EFFECT OF TOCOPHEROL, TREHALOSE AND SOIL IMPROVEMENT IN WATER PRODUCTIVITY AND INDUSTRIAL POTATOES UNDER WATER STRESS

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ABSTRACT

This study was aimed to investigate the impact of tocopherol, trehalose and soil improvement in water productivity and industrial potatoes (*Solanum tuberosum* L.), Austin hybrid. The field experiments were carried out during the fall season 2020-2021 and spring season 2021. The experiments were carried out as a factorial experiment within a split plot design. The irrigation interval factor was set every 4, 8 and 12 days for the fall season 2020-2021 and every 4, 7 and 10 days for the spring season 2021 (symbolized by I_0, I_1 and I_2) in the main plot, and the interaction factor between Eco Gel soil improvement and anti-stress spray in the Sub plot with three replications. a Eco Gel was added to the soil at the level of 50 kg ha^{-1} symbolized by E_1 and added to the level of 100 kg ha^{-1} symbolized by E_2 as well as the treatment without adding that Its symbol is E_0, and spraying with anti-stress, spraying tocopherol at a concentration of 30 mg L^{-1}, symbolized by T_1, and spraying trehalose with a concentration of 30 mmol L^{-1} and symbolized by T_2, in addition to spraying with ordinary water, symbolized by T_0, the results showed a significant superiority for the treatment of the triple interaction $I_1E_2T_2$ in the leaf area, the total chlorophyll concentration, the dry weight of the vegetative and the number of marketable tubers The marketable plant yield, the total marketable yield, the relative water content of leaf, the leaf water potential, and the water productivity for the two seasons respectively,compared to treatment $I_2E_0T_0$.

Keywords: vitamin E, sugars, *Solanum tuberosum* L., Eco Gel, polymers

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تأثير التوكوفيرول والتريهالوز ومحسن التربة في انتاجية المياه والبطاطا الصناعية تحت الاجهاد المائي

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المستخلص

دراسة تأثير التوكوفيرول والتريهالوز ومُحسن التربة في انتاجية المياه والبطاطا الصناعية تحت الاجهاد المائي بزراعة الهجين اوستن (Austin)، نُفذت تجربة حقلية خلال الموسم الخريفي 2020-2021 والربيعي2021. نُفذت كتجربة عاملية بحسب تصميم الالواح المنشقة حيث وضع عامل فاصلة الري كل 4 و 8 و 12 يوماً للموسم الخريفي 2020-2021 وكل 4 و 7 و 10 ايام للموسم الربيعي 2021 (الذي يرمز له I_0 و I_1 و I_2) في الالواح الرئيسة، وعامل التداخل بين مُحسن التربة Eco Gel والرش بمضادات الاجهاد في الالواح الثانوية بثلاثة مكررات، اذ اضيف Eco Gel الى التربة بمستوى 50 كغم هـ$^{-1}$ رمز له E_1 واضافته بمستوى 100 كغم هـ$^{-1}$ رمز له E_2 فضلاً عن المعاملة من دون اضافة التي رمز لها E_0، والرش بمضادات الاجهاد برش التوكوفيرول بتركيز 30 ملغم لتر$^{-1}$ رمز له T_1 ورش التريهالوز بتركيز 30 ملي مول$^{-1}$ ورمز له T_2، فضلاً عن الرش بالماء العادي الذي رمز له T_0، اظهرت النتائج تفوقاً معنوياً لمعاملة التداخل الثلاثي $I_1 E_2 T_2$ في المساحة الورقية وتركيز الكلوروفيل الكلي والوزن الجاف للمجوع الخضري وعدد الدرنات القابلة للتسويق وحاصل النبات القابل للتسويق والانتاج الكلي القابل للتسويق وفي قيم المحتوى المائي النسبي للاوراق والجهد المائي للورقة وانتاجية المياه للموسمين على التتابع قياساً في المعاملة $I_2 E_0 T_0$.

الكلمات المفتاحية: فيتامين E، سكريات، *Solanum tuberosum* L.، الهلام البيئي، بوليمرات

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INTRODUCTION

Potato *Solanum tuberosum* L. is one of the important vegetable crops. It is a daily consumed vegetable due to it is a balanced food that contains high energy, high quality protein, and essential vitamins and minerals (28). As a result; this strategic crop becomes a fertile ground for scientific research (10, 11, 12, 26, 32, 35) potatoes are medium to sensitive plants to water deficiency. The amount of water affects potato growth and production when exposed to water stress (13), which is the most important among the environmental stresses for agriculture all over the world (17), Therefore, potato cultivation needs appropriate water resources, as irrigation scheduling could be provide optimal management of plant growth, production, and has led irrigation scheduling for the best yield and quality of potato tubers (5,21), One of the modern technologies that reduce the impact of water stress on the soil is the addition of soil improvement to ameliorate it to conserve water for the longest possible period, as the addition of swollen gelatinous formulations in the potato root area improve water supply and productivity Potato, all the experimental results confirmed the high efficiency of the artificial gel structures that accumulate water and protect the plants from water stress, which led to increasing the potato yield and full retention of agricultural chemicals in the rhizosphere (33), the benefits of adding eco gel to the soil reduce water consumption, reduce the number of watering times, loss of water and nutrients in the soil, increase production and improve its quality, and reduce soil salinity The effect of water stress on the plant could be reduced by adding certain compounds represented by tocopherol (vitamin E), which is one of the basic antioxidants, and has importance in resisting plants subject to stress (18). Spraying trehalose on plants improves resistance to stresses and regulates the work of stomata. The efficiency of water use and its role in stress tolerance by protecting membranes and proteins from degradation (19), and spraying trehalose at a concentration of 75 mmol^{l-} achieved a significant increases in free radical scavenging activity (antioxidant activity), and an increases in carotenoids for carrot plant (7), and the researchers (6, 9) revealed that spraying trehalose at a concentration (75 mmol L^{-1}) led to an increase in yield and an increase in yield components. Even so flowering traits in carrots (8)., potato tubers are used for a variety of purposes, including industrial uses (16), The interest of agricultural companies importing potatoes in Iraq has increased recently to the adoption of industrial hybrids and for multiple purposes such as chips, French fries and starch, and based on the foregoing. This study was aimed at the possibility of improving the growth of industrial potato production and water productivity by adding moisture retention enhancers into the soil and spraying with (tocopherol and trehalose) treatments under water stress circumstances.

