EFFECT OF OZONE ENRICHMENT AND SPRAYING WITH ORGANIC NUTRIENT ON NUTRIENT AND WATER USE EFFICIENCY AND FERTILIZER PRODUCTIVITY OF BROCCOLI PLANT CULTIVATED HYDROPONICALLY WITH MODIFIED NFT TECHNOLOGY.

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ABSTRACT

This study was carried out at University of Baghdad - College of Agricultural Engineering Sciences - research station B during the fall season of 2019-2020, in order to evaluate the effect of Ozone enrichment and the foliar application of organic nutrient on nutrient and water use efficiency and fertilizer productivity of broccoli plant using the modified NFT film technology. A factorial experiment (2*5) was carried out within Nested Design with three replicates. The ozone treatment was distributed into the main plots which consisted of oxygen (O_2) and ozone (O_3). The foliar application of organic nutrients were distributed randomly within each replicate including five treatments, which were the control treatment (T0), Coconut water with two concentrations of 50 (T1) and 100 ml. L^{-1} (T2), and Moringa leaves extract at two concentrations 2% (T3) and 4% T4. Results revealed a significant effect of ozone and the foliar application of coconut water 100 ml. L^{-1} at the treatment of O3T2 on the leaves content of N, P, and K, and vegetative dry weight, vegetative to roots dry weight ratio, the recovering efficiency of N, P, k, the use efficiency of N, P, K, and fertilizer productivity, reaching 4.530, 0.674, 3.139%, 178.81 g. Plant^{-1}, 5.74, 8.21, 8.29, 8.68%, 65.17, 36.35, 24.48%, and 3.616 kg yield. Kg fertilizer, respectively, compared to the control treatment (O2T0). The treatment of ozone enrichment and the foliar application of 2% Moringa leaf extract (O3T3) or with coconut water 100 ml. L-1 (O3T2) gave a significant increment in plant yield reached 919.33 and 917.00 g. Plant^{-1} (O2T0) which gave the lowest plant yield reached 624.00 g. Plant^{-1}.

Key words: Moringa, Coconut water, hydroponics, NUE , WUE ,Yield.

تأثير الاغناء بالاوزون والرش بالمغذيات العضوية في كفاءة استعمال المياه والمغذيات وإنتاجية السماد لنبات البروكلي المزروع مائيا بتقنية فلم المحلول المغذي NFT المحور

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المستخلص

أُجري البحث في المحطة البحثية B التابعة الى كلية علوم الهندسة الزراعية – جامعة بغداد في الموسم الخريفي 2019– 2020 بهدف دراسة تاثير الاغناء بالاوزون والرش بالمغذيات العضوية في كفاءة استخدام المياه وانتاجية السماد لنبات البروكلي النامي بتقنية فلم المحلول المغذي NFT المحور، ونفذ كتجربة عاملية (2*5) ضمن تصميم Nested Design بثلاث مكررات وزع عامل نوعية الغاز المُجهز الى المحلول في القطع الرئيسة وشمل على الاغناء بالاوكسجين (O_2) وبالاوزون (O_3) ووزعت مستويات رش المغذيات العضوية ضمن كل مكرر بشكل عشوائي وشملت خمس معاملات هي معاملة القياس (T0) وماء جوز الهند بتركيزين 50 و 100مل.لتر$^{-1}$ (T1 وT2 على الترتيب) ومستخلص اوراق المورنكا بتركيزين 2 و4 % (T3 وT4 على الترتيب)، اظهرت النتائج تفوقا معنويا لمعاملة الاغناء بالاوزون والرش بماء جوز الهند 100مل.لتر$^{-1}$(O3T2) في محتوى الاوراق من N و P وK والوزن الجاف للمجموع الخضري ونسبة الوزن الجاف للمجموع الخضري/ الجذري وكفاءة استرداد النتروجين والفسفور والبوتاسيوم و كفاءة استعمال النتروجين والفسفور والبوتاسيوم وإنتاجية السماد والذي بلغ 4.530 و0.674 و3.139% و178.81 غم.نبات$^{-1}$ و5.74 و8.21 و8.29 و8.68% و65.17 و36.35 و24.48% و3.616 كغم حاصل.كغم سماد مضاف على الترتيب مقارنة بعاملة القياس (O2T0)، كما اعطت معاملة الاغناء بالاوزون والرش بكل من مستخلص اوراق المورنكا 2% (O3T3) أو بماء جوز الهند 100مل.لتر$^{-1}$ (O3T2) زيادة معنوية في حاصل النبات بلغ 919.33 و917.00 غم.نبات$^{-1}$ على الترتيب مقارنة بمعاملة القياس (O2T0) التي بلغ حاصل نباتها 624.00 غم.نبات$^{-1}$.

