RESPONSE OF GROWTH AND YIELD OF INDUSTRIAL BOTATOES TO SOIL IMPROVEMENT AND SPRAYING WITH TOCOPHEROL AND TREHALOSE UNDER WATER STRESS

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ABSTRACT

This study was aimed to investigate the response of the growth and yield of industrial potatoes (*Solanum tuberosum* L.) to the addition of soil improvement and spraying with tocopherol, The field experiments were carried out during the fall season 2020-2021 and the spring 2021 at one of the fields at the area located at 44.23° longitude and 33.32° latitude, The experiments carried out as a factorial experiment within a split plot design, where the irrigation interval factor was set every 4, 8 and 12 days for the fall season and every 4, 7 and 10 days for the spring season (symbolized by I_0, I_1 and I_2) in the main plot, and the interaction factor between Eco Gel soil improver 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, tocopherol with a concentration of 30 mg L^{-1} symbolized by T_1 and trehalose with a concentration of 30 mmol L^{-1} symbolized by T_2, as well as spraying with normal water symbolized by T_0, the results showed a significant superiority for the treatment of the triple interaction $I_1E_2T_2$ in percentage increase Nitrogen, phosphorous, potassium, plant length, total leaves and total tubers, yield per plant and total yield for the two seasons, respectively, compared to treatment I_2 E_0T_0.

Keywords: Vitamin E, sugars, *Solanum tuberosum* L., polymers, hydrogel
*** Part of a Ph.D. dissertation for the 1st author**

استجابة نمو وحاصل البطاطا الصناعية لإضافة محسن التربة والرش بالتوكوفيرول والتريهالوز تحت الاجهاد المائي

عبدالكريم حسن شياع الربيعي **كاظم ديلي حسن الجبوري**
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المستخلص

تهدف الدراسة استجابة نمو وحاصل البطاطا الصناعية لإضافة محسن التربة والرش بالتوكوفيرول والتريهالوز تحت الاجهاد المائي, نُفذت تجربة حقلية اثناء الموسم الخريفي 2020−2021 والربيعي 2021 بزراعة الهجين اوستن (Austin) في احد الحقول في المنطقة الواقعة على خط الطول 44.23° وخط العرض 33.32°, نُفذت كتجربة عاملية بحسب تصميم الالواح المنشقة حيث وضع عامل فاصلة الري كل 4 و 8 و 12 يوماً للموسم الخريفي وكل 4 و 7 و 10 ايام للموسم الربيعي (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 تفوق معنوي لمعاملة التداخل الثلاثي I_1 E_2 T_2 في زيادة النسب المئوية لعناصر النتروجين والفسفور والبوتاسيوم وطول النبات وعدد الاوراق الكلية وعدد الدرنات الكلية وحاصل النبات الواحد والانتاج الكلي للموسمين على التتابع قياساً بالمعاملة I_2 E_0T_0.

الكلمات المفتاحية: فيتامين E , سكريات, *Solanum tuberosum* L.، بوليمرات، هلام مائي
***مستل من اطروحة دكتوراه للباحث الاول.**

Received:25/9/2021, Accepted:12/12/2021

INTRODUCTION

Solanum tuberosum L. in general considered crops of high nutritional and health value, as they contain carbohydrates, proteins, minerals, vitamins, dietary fiber, and antioxidants, as a result the researchers focused on the mentioned crop (10, 12, 13, 27, 32, 33). Industrial potato could be used in industries, especially in the production of chips and starch. Therefore, the global interest in industrial potatoes was great, which led to a change Nutritional habits to the preference for light meals ready to eat, potatoes are a non-fattening, nutritious and healthy food, as they contain carbohydrates 16%, proteins 2%, minerals 1%, dietary fiber 0.6% and a good source of vitamin C and antioxidants, and it has several uses in the table and the manufacture of chips and livestock feed and industrial purposes (starch and alcohol) (26), The factors affecting potato productivity is the lack of water (water stress) that Iraq and the world suffer from, as water stress is one of the most important obstacles to plant growth and productivity of the terrestrial ecosystem in a number of regions that causes a severe reduction in plant growth, development, and production (4, 14, 17), This is done by using some modern techniques represented by adding polymers in agriculture, which provides solutions to agricultural problems, which are maximizing land productivity and water productivity without threatening the environment and natural resources (environmental sustainability and food security), and super absorbent hydrogels that affect soil permeability and water evaporation rates (19), The basis of potassium polymer's action is the absorption of water in excess of the plant's need in the root area to supply the plant later when water is lacking or the plant needs water. Scavenging free radicals, and then protecting the fatty acids from oxidation and protecting the plant from environmental stresses (abiotic) such as water stress, high temperatures and salinity (21). Trehalose sugar is used to improve the tolerance of abiotic stresses in plants because it is one of the antioxidants and its protective role in stabilizing molecules. In addition to its important physiological role in plants (9), Spraying trehalose at a concentration of 75 mmol L^{-1} achieved a significant increase in the activity of scavenging free radicals (antioxidant activity), and an increases in the carotenoids of carrot plants (6), The main function of trehalose is the osmotic regulation in plant cells, the removal of mention example of spraing trehalose on potato free radicals, the stability of the structure and integrity of the membrane proteins under different stress conditions (16), Other researchers (5, 7, 8) revealed that spraying trehalose at a concentration of (75 mmol L^{-1}) led to an increase in yield components and flowering traits, and based on what was mentioned above aimed this study was aimed to improve the growth and yield of industrial potatoes by adding Eco Gel soil conditioner and spraying with tocopherol and trehalose under water stress.