MATERIALS AND METHODS

The field experiments were conducted during the fall, 2020-2021 and spring 2021 seasons at the area located at 44.23° longitude and 33.32° latitude, using Austin industrial hybrid. The tubers of the industrial Austin potato hybrid, approved in Iraq by Ataa Al-Khaleej Company, were planted (23/9/2020) during fall season and (28/1/2021) for the spring season. Class A potato tubers were used for fall planting 2020 and Elite for spring planting 2021, The experimental unit consisted of 20 plants, the distance between one plant and another was 25 cm, and 10 plants were planted on each side. The plant management of hoeing, weeding and exporting was carried out as needed. The experiment were carried out as a factorial within a split plot design, where the irrigation interval factor was set every 4, 8 and 12 days for the fall season 2020-2021 and every 4, 7 and 10 days for the spring season 2021 (symbolized by I_0, I_1 and I_2) in the main plot, and the interaction factor between Eco Gel soil improvement and anti-stress spray in the Sub plot with three replications, as Eco Gel was added to the soil at the level of 50 kg ha^{-1} symbolized by E_1 and added to the level of 100 kg ha^{-1} symbolized by E_2 as well as the treatment without adding that its symbol is E_0, and spraying with anti-stress represents spraying tocopherol with a concentration of 30 mg L^{-1} symbolized by T_1 and spraying trehalose with a concentration of 30 mmol L^{-1} and symbolizing T_2, as well as spraying with ordinary water symbolized by T_0, and the treatments were distributed randomly within each repeater to be The number of treatments 27 treatments resulted from the interaction of the experimental factors (3 x 9) and with three replications, so that the number of experimental units was 81 units (3 x 9 x 3). The plants were sprayed three times, the period between one spray and another is 14 days. The tubers were harvested on 2/1/2021 for the fall season and on 17/5/2021 for the spring season. The water consumption of the potato crop was calculated based on the irrigation intervals for each agricultural season. The moisture content of the soil was estimated at each irrigation interval and completed to the limits of the field capacity. The irrigation time was calculated to add the depth of water to be added as indicated by (25). The vegetative growth indicators represented by [leaf area (dcm^2 plant^{-1}) (30) and the total chlorophyll concentration in leaf (mg 100 g fresh weight^{-1}) (24) and the dry weight of the vegetative growth (g plant^{-1}) were studied, and indicators of yield and its components [number of marketable tubers (tuber plant^{-1}), marketable tuber weight (g tuber^{-1}), marketable yield of plant (kg plant^{-1}) and total marketable yield (ton ha^{-1})] and indicators of plant tolerance for stress [relative water content (%) (2) and leaf water potential (34) and water productivity (kg m^{-3})].

RESULTS AND DISCUSSION

vegetative growth indicators: It is evident from the results of Table 1A show a significant effect of the triple interaction treatments between trehalose, soil improvement, irrigation interval on leaf area, total chlorophyll concentration and dry weight of the vegetative of industrial potatoes for the fall seasons 2020-2021 and spring 2021, as the treatment $I_1E_2T_2$ outperformed (under water stress conditions for intervals Irrigation I_1) in leaf area (347.73 and 229.18 dcm^2 plant^{-1}), total chlorophyll concentration (401.67 and 419.67 mg 100 g fresh weight^{-1}) and vegetative growth dry weight (45.42 and 56.51 g plant^{-1}) for the fall seasons 2020-2021 and spring 2021 respectively, compared to the lowest value when treatment $I_2E_0T_0$ for leaf area (151.19 and 140.59 dcm^2 plant^{-1}), total chlorophyll concentration (310.33 and 314.00 mg 100 g fresh weight^{-1}) and vegetative growth dry weight (29.06 and 35.59 g plant^{-1}) for the two seasons, relay. The treatment $I_0E_2T_2$ (under natural irrigation conditions for irrigation interval I_0) gave the highest value of leaf area (436.30 and 270.02 dcm^2 plant^{-1}), total chlorophyll concentration (432.00 and 459.00 mg 100 g fresh weight^{-1}) and dry weight of the vegetative growth (48.12 and 59.19 g Plant^{-1}) for the fall and spring seasons, respectively. The results of Table 1B indicate that there are significant differences for the two interactions of the study factors in the vegetative growth indicators, as the treatment of the interaction I_1E_2 (under water stress conditions for the irrigation interval I_1) excelled in the leaf area (320.72 and 211.63 dcm^2 plant^{-1}) and the total chlorophyll concentration (382.67 and 397.00 mg 100 g fresh weight^{-1}) for the fall and spring seasons, respectively, compared to the lowest value at treatment I_2E_0 for leaf area (205.21 and 159.61 dcm^2 plant^{-1}) and the total chlorophyll concentration (327.33 and 335.78 mg 100 g fresh weight^{-1}) for both seasons on relay. Interaction treatment I_0E_2 (under natural irrigation conditions for irrigation interval I_0) gave the highest leaf area (359.20 and 226.34 dcm^2 plant^{-1}) and the highest total chlorophyll concentration (408.00 and 421.89 mg 100 g fresh weight^{-1}) for the fall and spring seasons, respectively, and the treatment outperformed I_1E_2 (under water stress conditions for irrigation interval I_1) in the dry weight of the vegetative growth (51.98 g plant^{-1}) compared to the treatment I_2E_0, the lowest in the dry weight of the vegetative growth (42.26 g plant^{-1}) for the spring season, while the highest values were found at I_0 treatment E_2 (under natural irrigation conditions for irrigation interval I_0) on the dry weight of the vegetative growth (54.93 g plant^{-1}), and there was no significant effect of irrigation and ground application factors on the dry weight of the vegetative growth of the fall season. The results showed that treatment I_1T_2 (under water stress conditions for irrigation interval I_1) was significant in leaf area (312.85 and 212.73 dcm^2 plant^{-1}), total chlorophyll (384.78 and 395.89 mg 100 g fresh weight^{-1}) and dry weight of the vegetative growth (43.27 and 53.87 g plant^{-1}) for the fall and spring seasons, respectively, when compared with treatment