الكلمات المفتاحية: مورنكا، ماء جوز الهند، الزراعة المائية، الحاصل .
البحث مستل من إطروحة دكتوراه للباحث الاول

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INTRODUCTION

The sustainable human demand of food represents a global challenge, as the estimations revealed that this demand will be increased from 100 to 110% from 2005 to 2050 (38),In addition, the world will demand to increase the grain production by 60% during the period of 2000 to 2050, and because water resources play a vital role in human life and agricultural irrigation, so improving the use efficiency in agriculture is a major strategic choice (27), Improving NUE nutrient use efficiency and improving WUE water use efficiency are among the most important and worrying research issues of today (37) where water use efficiency is an indicator that reflects the ability of plants to invest water resources to produce the total yield per unit area (26) While the efficiency of nutrient use is defined as the yield per unit of fertilizer or is the recovery of fertilizers application (21). These efficiencies differ according to the type of crop, the amount of irrigation water, the environmental conditions and the fertilizer quality. Great effort on technologies that increase the efficiency of water and fertilizer use (14). One of the most important techniques is hydroponics, where crop production has increased dramatically in recent years all around the world because it allows the optimal use of water and fertilizers as well as better control of climate factors and pests, as well as water production increases the quality and productivity of crops and thus increases competitiveness and economic income (19), De la Rosa-Rodríguez et al. (17) observed when producing tomatoes in closed and open hydroponic systems that there were no significant differences between the two treatments in plant yield, while the water use efficiency of the two systems was 59.53 and 46.03 kg. The fertilizer reached 10.31 gm. Kg^{-1} of the yield when planting in a closed system, and the efficiency of water and fertilizer use was higher in the closed system by 22.68 and 22.69%, respectively, and the closed system was recommended as a good alternative for tomato production and preserving the resources involved in the production process (water and fertilizers) while minimizing pollution. Al-Shrouf (10) compared the closed and open systems of nutrients for hydroponics in the percent of both water consumption and composting and the increment in production and water productivity, considering that the closed system of the nutrient solution was the best. Hydroponics systems are affected by a set of factors, including dissolved oxygen (DO), which is one of the most important parameters of concern in any aquaculture system (23) and determines production and affects product quality (25) and under the growing in a closed aqueous system, as in the DFT or NFT technique, the problem of poor ventilation appears, and the reason is that the degree of dissolution of oxygen in the water is very slow and that its increased concentration is very beneficial for the health and growth of plants. Conesa et al. (15) indicated when growing red lettuce as a fresh product hydroponics that the aeration of the solution affected the percent of dry matter and most of the quality parameters measured for yield. Papadopoulos et, al. (33) revealed that the enrichment of the oxygen-nutrient solution when growing tomatoes under hydroponic conditions gave the highest marketable yield and the highest overall yield compared to the control treatment, and one of several methods of increasing the oxygen concentration is ozone enrichment, which is considered more soluble in water up to 13 times compared to oxygen at a temperature of 0-30 ° C, which is very unstable, it quickly turns back into oxygen (18), Nicoletto et al. (30) found that using ozone-treated water when growing dandelion increased antioxidant activity as well as saving up to 95% of the water normally used when planting.The expensive global prices of fertilizers and the skillful work in application and the dangerous pollution of land, water and nature associated with the use of inorganic fertilizers is an urgent need to search for alternative sources for plant nutrition, and many studies have been conducted on the use of organic nutrient as a possible supplement or alternative to chemical fertilizers as better, safer and cheaper. A cost, and among those nutrients is the use of coconut liquid to nourish the growing plant in the fields after it was used in the past by tissue culture technology because it contains many vitamins, minerals, amino acids and amides as well as being an important source of

