T_4) was 60.00 and 58.60 mg 100 g fresh weight^{-1}, respectively. The interaction had a significant effect on the percentage of carbohydrates in the heads. The treatment of ozone enrichment and the foliar application of moringa 4% (O_3T_4) showed a significant increase in plants grown with the standard solution, reaching 6.95%. The lowest percentage of the measured parameter has recorded by the treatment of (O_2T_0), which amounted to 5.75%. The plants grown in the alternative solution were significantly increased to the treatment of oxygen enrichment and coconut water 100 ml L^{-1} (O_2T_2) with the highest rate of 6.85% compared to the lowest percentage of carbohydrates in the measurement treatment heads (O_2T_0) which recorded 5.85%, while the interaction between the two factors did not have a significant effect on the percentage of dissolved solids in the heads of broccoli plants grown in both solutions. The interaction had a significant effect on the concentration of β-carotene in the main head. The treatment of ozone enrichment and coconut water 100 ml L^{-1} (O_3T_2) showed a significant superiority in the growing plants in both solutions, which amounted to 6.68 and 6.30 mg 100 g fresh weight^{-1}, respectively, in the standard and alternative solution, compared to the lowest concentration of the dye in the heads of measurement plants (O_2T_0), which amounted to 4.86 and 4.93 mg per 100 g fresh weight^{-1}, respectively, in the standard and alternative solutions. Also, the same treatment (O_2T_3) also showed a significant superiority in the concentration of folic acid in the heads of

plants growing in the standard solution, and it recorded 89.71 mg 100 g fresh weight^{-1}, compared to the lowest concentration in heads of measuring plants (O_2T_0), which amounted to 60.90 mg 100 g fresh weight^{-1}, while the interaction between the factors of the study did not affect the concentration of folic acid in the heads of broccoli grown in the alternative solution. Whereas, the treatment of oxygen enrichment and spraying with coconut water 100 ml L^{-1} (O_2T_2) showed a significant superiority in the concentration of Vit.C in the main head in plants grown with the standard solution, as it reached 112.00 mg 100 g fresh weight^{-1}, compared to the lowest concentration of Vit. C in heads of measurement plants (O_2T_0), which reached 84.00 mg 100 g fresh weight^{-1}. As for the plants growing in the alternative solution, the ozone enrichment treatment and spraying with coconut water 100 ml L^{-1} (O_3T_2) with the highest concentration of 119.46 mg 100 g fresh weight^{-1} were significantly increased, compared to the lowest concentration of the vitamin was in the head of the measurement treatment (O_2T_0), in which the concentration was 87.00 mg per 100 g fresh weight^{-1}. The interaction treatments of gas enrichment and foliar application of organic nutrients had no significant effect on the concentration of total carotenoids in the master head of broccoli plants grown in the standard solution. While the treatment of ozone enrichment and foliar application of moringa 2% (O_3T_3) showed a significant superiority in plants grown with the alternative solution, reaching 11.29 mg 100 g fresh weight^{-1}, compared to the lowest concentration, it was in the heads of the measurement treatment (O_2T_0), which recorded 7.215 mg 100 g fresh weight^{-1}. The interaction also had a significant effect on the concentration of I3C and sulforaphane in the main head, and the treatment of ozone enrichment and spraying with moringa 2% (O_3T_3) showed a significant superiority in the growing plants in both solutions, which amounted to 81.81 and 51.66 mg 100g fresh weight^{-1}, respectively, in the standard solution, and 87.87 and 43.95 mg kg dry weight^{-1}, respectively, in the alternate solution, compared to the lowest content of the compound was in the heads of the control treatment (O_2T_0), which recorded 53.11 and 9.00 mg kg dry weight^{-1}, respectively, in the standard solution, and 56.18 and 10.16 mg 100g fresh weight^{-1}, respectively, in the alternate solution.

Table 4. Effect of gas enrichment and spraying with organic nutrients on yield quality indicators of broccoli plants growing in two types of nutrient solutions for the fall season 2019-2020