I_1T_0 (fall season) and treatment I_2T_0 (spring season), which gave the least leaf area (211.63 and 157.31 dcm^2 $plant^{-1}$) respectively, and treatment I_2T_0 continued to give the lowest values In the concentration of total chlorophyll (327.00 and 334.11 mg 100 g fresh $weight^{-1}$) and the dry weight of the vegetative growth (32.54 and 39.59 g $plant^{-1}$) for the two seasons respectively, and treatment I_0T_2 (under normal irrigation conditions for irrigation interval I_0) gave the highest values in the leaf area (356.55 and 229.86 dcm^2 $plant^{-1}$), total chlorophyll concentration (408.56 and 420.78 mg 100 g fresh $weight^{-1}$) and vegetative growth dry weight (44.82 and 55.93 g $plant^{-1}$) for the fall and spring seasons, respectively. The results showed that E_2T_2 treatment was significantly superior in leaf area (371.61 and 238.29 dcm^2 $plant^{-1}$), total chlorophyll (405.33 and 429.44 mg 100 g fresh $weight^{-1}$) and vegetative growth dry weight (45.82 and 56.36 g $plant^{-1}$) for the two seasons respectively compared to the treatment E_0T_0 which gave the least leaf area (168.19 and 144.68 dcm^2 $plant^{-1}$), total chlorophyll (324.22 and 337.11 mg 100 g fresh $weight^{-1}$) and the dry weight of vegetative growth (31.77 and 38.08 g $plant^{-1}$) for the two seasons respectively. The results in Table 1C for the single study factors show a significant difference by the superiority of treatment I_1 (under water stress conditions) in leaf area (270.23 and 192.20 dcm^2 $plant^{-1}$), total chlorophyll concentration (366.19 and 378.63 mg 100 g fresh $weight^{-1}$) and dry weight The vegetative growth (40.50 and 49.24 g $plant^{-1}$) for the two seasons, respectively, as measured by the lowest value of I_2 in leaf area (261.34 and 182.91 dcm^2 $plant^{-1}$), total chlorophyll (347.85 and 360.48 mg 100 g fresh $weight^{-1}$) and the dry weight of the vegetative growth (38.09 and 46.27 g $plant^{-1}$) for both seasons respectively, and treatment I_0 (under natural irrigation conditions) was superior by giving it the highest leaf area (303.54 and 201.42 dcm^2 $plant^{-1}$) and total chlorophyll (387.93 and 397.67 mg 100 g fresh $weight^{-1}$) and dry weight For the vegetative growth (42.49 and 51.62 g $plant^{-1}$) for the two seasons respectively, the results showed a significant effect of the E_2 ground treatment by its superiority in leaf area (327.06 and 212.34 dcm^2 $plant^{-1}$) and total chlorophyll (385.52 and 400.78 mg 100 g fresh $weight^{-1}$) and the dry weight of vegetative growth (43.12 and 52.16 g $plant^{-1}$) for the two seasons, successively, compared to the treatment of E_0, which gave the least leaf area (223.38 and 169.09 dcm^2 $plant^{-1}$), total chlorophyll (348.81 and 356.44 mg 100 gm fresh weight-1) and dry weight of the vegetative growth (37.52 and 45.44 g $plant^{-1}$) for the two seasons respectively, and the results showed superiority Significant for T2 treatment in leaf area (323.49 and 215.33 dcm^2 $plant^{-1}$), total chlorophyll (386.11 and 399.67 mg 100 g fresh $weight^{-1}$) and vegetative growth dry weight (43.18 and 53.30 g $plant^{-1}$) for the two seasons respectively compared to the control treatment T_0 which It gave the least leaf area (222.95 and 162.43 dcm^2 $plant^{-1}$), total chlorophyll (341.41 and 351.52 mg 100 g fresh $weight^{-1}$) and the vegetative growth dry weight (35.51 and 41.83 g $plant^{-1}$) for the two seasons respectively. The reason for the significant superiority of the $I_1E_2T_2$ treatment in most of the vegetative growth indicators for both seasons is due to the fact that the addition of hydrogels and spraying with trehalose reduced the effect of water stress doe the hydrogels increases the ability of the soil to retain water and regulate its supply to plants, especially when the period is relatively between irrigation and this is positively reflected in plant growth and improving its performance (3), in addition to that spraying with trehalose leads to an improvement in photosynthesis, especially under conditions of water stress, which leads to increasing sugar manufacturing and improving metabolism and then increasing vegetative growth (22, 29). The application of these treatments (adding gels to the soil and spraying with trehalose) with good water management by applying appropriate intervals between irrigation and another leads to optimal efficiency in the use of water, which causes an increase in plant growth and development through important morphological and physiological mechanisms that increase plant tolerance to water stress (20).

Table 1A. The effect of triple interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in the vegetative growth indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	Leaf area (dcm^2 $plant^{-1}$)		total chlorophyll concentration (mg100g freshweight^{-1})		Dry weight vegetative growth (g $plant^{-1}$)	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I x E x T			
I_0 E_0T_0	189.59	150.13	336.00	358.00	34.46	40.08
I_0 E_0T_1	268.52	187.79	383.67	381.33	41.66	50.73
I_0 E_0T_2	272.41	194.88	390.33	389.67	42.10	53.37
I_0 E_1T_0	253.76	167.69	360.67	369.67	40.48	45.17
I_0 E_1T_1	309.00	208.60	393.33	401.00	43.28	55.23
I_0 E_1T_2	360.95	224.69	403.33	413.67	44.26	55.22
I_0 E_2T_0	260.12	176.19	371.67	376.00	40.77	47.21
I_0 E_2T_1	381.17	232.80	420.33	430.67	47.28	58.39
I_0 E_2T_2	436.30	270.02	432.00	459.00	48.12	59.19
I_1 E_0T_0	163.78	143.33	326.33	339.33	31.79	38.57
I_1 E_0T_1	220.25	173.30	351.00	361.67	40.51	48.01
I_1 E_0T_2	280.27	193.60	370.00	370.67	41.45	51.48
I_1 E_1T_0	198.69	167.50	343.00	355.33	36.12	42.41
I_1 E_1T_1	296.41	201.77	374.67	392.33	42.80	53.13
I_1 E_1T_2	310.54	215.40	382.67	397.33	42.94	53.62
I_1 E_2T_0	272.41	185.08	354.00	363.00	38.40	44.30
I_1 E_2T_1	342.01	220.61	392.33	408.33	45.06	55.14
I_1 E_2T_2	347.73	229.18	401.67	419.67	45.42	56.51
I_2 E_0T_0	151.19	140.59	310.33	314.00	29.06	35.59
I_2 E_0T_1	195.06	154.02	321.00	338.33	37.64	44.93
I_2 E_0T_2	269.36	184.21	350.67	355.00	39.03	46.25
I_2 E_1T_0	251.40	163.19	328.00	339.33	32.56	40.92
I_2 E_1T_1	278.23	196.64	361.00	365.00	40.09	49.40
I_2 E_1T_2	303.04	210.35	362.00	382.33	41.36	50.64
I_2 E_2T_0	265.58	168.16	342.67	349.00	36.00	42.25
I_2 E_2T_1	307.40	213.38	372.67	391.67	43.14	53.08
I_2 E_2T_2	330.80	215.65	382.33	409.67	43.92	53.40
$L.S.D._{0.05}$	6.819	4.479	5.182	6.835	0.872	0.710

Table 1B. The effect of binary interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in vegetative growth indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	Leaf area (dcm^2 $plant^{-1}$)		total chlorophyll concentration (mg100g freshweight^{-1})		Dry weight vegetative growth (g $plant^{-1}$)	
Seasons	2021-2020	2021	2021-2020	Seasons	2021-2020	2021
			I x E			
I_0 E_0	243.51	177.60	370.00	376.33	39.40	48.06
I_1 E_0	221.43	170.08	349.11	357.22	37.92	46.02
I_2 E_0	205.21	159.61	327.33	335.78	35.24	42.26
I_0 E_1	307.90	200.33	385.78	394.78	42.67	51.87
I_1 E_1	268.55	194.89	366.78	381.67	40.62	49.72
I_2 E_1	277.55	190.06	350.33	362.22	38.00	46.98
I_0 E_2	359.20	226.34	408.00	421.89	45.39	54.93
I_1 E_2	320.72	211.63	382.67	397.00	42.96	51.98
I_2 E_2	301.26	199.06	365.89	383.44	41.02	49.57
L.S.D.$_{0.05}$	3.937	2.586	2.992	3.946	N.S	0.410
			I x T			
I_0 T_0	234.49	164.67	356.11	367.89	38.57	44.15
I_1 T_0	211.63	165.31	341.11	352.56	35.43	41.76
I_2 T_0	222.72	157.31	327.00	334.11	32.54	39.59
I_0 T_1	319.56	209.73	399.11	404.33	44.07	54.78
I_1 T_1	286.22	198.56	372.67	387.44	42.79	52.09
I_2 T_1	260.23	188.01	351.56	365.00	40.29	49.13
I_0 T_2	356.55	229.86	408.56	420.78	44.82	55.93
I_1 T_2	312.85	212.73	384.78	395.89	43.27	53.87
I_2 T_2	301.07	203.40	365.00	382.33	41.43	50.09
L.S.D.$_{0.05}$	3.937	2.586	2.992	3.946	0.503	0.410
			E x T			
E_0T_0	168.19	144.68	324.22	337.11	31.77	38.08
E_0T_1	227.94	171.70	351.89	360.44	39.94	47.89
E_0T_2	274.02	190.90	370.33	371.78	40.86	50.36
E_1T_0	234.61	166.13	343.89	354.78	36.38	42.83
E_1T_1	294.55	202.34	376.33	386.11	42.05	52.58
E_1T_2	324.84	216.81	382.67	397.78	42.85	53.16
E_2T_0	266.04	176.48	356.11	362.67	38.39	44.58
E_2T_1	343.53	222.26	395.11	410.22	45.16	55.53
E_2T_2	371.61	238.29	405.33	429.44	45.82	56.36
L.S.D.$_{0.05}$	3.937	2.586	2.992	3.946	0.503	0.410