cytokinins (34), Attia et al. (12) stated that spraying the black seed plant with coconut milk led to an increase in the dry weight of the leaves, the biological yield of the plant, the roots weight, the ratio of the vegetative dry weight / the roots dry weight, and the Moringa leaves extract is a source of many minerals necessary for growth and development and for vitamins and essential amino acids, including those containing sulfur as well as proteins (2), Mohammed et al. (29) revealed that spraying the onion plant with 2% Moringa leaf extract had a significant effect on the growth and yield of the plant, as Culver et al. (16) noted that the foliar application of Moringa extract has significantly increased the dry matter production for vegetative and root growth. The yield has increased by increasing the number of spraying times (every two weeks until maturity). Nutritionists describe some fruits and vegetables as miraculous because their continued consumption helps to reduce weight and gives those who eat them a feeling of satiety thanks to the fibers they contain and among the most important vegetables is broccoli, which is considered as one of the most promising plants and a source of valuable nutrients (20). Therefore, the aim of the research was to study the possibility of increasing the solubility of oxygen in the nutrient solution by enriching with ozone and spraying with natural nutrients in improving the efficiency of water use, nutrients and fertilizer productivity of hydroponically grown broccoli with NFT modified technology.

MATERIALS AND METHODS

This experiment was carried out at the University of Baghdad - College of Agricultural Engineering Sciences - Research Station B during the autumn season 2019-2020 inside a greenhouse partially covered by saran with a dimension of 9 * 45 m. Two hydroponic systems were installed including a 1000 liter tank underground containing a standard nutrient solution Copper (1979) (8) and a water pump to raise the solution into three 18 m long and 6-inch plastic tubes fixed on iron stands and perforated with 7 cm holes suitable for a planting pots and ending with 4-inch tube to collect the flowed solution back to the tank in a closed loop. Also the drainage system holes were installed by a distance of 1/3 in diameter of the planting tube, in order to keep the nutrient solution in the culture tubes as a precaution for electrical power cut off. Each tank was equipped with an air pump to ventilate the nutrient solution around the clock; also, the deionizing device was installed at the main water source to provide deionized water Reverse Osmosis (RO), that applied in preparing the solution confirmed in the experiment (Table 1**)** after moving over a water meter to continuously calculate the amount of water gathered into the tanks.

Table 1. Salts used in preparation of standard nutrient solution and elements concentration in it (Cooper,1979)

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

The hybrid broccoli seeds Jassmina F1 were used which is produced by DELTA SEEDS (D/S) in the experiment and after growing to an appropriate size, the seedlings were

transferred into the hydroponic system on 9/16/2019 after being planted in plastic cups for hydroponics filled with perlite at a planting distances of 30 cm between plants, and 60 cm between tubes, 10 plants per experimental unit, then the nutrients pumping process was started on 26/9/2019. A factorial experiment (2*5) was carried out according to Nested Design with three replications. Ozone treatment was in main plots which consisted of oxygen enrichment (O_2) and Ozone enrichment (O_3) by an ozone generating device at a concentration of 3 gm as an additional source of oxygen which works to pump the oxygen to the tank at a rate of four times per half an hour during the 12 hours of the day during the growth season. The foliar application of plant extracts were distributed randomly within the replicates and included five treatments, which were the control treatment (T0), the foliar application of coconut water at a concentration of 50 ml. L^{-1} (12) (T1) , the foliar application of coconut water at a concentration of 100 ml. L^{-1} (T2), the foliar application of Moringa leaves extract in a concentration of 2% (3) (T3) and the foliar application of Moringa leaves extract in a concentration of 4% (T4). The foliar applications were applied after 2 weeks of cultivation and one month between each application, The nutrient solution was changed five times during the season and the amount of water used with applications was calculated along the growing season. five plants were selected randomly from each experimental unit and the following characters were measured:

1. Leaves content of nutrients: The leaves content of nitrogen was determined using the Kjeldahl Micro (24) device and the leaves content of phosphorous were determined using the ammonium molybdate and ascorbic acid using a spectrophotometer at a wavelength of 620 nm and the leaves content of potassium using the Atomic Absorption device. (9).
2. Growth and yield parameters: The shoots dry weight (gm.$Plant^{-1}$), the ratio of the shoots to roots dry weight, and the plant yield (gm. $Plant^{-1}$)
3. Water Use Efficiency or Water Productivity (kg M^{-3}): calculated according to Ali (5) and according to the following equation :

Water productivity (kg. m^{-3}) = production volume (kg) / applied water volume (m^3)

4. Fertilizer Use Efficiency or Fertilizer recovery efficiency (%) was calculated according to the following equation (5):

Fertilizer application efficiency (%) = [(absorption of fertilized treatment - absorption of control treatment) / amount of fertilizer applied] X 100.