Treatments	Protein %	Nitrates mg 100gm dry weight^{-1}	Carbohydrates %	T.S.S. %	*B*-Carotene mg.100g^{-1} fresh weight	V.B_9 µg 100g^{-1} fresh weight	V.C mg.100g^{-1} fresh weight	total carotenoids mg.100g^{-1} fresh weight	I3C mg kg dry weight^{-1}	Sulforaphane mg kg dry weight^{-1}
Standard nutrient solution (Cooper solution 79)										
O_2	29.21	39.29	6.18	8.36	5.61	80.80	98.63	9.62	54.39	23.36
O_3	29.93	56.57	6.69	8.58	5.66	79.68	99.67	9.94	68.59	33.43
L.S.D $_{0.05}$	0.32	1.37	0.09	N.S	N.S	N.S	N.S	0.14	3.66	1.57
T_0	28.28	54.15	6.10	7.83	4.90	66.62	86.80	8.71	56.52	13.02
T_1	29.09	49.80	6.42	5.58	5.53	77.47	100.58	9.33	58.37	19.12
T_2	30.68	42.62	6.67	9.10	6.60	82.98	110.80	9.91	66.86	42.14
T_3	30.06	46.33	6.52	8.62	5.75	87.08	103.59	10.28	68.76	41.93
T_4	29.75	46.75	6.45	8.24	5.40	87.06	94.00	10.66	56.95	25.78
L.S.D $_{0.05}$	0.34	1.96	0.17	0.32	0.25	4.68	2.39	0.28	5.63	4.62
O_2 T_0	27.62	45.80	5.75	7.50	4.86	60.90	84.00	8.53	53.11	9.00
O_2 T_1	28.93	38.50	6.30	8.66	5.73	82.12	98.50	9.16	54.01	14.84
O_2 T_2	30.81	35.25	6.55	9.00	6.53	82.34	112.00	9.87	55.22	37.72
O_2 T_3	29.18	38.90	6.35	8.50	5.37	89.71	102.66	9.86	55.71	32.20
O_2 T_4	29.50	38.00	5.95	8.16	5.58	88.93	96.00	10.69	53.94	23.07
O_3 T_0	28.93	62.50	6.45	8.16	4.95	72.34	89.60	8.90	59.93	17.04
O_3 T_1	29.25	61.10	6.55	8.50	5.32	72.82	102.66	9.51	62.74	23.41
O_3 T_2	30.56	50.00	6.80	9.20	6.68	83.62	109.60	9.96	78.50	46.57
O_3 T_3	30.93	53.75	6.70	8.75	6.13	84.45	104.53	10.70	81.81	51.66
O_3 T_4	30.00	55.50	6.95	8.33	5.21	85.19	92.00	10.64	59.97	28.50
L.S.D $_{0.05}$	0.50	2.65	0.23	N.S	0.38	7.26	3.78	N.S	7.55	5.93
Alternative nutrient solution (ABEER)										
O_2	29.58	36.89	6.40	8.16	5.09	76.28	98.65	7.68	59.38	23.01
O_3	30.17	56.32	6.27	8.32	5.72	80.45	106.98	9.99	75.28	31.82
L.S.D $_{0.05}$	0.18	1.04	N.S	N.S	0.17	1.78	1.86	0.44	6.64	1.50
T_0	28.71	49.50	6.02	7.53	5.02	66.17	88.30	8.05	57.57	13.20
T_1	29.75	46.10	6.32	8.16	5.02	71.55	99.53	8.67	58.63	22.09
T_2	30.84	43.50	6.58	8.87	5.71	77.60	109.69	8.95	72.57	36.58
T_3	30.49	45.75	6.49	8.91	5.57	94.01	107.29	9.53	76.90	38.74
T_4	29.59	48.17	6.27	7.74	5.66	82.50	109.26	8.97	70.99	26.47
L.S.D $_{0.05}$	0.38	1.21	0.12	0.22	0.24	3.31	3.87	0.48	6.25	4.29
O_2 T_0	28.18	39.00	5.85	7.52	4.93	62.23	87.00	7.21	56.18	10.16
O_2 T_1	29.00	36.20	6.35	7.83	4.94	70.48	96.66	7.33	57.18	14.85
O_2 T_2	30.87	36.00	6.85	9.00	5.11	76.23	99.93	8.16	58.54	35.76
O_2 T_3	30.31	35.50	6.71	8.83	5.13	89.73	103.66	7.77	65.94	33.54
O_2 T_4	29.56	37.75	6.25	7.66	5.33	82.74	106.00	7.93	59.07	20.74
O_3 T_0	29.25	60.00	6.19	7.55	5.12	70.12	89.60	8.88	58.96	16.25
O_3 T_1	30.50	56.00	6.30	8.50	5.16	72.63	102.40	10.01	60.08	29.33
O_3 T_2	30.81	51.00	6.31	8.75	6.30	78.97	119.46	9.75	86.60	37.40
O_3 T_3	30.68	56.00	6.28	9.00	6.01	98.30	110.93	11.29	87.87	43.95
O_3 T_4	29.62	58.60	6.29	7.83	5.99	82.26	112.53	10.02	82.91	32.20
L.S.D $_{0.05}$	0.49	1.70	0.23	N.S	0.33	N.S	5.05	0.68	9.28	5.52

The increase of most of the quality parameters in the main discs when enriched with gas in both solutions may be attributed to the role of this treatment in the positive effect on plant growth, which increased the efficiency of the photosynthesis process. In addition to increasing the nutrients availability in the solutions, which is reflected on the increase in its concentration in the plant, which in turn enters directly and indirectly in the manufacture of chlorophyll and the activation of a number of carbon metabolism enzymes that contribute to increasing the outputs by the availability of energy compounds necessary for vital activities and supplied continuously through gas enrichment in the technique

Hydroponics. The foliar application of organic nutrients has increased the quality parameters in the heads, and the reason for this may be due to the role of these nutrients and the macro and micro nutrients they contain, which increased their availability and absorption by applying foliar application and their impact on the plant content of those nutrients, which reflected positively on improving the characteristics of vegetative and root growth and increasing biological processes, including photosynthesis and the production of complex compounds, including carbohydrates, amino acids and organic acids, and their transport to the head of broccoli(**4** and **21**) . The positive effect of the interaction of factors may be due to the plant's exposure of the surrounding environmental conditions, the nutrients increase, and the nutrients foliar application, and their employment in the growth of healthy plant, which was reflected in the productions of the photosynthesis process, which contributes increase the transfer of manufactured compounds (24) It is concluded from this study that the treatment of ozone enrichment and the foliar application of organic nutrients in the standard solution experiment and the treatment of oxygen enrichment and the foliar application of organic nutrients in the alternative solution experiment had a significant effect on most of the chemical parameters and the qualitative characteristics of broccoli discs grown hydroponically using NFT technology, as well as improving its content of medically active compounds.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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The authors declare that they have not received a fund.

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