Industrial potato yield indicators

The results in Table 2A show a significant effects of the triple interaction treatments between trehalose, soil improvement and irrigation interval in the indicators of industrial potato yield for the fall seasons 2020-2021 and spring 2021, number of marketable tuber (4.41 and 4.53 tuber $plant^{-1}$), marketable tuber weight (135.80 and 136.51 g $tuber^{-1}$), marketable plant yield (0.599 and 0.618 kg $plant^{-1}$), and total marketable yield (31,984 and 33.004 ton ha^{-1}) for both seasons respectively, as measured by the lowest value in $I_2E_0T_0$ for the number of marketable tubers (3.16 and 3.43 tuber $plant^{-1}$), the marketable plant yield (0.372 and 0.384 kg $plant^{-1}$) and the total marketable yield (19.884 and 20,489 ton ha^{-1}) for the two seasons respectively, and measured by treatment $I_0E_2T_2$ by giving it the lowest value of marketable tuber weight (113.34 g $tuber^{-1}$) in the fall season and when treatment $I_2E_0T_0$ (112.39 g $tuber^{-1}$) in the spring season.

Table 1C. The effect of individual of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in the vegetative growth indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	Leaf area (dcm^2 $plant^{-1}$)		total chlorophyll concentration (mg100g freshweight^{-1})		Dry weight vegetative growth (g $plant^{-1}$)	
Seasons	2021-2020	2021	2021-2020	Seasons	2021-2020	2021
			I			
I_0	303.54	201.42	387.93	397.67	42.49	51.62
I_1	270.23	192.20	366.19	378.63	40.50	49.24
I_2	261.34	182.91	347.85	360.48	38.09	46.27
$L.S.D._{0.05}$	4.237	2.185	3.110	2.691	0.262	0.334
			E			
E_0	223.38	169.09	348.81	356.44	37.52	45.44
E_1	284.67	195.09	367.63	379.56	40.43	49.53
E_2	327.06	212.34	385.52	400.78	43.12	52.16
$L.S.D._{0.05}$	2.273	1.493	1.727	2.278	0.290	0.236
			T			
T_0	222.95	162.43	341.41	351.52	35.51	41.83
T_1	288.67	198.77	374.44	385.59	42.38	52.00
T_2	323.49	215.33	386.11	399.67	43.18	53.30
$L.S.D._{0.05}$	2.273	1.493	1.727	2.278	0.290	0.236