5. Efficiency of nutrient utilization (%): calculated according to the following equation (7):

Fertilized element use efficiency (%) = [(the amount of the absorbed element in the fertilized treatment - Quantity of absorbed element in the control treatment) / Quantity of applied element] X 100.

6. Fertilizer Productivity (kg yield. Kg $fertilizer^{-1}$) was calculated according to the following equation Ali (5):

Fertilizer productivity (kg yield; kg $fertilizer^{-1}$) = [yield of fertilized treatment (kg) – yield of non-fertilized treatment (kg)] / amount of applied fertilizer (kg).

RESULTS AND DISCUSSIONS

1- Chemical indicators, plant growth and yield

The results in Table 2 revealed that the significant effect under the ozone enrichment (O3) in leaves content of N, P and K, shoots dry weight, the shoots dry weight / root system ratio, plant yield and water use efficiency, which reached 4.348, 0.555 and 3.051%, 159.41 gm. $Plant^{-1}$, 5.40, and 867.83 gm. $Plant^{-1}$ and 22.63 kg. M^{-3}, respectively, compared to the oxygen-enriched plants, which recorded 3.756, 0.523, 3.045% and 150.75 gm 5.14 and 783.50 gm $plant^{-1}$ and 20.43 kg. m^{-3}, respectively. The foliar application of plant extracts has significantly affected the studied parameters; the application of coconut water at 100 ml. l^{-1} (T2) had a significant increment in the leaves content of N, P, the dry weight of the vegetative growth, the shoots dry weight / roots dry weight ratio, the plant yield and the water use efficiency which reached 4.230, 0.638%, and 169.73 gm. $Plant^{-1}$, 5.45 and 875.75 gm. $Plant^{-1}$ and 22.84 kg M^{-3} respectively. The foliar application Moringa leaf extract 2% (T3) has a significant increment in leavs content of K, reached 3.126 % compared to the control treatment (T0),

which recorded 3.815, 0.454, 2.953%, 117.53 gm. Plant^{-1}, 4.60 and 675.16 gm. Plant^{-1} and 17.60 kg m^{-3}, respectively. The interaction between the two factors of Ozone and oxygen enrichment and spraying with plant extracts had a significant effect on these parameters, as the treatment of enrichment with ozone and spraying with coconut water 100 ml. L^{-1} (O3T2) showed significant effect on the leaves content of N, P and K, the shoots dry weight and the dry weight of shoots / roots ratio, which were 4.530, 0.674, 3.139%, 178.81 gm. plant^{-1} and 5.74, respectively, compared to the control treatment (O2T0), which recorded 3.500, 0.446, 2.949% and 107.30 gm and 4.29, respectively. The treatment of ozone enrichment and the foliar application of 2% Moringa leaf extract (O3T3) gave a significant increase in the plant yield, which reached 919.33 gm. Plant^{-1}, which was not significantly differed from the ozone enrichment and spraying with coconut water 100 ml. L^{-1} (O3T2), which reached 917.00 gm. Plant^{-1} compared to (O2T0) plants which were recorded 624.00 gm. Plant^{-1}, while the interaction between the study factors had no significant effect on water use efficiency.

Table 2. Effect of ozone enrichment and organic nutrients spray and their interaction on leaves minerals content, growth, yield and water use efficiency of broccoli plants cultivated hydroponically for autumn season 2019-2020.