The treatment $I_0E_2T_2$ (under natural irrigation conditions for irrigation interval I_0) was superior in giving it the highest values in the number of marketable tubers (5.52 and 5.59 tuber $plant^{-1}$), the marketable plant yield (0.628 and 0.662 kg $plant^{-1}$) and the total marketable yield (33.530 and 35.346 ton ha^{-1}) and upon treatment $I_0E_2T_1$ in marketable tuber weight (138.93 and 140.93 g $tuber^{-1}$) for the fall 2020-2021 and spring 2021 seasons respectively. The results in Table 2B indicate that there are significant differences for the two interaction treatments of the study factors in the yield indicators, as the interaction treatment I_1E_2 outperformed the marketable plant yield (0.536 and 0.553 kg $plant^{-1}$) and the total marketable yield (28.637 and 29.532 ton ha^{-1}) for the two seasons respectively, the number of marketable tubers (4.26 tuber $plant^{-1}$) for the spring season, compared to treatment I_2E_0, which gave the lowest marketable yield (0.396 and 0.420 kg $plant^{-1}$) and the total marketable yield (21.167 and 22.412 ton ha^{-1}) for the two seasons respectively, and the number of marketable tubers (3.55 tuber $plant^{-1}$) for the spring season, and the interaction treatment between irrigation and ground application did not show a significant effect on the number of marketable tubers in the fall season, while the highest values were found at Treatment I_0E_2 (under natural irrigation conditions for irrigation interval I_0) in the marketable plant yield (0.563 and 0.579 kg $plant^{-1}$) and the total marketable yield (30.057 and 30,880 ton ha^{-1}) for the two seasons respectively, and the number of marketable tubers (4.60 tuber $plant^{-1}$) for the spring season, wa Treatment E_2I_1 (under water stress conditions for irrigation interval I_1) showed a significant superiority in the marketable tuber weight (132.39 g $tuber^{-1}$) compared to treatment I_2E_0 in the lowest value of marketable tuber weight (122.66 g $tuber^{-1}$) for the fall season, while the highest a value was found when treatment E_1I_0 (under natural irrigation conditions for irrigation interval I_0) in the marketable tuber weight (134.91 g $tuber^{-1}$) for the fall season, and treatment I_2E_2 (under water stress conditions for irrigation interval I_2) had the highest value of marketable tuber weight (130.64 g $tuber^{-1}$) compared to the lowest value in treatment I_1E_0 (115.78 g $tuber^{-1}$) for the spring season. The results showed that the treatment I_1T_2 was significant in the number of marketable tubers (4.09 and 4.37 tuber $plant^{-1}$), the marketable plant yield (0.544 and 0.560 kg $plant^{-1}$) and the total marketable yield (29.043 and 29.881 ton ha^{-1}) for the two seasons respectively when compared with treatment I_2T_0 which gave the lowest marketable plant yield (0.396 and 0.414 kg plant^{-1}) and total marketable yield (21.167 and 22.112 ton ha^{-1}) for the two seasons respectively and in treatment I_1T_0 The number of marketable tubers (3.28 tuber plant^{-1}) for the fall season and in the treatment I_2T_0 for the number of marketable tubers (3.53 tuber plant^{-1}) for the spring season, while the highest values were found at the treatment I_0T_2 in the number of Marketable tubers (4.58 and 4.68 tuber plant^{-1}) and marketable plant yield (0.582 and 0.596 kg plant^{-1}) and total marketable yield (31.060 and 31,832 ton ha^{-1}) for the two seasons respectively, and the I_2T_2 treatment (under stress conditions the water of irrigation interval I_2) was significant in the value of the marketable weight of the tuber (133.1 7 g tuber^{-1}) compared to the lowest value of treatment I_2T_0 (120.31 g tuber^{-1}) for the fall season, while treatment I_0T_1 gave the highest marketable weight of tuber (136.07 g tuber^{-1}) for the season, while treatment I_2T_2 (under water stress conditions for irrigation interval I_2) gave the highest tuber weight (131.29 g tuber^{-1}) compared to treatment I_1T_0, which gave the lowest tuber weight (116.41 g tuber^{-1}) for the spring season. The results showed that the treatment E_2T_2 was significantly superior to the highest value of the marketable tubers (4.74 and 4.83 tuber plant^{-1}) and the marketable plant yield (0.603 and 0.625 kg plant^{-1}) and the total marketable yield (32.180 and 33.357 ton ha^{-1}) for both seasons, the sequence as measured by the lowest values in treatment E_0T_0 for the number of marketable tubers (3.19 and 3.48 tuber plant^{-1}), the marketable plant yield (0.382 and 0.397 kg plant^{-1}) and the total marketable yield (20,393 and 21.189 ton ha^{-1}) for the two seasons respectively, The treatment E_2T_1 was significantly superior to the highest marketable tuber weight (136.64 and 136.18 g tuber^{-1}) for the two seasons respectively when compared with the treatment E_0T_0 which gave the lowest marketable tuber weight (120.01 and 114.16 g tuber^{-1}) for the two seasons respectively. The results show in Table 2C that the single study factors had a significant effect when treatment I_1 (under water stress conditions) in marketable plant yield (0.484 and 0.504 kg plant^{-1}) and total marketable yield (25.821 and 26.930 ton ha^{-1}), irrigation interval I_2 gave the lowest marketable yield (0.468 and 0.487 kg plant^{-1}) and the total marketable yield (24.995 and 26,018 ton ha^{-1}) for the two seasons respectively, for marketing (3.98 and 4.17 tuber plant^{-1}) for the two seasons respectively, compared to the treatment of irrigation interval I_2, which gave the lowest number of marketable tubers (3.65 and 3.88 tuber plant^{-1}) for the two seasons respectively, the highest values were found at the treatment interval I_0 (under irrigation conditions natural) in marketable plant yield (0.518 and 0.524 kg plant^{-1}) and total marketable yield (27,644 and 27.982 ton ha^{-1}) for the two seasons respectively, and the results did not show a significant effect of irrigation interval I treatment in marketable tuber weight for both seasons, the results showed a significant effect of ground additive E_2 was superior in the number of marketable tubers (4.15 and 4.33 tuber plant^{-1}), marketable plant yield (0,540 and 0.557 kg plant^{-1}) and total marketable yield (28,850 and 29,734 ton ha^{-1}) for the two seasons respectively compared to the treatment without the addition of E_0, which gave the lowest number of marketable tubers (3.36 and 3.71 tuber plant^{-1}), marketable plant yield (0.420 and 0.438 kg plant^{-1}) and total marketable yield (22.429 and 23,402 ton ha^{-1}) for the two seasons respectively, treatment E_1 excelled in the highest value of marketable tuber weight (131.27 g tuber^{-1}) for the fall season and for the ground addition treatment E_2 (128.38 g tuber^{-1}) for the spring season compared to the treatment without the addition of E_0 (125.01 and 118.31 g tuber^{-1}) for both seasons, The results showed a significant superiority of spraying with trehalose T_2 in the number of marketable tubers (4.19 and 4.38 tuber plant^{-1}), the marketable plant yield (0.548 and 0.565 kg plant^{-1}) and the total marketable yield (29.261 and 30,170 ton ha^{-1}), for the two seasons, respectively, as measured by the T_0 coefficient of the number of marketable tubers (3.29 and 3.59 tuber plant^{-1}), marketable plant yield (0.405 and 0.420 kg plant^{-1}) and total marketable yield (21.619 and 22,444 ton ha^{-1}) for the two seasons respectively, and spraying treatment with tocopherol (vitamin E) T_1 had the highest marketable tuber weight (132.04 g tuber^{-1}) for the fall season and trehalose spray T_2 (128.97

g tuber^{-1}) for the spring season compared to the lowest value for treatment T_0 (123.37 and 117.24 g tuber^{-1}) for the two seasons respectively. The reason for the significant superiority of the $I_1E_2T_2$ treatment in the yield indicators for both seasons is attributed to the role of trehalose sugar and soil improve in reducing the effect of water stress resulting from the relative length of the irrigation interval, as trehalose stabilizes the structure and integrity of membrane proteins and preserves lipids from through the formation of hydrogen bonds for phosphorylated lipids (14), and trehalose contributes to increasing the natural physiological activity by replacing the water molecules that form the hydration layer around biological structures due to the flexibility of the high glycosidic bond that allows it to interact with the irregular polar groups of biomolecules Which increases the photosynthesis process and improves plant growth and its tolerance to abiotic stresses (27), and then contributes to improving the metabolism of the absorbed elements and then participating in the transfer of the products of this process to the places of need (4), as well as trehalose sugar acts on the osmotic regulation in plant cells under water stress conditions and possibly to the physiological activity of trehalose, which was explained by three n theories are replacement theory, water trapping theory and vitrification theory for plant tolerance to water stress and then increasing the accumulation of dry matter in plant tissues and then increasing yield indicators (15 , 27), in addition to the significant role that soil improvers play in regulating spacing irrigation extended as it works to absorb excess water from the plant's need in the root area and retain it to gradually prepare it for the plant, which is positively reflected in the growth of the plant and the continuity of absorption of nutrients by the roots and its reflection on the increase in plant productivity (1). This action of both trehalose and the soil improve made the plants to resist the water stresses resulting from the average irrigation interval (7 or 8 days depending on the growing season) and that the application of irrigation intervals that specify the number of days until irrigation and the amount of water to be added in each irrigation means the optimal management of water use efficiency and from Then improve plant productivity (31). The optimum conditions (appropriate irrigation interval, trehalose spray, and soil improve addition) led to an increase in the absorption of water and nutrients and this was reflected in the improvement of the vegetative growth of the plant (Table 1A, B and C), which led to an increase in the efficiency of the photosynthesis process, the manufacture of nutrients and their accumulation, and then its transfer to the tubers, which caused an increase in the yield and its components (2A, B and C).

Indicators of stress tolerance

The results in Table 3A show a significant effects of the triple interaction of the study factors on the stress tolerance indicators of industrial potatoes for the fall seasons 2020-2021 and spring 2021, as the treatment $I_1E_2T_2$ (under water stress conditions for the irrigation interval I_1) excelled in the value of the relative water content of the leaf (78.42 and 77.37%), leaf water potential (-3.80 and -3.89 bar) and water productivity (19.96 and 12.13 kg m^{-3}) for the fall and spring seasons respectively, compared to treatment $I_2E_0T_0$, which gave the lowest values of the relative water content of leaf (60.31 and 58.06 %), leaf water potential (-6.71 and -7.82 bar) and water productivity (12.85 and 7.93 kg m^{-3}) for the two seasons respectively, and $I_0E_2T_2$ treatment was superior in the highest value of the relative water content of leaf(88.07 and 79.09%), leaf water potential (-3.50 and -3.70 bar) and water productivity (20.38 and 12.76 kg m^{-3}) for the two seasons respectively. It is reveal from the results in Table 3B that there are significant differences for the coefficients of the binary interaction of the study factors in the stress tolerance indicators of industrial potatoes for the fall seasons 2020-2021 and spring 2021 (76.11 and 74.49%), leaf water potential (-4.48 and -4.68 bar) and water productivity (17.95 and 10.91 kg m^{-3}) for the fall and spring seasons respectively, as measured by the lowest values in relative water content, leaf water potential and water productivity in treatment I_2E_0 (65.90 and 62.40%) (-6.07 and -6.88-bar) (13.63 and 8.62 kg m^{-3}) for the two seasons respectively, and the treatment of interference I_0E_2 (under natural irrigation conditions for irrigation interval I_0) had the highest values in the relative water content of leaf (82.49 and 75.99). %), leaf water potential (-3.99 and -4.47bar) and water productivity (18.33 and 11.21 kg m^{-3}) for the two seasons respectively.

Table 2A. The effect of triple interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in yield indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	number of marketable tubers (tuber $plant^{-1}$)		marketable tuber weight (g $tuber^{-1}$)		marketable plant yield (kg $plant^{-1}$)		total marketable yield (ton ha^{-1})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021	2021-2020	2021
				I x E x T				
$I_0 E_0 T_0$	3.22	3.50	122.59	116.34	0.393	0.407	20.989	21.747
$I_0 E_0 T_1$	3.44	3.88	130.82	116.91	0.450	0.453	24.032	24.209
$I_0 E_0 T_2$	3.80	3.95	133.49	129.00	0.507	0.509	27.050	27.160
$I_0 E_1 T_0$	3.30	3.58	128.63	118.63	0.422	0.424	22.551	22.649
$I_0 E_1 T_1$	4.25	4.36	138.46	130.84	0.588	0.570	31.402	30.444
$I_0 E_1 T_2$	4.44	4.50	137.63	137.51	0.611	0.618	32.601	32.991
$I_0 E_2 T_0$	3.37	3.70	131.54	118.24	0.443	0.438	23.627	23.373
$I_0 E_2 T_1$	4.45	4.51	138.93	140.93	0.619	0.636	33.012	33.920
$I_0 E_2 T_2$	5.52	5.59	113.34	116.44	0.628	0.662	33.530	35.346
$I_1 E_0 T_0$	3.20	3.51	119.34	113.77	0.380	0.400	20.307	21.333
$I_1 E_0 T_1$	3.25	3.66	123.69	118.46	0.400	0.433	21.359	23.111
$I_1 E_0 T_2$	3.63	4.22	127.15	115.10	0.461	0.484	24.623	25.822
$I_1 E_1 T_0$	3.21	3.59	121.24	118.02	0.387	0.424	20.644	22.613
$I_1 E_1 T_1$	4.06	4.44	133.82	127.10	0.544	0.563	29.024	30.075
$I_1 E_1 T_2$	4.23	4.37	135.08	132.27	0.572	0.577	30.521	30.818
$I_1 E_2 T_0$	3.42	3.83	126.08	117.43	0.430	0.448	22.955	23.942
$I_1 E_2 T_1$	4.29	4.43	135.29	133.99	0.580	0.593	30.972	31.649
$I_1 E_2 T_2$	4.41	4.53	135.80	136.51	0.599	0.618	31.984	33.004
$I_2 E_0 T_0$	3.16	3.43	118.08	112.39	0.372	0.384	19.884	20.489
$I_2 E_0 T_1$	3.21	3.50	119.70	116.38	0.383	0.407	20.468	21.724
$I_2 E_0 T_2$	3.33	3.71	130.21	126.42	0.434	0.469	23.149	25.022
$I_2 E_1 T_0$	3.31	3.51	120.49	118.25	0.398	0.415	21.252	22.178
$I_2 E_1 T_1$	3.94	4.17	131.97	129.05	0.520	0.538	27.769	28.733
$I_2 E_1 T_2$	4.03	4.23	134.07	131.24	0.541	0.555	28.862	29.649
$I_2 E_2 T_0$	3.43	3.64	122.35	122.05	0.419	0.443	22.366	23.671
$I_2 E_2 T_1$	4.17	4.34	135.71	133.64	0.565	0.580	30.177	30.978
$I_2 E_2 T_2$	4.30	4.36	135.25	136.21	0.581	0.594	31.026	31.720
$L.S.D._{0.05}$	0.245	0.159	8.464	4.503	0.031	0.021	1.061	1.000

Table 2B. The effect of binary interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in yield indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	number of marketable tubers (tuber plant^{-1})		marketable tuber weight (g tuber^{-1})		marketable plant yield (kg plant^{-1})		total marketable yield (ton ha^{-1})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021	2021-2020	2021
				I x E				
$I_0 E_0$	3.49	3.78	128.97	120.75	0.450	0.456	24.024	24.372
$I_1 E_0$	3.36	3.80	123.39	115.78	0.414	0.439	22.096	23.422
$I_2 E_0$	3.23	3.55	122.66	118.40	0.396	0.420	21.167	22.412
$I_0 E_1$	3.99	4.14	134.91	128.99	0.540	0.538	28.851	28.695
$I_1 E_1$	3.83	4.13	130.05	125.80	0.501	0.521	26.730	27.835
$I_2 E_1$	3.76	3.97	128.84	126.18	0.486	0.503	25.961	26.853
$I_0 E_2$	4.44	4.60	127.94	125.20	0.563	0.579	30.057	30.880
$I_1 E_2$	4.04	4.26	132.39	129.31	0.536	0.553	28.637	29.532
$I_2 E_2$	3.96	4.11	131.10	130.64	0.522	0.539	27.856	28.789
L.S.D.$_{0.05}$	N.S	0.091	4.887	2.600	0.011	0.014	0.511	0.341
				I x T				
$I_0 T_0$	3.29	3.59	127.59	117.74	0.419	0.423	22.389	22.589
$I_1 T_0$	3.28	3.64	122.22	116.41	0.399	0.424	21.302	22.629
$I_2 T_0$	3.30	3.53	120.31	117.57	0.396	0.414	21.167	22.112
$I_0 T_1$	4.05	4.25	136.07	129.56	0.552	0.553	29.482	29.524
$I_1 T_1$	3.87	4.17	130.94	126.52	0.508	0.530	27.119	28.278
$I_2 T_1$	3.77	4.00	129.13	126.36	0.490	0.508	26.138	27.145
$I_0 T_2$	4.58	4.68	128.15	127.65	0.582	0.596	31.060	31.832
$I_1 T_2$	4.09	4.37	132.68	127.96	0.544	0.560	29.043	29.881
$I_2 T_2$	3.89	4.10	133.17	131.29	0.519	0.539	27.679	28.797
L.S.D.$_{0.05}$	0.142	0.091	4.887	2.600	0.011	0.014	0.511	0.341
				E x T				
E_0T_0	3.19	3.48	120.01	114.16	0.382	0.397	20.393	21.189
E_0T_1	3.30	3.68	124.73	117.25	0.411	0.431	21.953	23.015
E_0T_2	3.59	3.96	130.28	123.51	0.467	0.487	24.941	26.001
E_1T_0	3.27	3.56	123.45	118.30	0.402	0.421	21.482	22.480
E_1T_1	4.08	4.32	134.75	129.00	0.551	0.557	29.398	29.751
E_1T_2	4.23	4.36	135.59	133.67	0.574	0.584	30.661	31.152
E_2T_0	3.41	3.72	126.66	119.24	0.430	0.443	22.983	23.662
E_2T_1	4.30	4.43	136.64	136.18	0.588	0.603	31.387	32.182
E_2T_2	4.74	4.83	128.13	129.72	0.603	0.625	32.180	33.357
L.S.D.$_{0.05}$	0.142	0.091	4.887	2.600	0.011	0.014	0.511	0.341