Treatment	%			g.plant^{-1}	/	g.plant^{-1}	Kg.m^3
	N	P	K	Dry weight of the plant	Shoots: Roots dry weight	Yield of plant	Water Use Efficiency
O_2	3.756	0.523	3.045	150.75	5.14	783.50	20.43
O_3	4.348	0.555	3.051	159.41	5.40	867.83	22.63
L.S.D.$_{0.05}$	0.034	0.011	0.001	4.00	0.07	4.73	0.86
T_0	3.815	0.454	2.953	117.53	4.60	675.16	17.60
T_1	4.065	0.509	2.987	161.99	5.44	851.83	22.21
T_2	4.230	0.638	3.124	169.73	5.45	875.75	22.84
T_3	4.195	0.606	3.126	163.50	5.44	874.91	22.82
T_4	3.955	0.489	3.051	162.66	5.43	850.66	22.18
L.S.D.$_{0.05}$	0.036	0.023	0.003	3.98	0.10	7.02	1.21
O_2 T_0	3.500	0.446	2.949	107.30	4.29	624.00	16.27
O_2 T_1	3.750	0.512	2.974	160.98	5.31	814.50	21.24
O_2 T_2	3.930	0.603	3.110	160.66	5.16	834.50	21.76
O_2 T_3	3.890	0.550	3.114	156.05	5.26	830.50	21.66
O_2 T_4	3.710	0.504	3.081	168.77	5.71	814.00	21.23
O_3 T_0	4.130	0.462	2.958	127.76	4.91	726.33	18.94
O_3 T_1	4.380	0.506	3.000	163.00	5.57	889.16	23.19
O_3 T_2	4.530	0.674	3.139	178.81	5.74	917.00	23.92
O_3 T_3	4.500	0.663	3.138	170.95	5.63	919.33	23.98
O_3 T_4	4.200	0.474	3.022	156.56	5.15	887.33	23.14
L.S.D.$_{0.05}$	0.051	0.030	0.005	5.81	0.14	9.45	N.S

The reason for the highest content of nitrogen and phosphorous in the leaves (Table 2) as a result of ozone enrichment may be attributed to the content of this solution of nitrate NO_3^- as a source of nitrogen and upon absorption, the roots will release bicarbonate ions HCO_3^- and hydroxyl OH^- to the nutrient solution, which gradually raises the pH of the solution, which will be reflected negatively on the absorption of negative ions, including NO_3^- and HPO_4^{-2}, compared to positive ions, including K^+ (5). Since the ozone generator is supplied through the air instead of oxygen, thus some nitrogenous or nitric acids HNO_3 can be produced from nitrogen oxides, which may greatly affect the acidity of the solution and is considered a means of continuously correcting and controlling it, which increases the readiness of nutrients and throughout the season Growth It is a method similar to the natural nitrogen fixation by lightning and nitric acid formation (35). Also, these acids may interact with calcium in the standard solution and form calcium nitrate $Ca(NO_3)_2$, which is a salt dissolved in water that the plant can use as a source of nitrogen and calcium (6), this was in agreement with what was stated by Nicoletto et, al. (30) that the use of this type of ozone generator has a role in the production of nitrogenous acids that have a great impact on the pH of water, or perhaps the reason is due to the fact that ozone is very unstable and its