The results showed that treatment I_1T_2 (under water stress conditions for irrigation interval I_1) was significant in the values of the relative water content of leaf (76.68 and 74.43%), leaf water potential (-4.02 and -4.41 bar) and water productivity (18.18 and 11.03 kg m^{-3}). For the two seasons respectively, compared to treatment I_2T_0, which gave the lowest values in the relative water content of leaf (65.66 and 62.18%), leaf water potential (-6.30 and -7.30 bar) and water productivity (13.56 and 8.45 kg m^{-3}) for the two seasons respectively, and the treatment outperformed I_0T_2 (under natural irrigation conditions for irrigation interval I_0) was significant in giving the highest values in the relative water content of leaf (81.32 and 76.99%), leaf water potential (-3.62 and -4.08bar) and water productivity (18.95 and 11.54 kg m^{-3}) for both seasons respectively.

Table 2C. The effect of individual of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in yield indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	number of marketable tubers (tuber plant^{-1})		marketable tuber weight (g tuber^{-1})		marketable plant yield (kg plant^{-1})		total marketable yield (ton ha^{-1})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021	2021-2020	2021
				I				
I_0	3.98	4.17	130.60	124.98	0.518	0.524	27.644	27.982
I_1	3.75	4.06	128.61	123.63	0.484	0.504	25.821	26.930
I_2	3.65	3.88	127.54	125.07	0.468	0.487	24.995	26.018
L.S.D.$_{0.05}$	0.149	0.241	N.S	N.S	0.008	0.006	0.422	0.327
				E				
E_0	3.36	3.71	125.01	118.31	0.420	0.438	22.429	23.402
E_1	3.86	4.08	131.27	126.99	0.509	0.521	27.181	27.794
E_2	4.15	4.33	130.48	128.38	0.540	0.557	28.850	29.734
L.S.D.$_{0.05}$	0.082	0.053	2.821	1.501	0.006	0.004	0.300	0.197
				T				
T_0	3.29	3.59	123.37	117.24	0.405	0.420	21.619	22.444
T_1	3.90	4.14	132.04	127.48	0.517	0.530	27.580	28.316
T_2	4.19	4.38	131.34	128.97	0.548	0.565	29.261	30.170
L.S.D.$_{0.05}$	0.082	0.053	2.821	1.501	0.006	0.004	0.300	0.197

The results showed that the E_2T_2 treatment was significantly superior in the relative water content of leaf (81.27 and 76.56%), leaf water potential (-3.78 and -3.91 bar) and water productivity (19.98 and 12.29 kg m^{-3}) for the two seasons respectively, compared to treatment E_0T_0, which gave the lowest relative water content for leaf (62.11 and 61.80%), leaf water potential (-6.11 and -6.83bar) and water productivity (12.94 and 7.99 kg m^{-3}) for the two seasons respectively. The results in Table 3C show a significant effect of I_1 (under water stress conditions) in the values of leaf relative water content (73.01 and 70.51%) and leaf water potential (-4.84 and -5.21 bar) for the two seasons respectively, and water productivity (16.26 kg m^{-3}) for the fall season compared to the lowest values in the relative water content of leaf (69.96 and 66.97%), leaf water potential (-5.28 and -5.86 bar) and water productivity (15.97 kg m^{-3}) in treatment I_2 for the two seasons respectively, and there was no interval irrigation I_1 had a significant effect on the water productivity of the spring season, while the highest values were found at treatment I_0 (under natural irrigation conditions for irrigation interval I_0) in the relative water content of leaf (76.82 and 73.59 %), leaf water potential (-4.33 and -4.91 bar) and water productivity (16.94 and 10.20 kg m^{-3}) for the two seasons respectively, and the E_2 ground addition treatment showed a significant effect with the highest values in the relative water content of leaf (77.27 and 73.68 %), leaf water potential (-4.40 and -4.74 bar) and water productivity (18.00 and 11.02 kg m^{-3}) for the two seasons respectively, compared to the treatment without adding E_0, which gave less The values in the relative water content of leaf (69.25 and 66.70%), leaf water potential (-5.37 and -6.09 bar) and water productivity (14.16 and 8.77 kg m^{-3}) for the two seasons respectively, and the results showed a significant superiority of T_2 spraying treatment with trehalose in relative water content for leaf (77.17 and 74.22%), leaf water potential (-4.03 and -4.36bar) and water productivity (18.24 and 11.17 kg m^{-3}) for the two seasons respectively, compared to the lowest values in the relative water content of leaf (67.57 and 65.27%) and leaf water potential (-5.85 and -6.52bar) and water productivity (13.69 and 8.44 kg m^{-3}) in the treatment of spraying with normal water T_0 for the two seasons respectively.