decomposition rate is very fast (39). In this way, plants in hydroponics are equipped with additional quantities of oxygen, which provides an increase in the energy required for absorption. The root system, which is in direct contact with these nutrients in the NFT system, absorbs the elements necessary for growth, including N, P and K (32). The increment in the dry weight of the plant under the ozone enrichment may be due to its role in providing growth-promoting factors such as good ventilation, moderate heat and energy that may improve the vegetative characteristics and increase the photosynthesis and accumulated manufactured nutrients, and then increase the dry weight of the shoots (13) As well as the distribution of the manufactured compounds between the vegetative and root growth, as the roots contributes to obtain greater nutrient accumulation, while the vegetative growth accumulate a greater amount of light energy, which results in an increase in the dry weight of the vegetative and root growth and affects the ratio between them according to internal and external factors, including nutrition and surrounding environmental conditions (1) and its reflection on the plant yield, which is the final outcome of all physiological activities that occurred during its growth. The increment in the percent of nutrients in broccoli leaves under the foliar application with organic nutrient may be due to the fact that they are a rich source of mineral nutrients available for the plant and with amino acids, which are one of the most important sources of nitrogen, as well as their content of organic acids that encourage growth because they are carbon compounds that work on tissue building (36) so that the dry weight of the plant increases and reflects positively on the ratio between the vegetative and root growth, and its nutrient content may achieve nutritional balance that prevents the occurrence of a physiological or biological imbalance in the plant life cycle, which increases the efficiency of agricultural production by applying nutrients in various sources create a state of balance between the size of their vegetative growth and the resulting dry matter and what is required during the growth phase and its reflection on the plant yield. This result is in consistent with what Mohammed et, all (29) have reached on the onion plant. The significant results of ozone enrichment treatment in the standard solution and the foliar application of organic nutrient of broccoli plants in increasing the efficiency of water use may be due to the treated plants content of P (Table 2), where the water absorption by cells and tissues is related to the active absorption of potassium. Potassium is one of the important osmotic substances that participate on the plant's water retention and high efficiency of water use by the plant (31). In addition to the important and well-known role in plant physiological and biochemical activities, especially in organizing the process of opening and closing stomata and water absorption, which is positively reflected on the efficiency of water use (22) and this is in agreement with Martineau et, al. (28) whom mentioned that the efficiency of water use tends to increase with the potassium supplementation increment, it also was in agreement with Amanullah and Stewart (11), that the increase in water use efficiency is due to the increase in the efficiency of the carbon assimilation process and the higher productivity of dry matter (Table 2) at a faster rate than the loss of water by plants.

2- Efficiency and productivity of Fertilizer.

The results in Table 3 revealed that the highest increment in nitrogen, phosphorous and potassium recovering efficiency, calculated according to the amount of fertilizer applied as a source of these nutrients in the standard solution, under the treatment of Ozone enrichment and the foliar application of coconut water extract 100 ml^{-1} (O3 T2), which reached 8.21 and 8. 29 and 8.68%, respectively. The highest increment in the use efficiency of nitrogen, phosphorous, and potassium, were calculated according to the amount of the applied component in the standard solution, under the treatment of ozone enrichment and the foliar application of coconut water extract 100 ml^{-1} (O3 T2), which reached to 65.17, 36.35 and 24.48%, respectively. The highest increment in the fertilizer productivity was 2% (O3 T3) under the application of ozone and the foliar application of Moringa leaves extract, which reached 3,616 kg yield. Kg of applied fertilizer.

Table 3. Effect of ozone enrichment and organic nutrients spray and their interaction on fertilizer recovery, Nutrient Use Efficiency and Fertilizer Productivity of broccoli plants cultivated hydroponically for autumn season 2019-2020.

Treatment	Fertilizer recovery(%)			Nutrient Use Efficiency (%)			Fertilizer Productivity kg yield. kg fertilizer
	N	P	K	N	P	K	
O_2 T_1	4.314	3.946	5.755	34.21	17.30	16.23	2.332
O_2 T_2	4.838	5.589	6.496	38.37	24.50	18.32	2.577
O_2 T_3	4.378	4.334	6.010	34.72	19.00	16.95	2.528
O_2 T_4	4.740	4.243	7.216	37.59	18.60	20.35	2.326
O_3 T_0	2.877	1.277	2.180	22.81	5.60	6.15	1.253
O_3 T_1	6.401	3.955	6.120	50.76	17.33	17.26	3.246
O_3 T_2	8.218	8.294	8.683	65.17	36.35	24.48	3.587
O_3 T_3	7.448	5.685	7.802	59.06	32.76	22.00	3.616
O_3 T_4	5.335	3.012	5.557	42.30	13.20	15.67	3.224
Standard deviation	1.676	1.946	1.826	13.29	9.480	5.147	0.758

The high values under treatment of ozone enrichment and the foliar application of coconut water 100 ml^{-1} in increasing the recovering efficiency and the use efficiency of N, P and K may be due to the environmental and physiological improvement of plants and the provision of energy sources, which increased the absorption of nutrients and by the products of photosynthesis, which was reflected in an increase The dry weight of the plant, as well as the increase in the production that given by the fertilization, which increased the fertilizer productivity. We conclude from this study the possibility of Ozone enrichment in the standard solution as an additional source of oxygen and the foliar application of organic nutrient to improve the efficiency of nutrients recovery and the use efficiency of nutrient and increase the fertilizer productivity of hydroponically grown broccoli with NFT modified technology.

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