Table 3A. The effect of triple interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in stress tolerance indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	Relative water content (%)		Leaf water potential (bar)		Water productivity (kg m^{-3})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I x E x T			
$I_0 E_0T_0$	64.13	65.19	-5.66	-6.09	13.06	8.04
$I_0 E_0T_1$	75.32	73.19	-4.74	-5.82	14.81	8.89
$I_0 E_0T_2$	77.65	74.72	-3.76	-4.67	16.62	9.90
$I_0 E_1T_0$	70.61	68.25	-5.57	-6.01	13.94	8.36
$I_0 E_1T_1$	77.95	75.80	-3.66	-4.32	19.15	11.05
$I_0 E_1T_2$	78.24	77.17	-3.60	-3.87	19.84	11.97
$I_0 E_2T_0$	73.82	70.57	-4.90	-5.91	14.59	8.59
$I_0 E_2T_1$	85.56	78.32	-3.56	-3.80	20.04	12.27
$I_0 E_2T_2$	88.07	79.09	-3.50	-3.70	20.38	12.76
$I_1 E_0T_0$	61.90	62.16	-5.96	-6.59	12.91	8.00
$I_1 E_0T_1$	71.51	65.93	-5.81	-6.10	13.57	8.62
$I_1 E_0T_2$	75.02	71.95	-4.23	-4.95	15.56	9.60
$I_1 E_1T_0$	67.98	64.01	-5.90	-6.20	13.22	8.43
$I_1 E_1T_1$	75.71	73.09	-4.15	-4.61	18.20	11.09
$I_1 E_1T_2$	76.60	73.95	-4.05	-4.40	19.01	11.36
$I_1 E_2T_0$	72.74	70.75	-5.74	-6.03	14.56	8.93
$I_1 E_2T_1$	77.18	75.35	-3.91	-4.12	19.33	11.68
$I_1 E_2T_2$	78.42	77.37	-3.80	-3.89	19.96	12.13
$I_2 E_0T_0$	60.31	58.06	-6.71	-7.82	12.85	7.93
$I_2 E_0T_1$	66.65	60.31	-6.59	-7.68	13.19	8.35
$I_2 E_0T_2$	70.74	68.82	-4.93	-5.14	14.85	9.60
$I_2 E_1T_0$	67.97	62.69	-6.30	-7.39	13.72	8.57
$I_2 E_1T_1$	71.85	69.52	-4.49	-5.05	17.62	10.90
$I_2 E_1T_2$	72.49	71.67	-4.36	-4.52	18.36	11.24
$I_2 E_2T_0$	68.69	65.80	-5.89	-6.69	14.39	9.07
$I_2 E_2T_1$	73.59	72.65	-4.25	-4.34	19.12	11.74
$I_2 E_2T_2$	77.33	73.21	-4.06	-4.15	19.61	11.97
L.S.D.$_{0.05}$	2.058	1.663	0.050	0.062	0.120	0.096

The superiority of the treatment of the triple interaction $I_1E_2T_2$ significantly in the indicators of stress tolerance of industrial potatoes for the fall season 2020-2021 and spring season 2021 could be due to the role of each of the ground gels and spraying with trehalose sugar, which reduced the water stress caused by the irrigation separator I_1, since the addition of soil improvement works on ameliorate the physical properties of the soil, causing an increase in its ability to retain water and then increasing the efficiency of water use, which is positively reflected on the performance of the plant in bearing water stress, as well as the great effect of trehalose sugar in increasing the plant's tolerance to water stress. This could be due to its very stable glassy state and from Then the formation of a gelatinous state more than crystalline, which caused an increase in plant growth and then its resistance to water stress (23), and this led to the availability of appropriate conditions for the optimal management of irrigation intervals, which led to the provision of moisture necessary for plant growth continuously (especially in the irrigation interval I_1 This led to an increase in the absorption of nutrients and an increase in vegetative growth indicators (Table 1 A, B and C), and this was reflected in the yield and its components (Table 2 A, B and C), and all of this led to the The study factors had an effect on increasing the relative water content, leaf water potential and water productivity. As for the explanation of the decrease in the relative water content and the decreases in the water potential of the leaf (the most negative) and the decreases in water productivity in the measurement treatment for both seasons, it is attributed to the decrease in the water absorbed by the roots when the plant is exposed to water stress, and this leads to a decrease in the indicators of vegetative growth, which negatively affected the photosynthesis process and from Then lack of absorption and growth.

Table 3B. The effect of binary interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in stress tolerance indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	Relative water content (%)		Leaf water potential (bar)		Water productivity (kg m^{-3})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I x E			
I_0 E_0	72.37	71.03	-4.72	-5.53	14.83	8.95
I_1 E_0	69.47	66.68	-5.33	-5.88	14.01	8.74
I_2 E_0	65.90	62.40	-6.07	-6.88	13.63	8.62
I_0 E_1	75.60	73.74	-4.27	-4.73	17.64	10.46
I_1 E_1	73.43	70.35	-4.70	-5.07	16.81	10.29
I_2 E_1	70.77	67.96	-5.05	-5.65	16.57	10.24
I_0 E_2	82.49	75.99	-3.99	-4.47	18.33	11.21
I_1 E_2	76.11	74.49	-4.48	-4.68	17.95	10.91
I_2 E_2	73.20	70.55	-4.73	-5.06	17.71	10.93
L.S.D.$_{0.05}$	1.188	0.960	0.029	0.035	0.069	0.055
			I x T			
I_0 T_0	69.52	68.00	-5.38	-6.00	13.86	8.33
I_1 T_0	67.54	65.64	-5.86	-6.27	13.66	8.52
I_2 T_0	65.66	62.18	-6.30	-7.30	13.56	8.45
I_0 T_1	79.61	75.77	-3.98	-4.64	18.00	10.74
I_1 T_1	74.80	71.46	-4.62	-4.94	17.03	10.46
I_2 T_1	70.70	67.49	-5.11	-5.69	16.64	10.33
I_0 T_2	81.32	76.99	-3.62	-4.08	18.95	11.54
I_1 T_2	76.68	74.43	-4.02	-4.41	18.18	11.03
I_2 T_2	73.52	71.23	-4.45	-4.60	17.60	10.94
L.S.D.$_{0.05}$	1.188	0.960	0.029	0.035	0.069	0.055
			E x T			
E_0T_0	62.11	61.80	-6.11	-6.83	12.94	7.99
E_0T_1	71.16	66.48	-5.71	-6.53	13.86	8.62
E_0T_2	74.47	71.83	-4.31	-4.92	15.68	9.70
E_1T_0	68.86	64.98	-5.92	-6.53	13.63	8.45
E_1T_1	75.17	72.80	-4.10	-4.66	18.32	11.01
E_1T_2	75.77	74.26	-4.00	-4.26	19.07	11.52
E_2T_0	71.75	69.04	-5.51	-6.21	14.51	8.86
E_2T_1	78.78	75.44	-3.91	-4.09	19.49	11.90
E_2T_2	81.27	76.56	-3.78	-3.91	19.98	12.29
L.S.D.$_{0.05}$	1.188	0.960	0.029	0.035	0.069	0.055

Table 3C. The effect of individual of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress in stress tolerance indicators of industrial potatoes for the fall 2020-2021 and spring 2021 seasons

treatments	Relative water content (%)		Leaf water potential (bar)		Water productivity (kg m^{-3})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I			
I_0	76.82	73.59	-4.33	-4.91	16.94	10.20
I_1	73.01	70.51	-4.84	-5.21	16.26	9.98
I_2	69.96	66.97	-5.28	-5.86	15.97	9.93
L.S.D.$_{0.05}$	2.112	0.565	0.029	0.038	0.081	0.069
			E			
E_0	69.25	66.70	-5.37	-6.09	14.16	8.77
E_1	73.27	70.68	-4.67	-5.15	17.01	10.33
E_2	77.27	73.68	-4.40	-4.74	18.00	11.02
L.S.D.$_{0.05}$	0.686	0.554	0.016	0.020	0.040	0.032
			T			
T_0	67.57	65.27	-5.85	-6.52	13.69	8.44
T_1	75.04	71.57	-4.57	-5.09	17.23	10.51
T_2	77.17	74.22	-4.03	-4.36	18.24	11.17
L.S.D.$_{0.05}$	0.686	0.554	0.016	0.020	0.040	0.032

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