MATERIALS AND METHODS

The field experiments were conducted for the cultivation of the potato crop *Solanum tuberosum* L. during the fall planting seasons 2020-2021 and spring 2021 at two fields at the area located at 44.23° longitude and 33.32° latitude, where the industrial hybrid Austin certified in Iraq was planted. The tubers were planted on (23/9/2020) for the fall season and on (28/1/2021) for the spring season. Potato tubers were used Class A for fall planting 2020 and Elite for spring planting 2021, the experimental unit represented 20 plants, the distance between one plant to another. 25 cm and 10 plants were planted on each meadow. The two experiments were carried out as a factorial experiment according to 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 addition Eco Gel soil improver 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 replicate experiment gave 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 experimental 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 at 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 soil moisture content 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 (23). The indicators of nutrients in leaves, represented by [Nitrogen in leaves (%) (24) and phosphorous in leaves (%) (30), Potassium in leaves (%) (11) Were studied vegetative growth indicators plant height (cm plant^{-1}), number of main aerial stems (stem plant^{-1}) and number of total leaves (leaf plant^{-1}). Indicators of yield and its components number of total tubers of the plant (tuber plant^{-1}) and tuber weight (g tuber^{-1}), yield per plant (kg plant^{-1}) and total production (ton ha^{-1})].

RESULTS AND DISCUSSION

Percentages of nitrogen, phosphorous and potassium in artificial potato leaves: It is evident from the results of Table 1A that there is a significant effect of the triple interaction treatments between trehalose, soil improvement and irrigation interval on the percentages of nutrients N, P and K in artificial potato leaves for the fall 2020-2021 and spring 2021 seasons, as the treatment $I_1E_2T_2$ outperformed (under water stress conditions For the irrigation interval I_1) in the percentages of the nutrients, nitrogen (2.81 and 2.88%), phosphorous (0.41 and 0.40%) and potassium (3.18 and 3.20%) for the fall seasons 2020-2021 and spring 2021, respectively, compared to the lowest percentages when treatment $I_2E_0T_0$ for the nutrients, nitrogen (2.55 and 2.54%), phosphorous (0.17 and 0.10%) and potassium (2.88 and 2.89%) for the two seasons, respectively, The highest values were found at treatment $I_0E_2T_2$ (under natural irrigation conditions for irrigation interval I_0) for the aforementioned elements (2.91 and 2.97%), (0.43 and 0.48%) and (3.31 and 3.29%) 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 percentages of nutrients in the leaves, as the I_1 E_2 treatment (under water stress conditions for the irrigation interval I_1) was superior to the percentages of nitrogen elements (2.77 and 2.83%) and phosphorous (0.37 and 0.37%) and potassium (3.12 and 3.14%) for the fall and spring seasons, respectively, compared to the lowest percentages when treatment I_2 E_0 for the elements nitrogen (2.63 and 2.66%), phosphorous (0.24 and 0.21%) and potassium (2.93 and 2.95%) for the two seasons, respectively. It is also noted from the same table that the highest values of percentages of nutrients were found at treatment I_0 E_2 (under natural irrigation conditions for irrigation interval I_0) (2.82 and 2.86%) (0.38 and 0.41%) (3.20 and 3.20%) for both seasons, respectively. The results showed that the I_1 T_2 treatment was significantly superior in the percentages of nitrogen (2.76 and 2.84%), phosphorous (0.37 and 0.37%) and potassium (3.11 and 3.14%) in the leaves of the fall and spring seasons, respectively, when compared with the treatment I_2 T_0, which gave the lowest percentages of nitrogen (2.63 and 2.67%), phosphorous (0.25 and 0.22%) and potassium (2.95 and 2.96%) for the two seasons, respectively. It is also noted that the highest values of percentages of nutrients were found when treatment I_0 T_2 (under natural irrigation conditions for irrigation interval I_0) for nitrogen elements (2.81 and 2.89%), phosphorous (0.39 and 0.41%) and potassium (3.22 and 3.20%) for the two seasons, respectively (Table 1B). The results showed that the E_2T_2 treatment was significantly superior in the percentages of the nutrients, nitrogen (2.83 and 2.90%), phosphorous (0.41 and 0.42%) and potassium (3.21 and 3.21%) for the two seasons, respectively, compared to the measurement treatment E_0T_0, which gave the lowest percentages of nitrogen (2.59 and 2.59%) and phosphorous (0.20 and 0.15%) and potassium (2.94 and 2.91%) for the two seasons, respectively. The results obtained in Table 1C for the single study factors show that there is a significant difference for the irrigation interval I_1 treatment (under water stress conditions) with its superiority in the percentages of nutrients in the leaves for nitrogen (2.72 and 2.77%), phosphorous (0.32 and 0.32%) and potassium (3.06 and 3.07%) for the two seasons respectively, compared to the lowest percentages of the irrigation interval I_2 for the indicated elements (2.69 and 2.74%) (0.31 and 0.29%) (3.02 and 3.03%) for both seasons respectively, while the highest values for the percentages of nutrients were found in Irrigation interval treatment I_0 (under natural irrigation conditions) for nitrogen (2.75 and 2.81%), phosphorous (0.34 and 0.36%) and potassium (3.15 and 3.12%) elements for the two seasons respectively, and the results showed a significant effect of the E_2 ground addition treatment by giving it the highest percentages of nitrogen (2.77 and 2.83%), phosphorous (0.37 and 0.37%) and potassium (3.14 and 3.15%) for the two seasons, respectively, compared to the measurement treatment E_0, which gave the lowest percentages of the aforementioned elements (2.66 and 2.71%), (0.27 and 0.26%) and (3.01 and 3.01%) for the two seasons respectively, as it was observed that there was a significant superiority of T_2 treatment in The percentages of nitrogen elements (2.77 and 2.85%), phosphorous (0.37 and 0.38%) and potassium (3.14 and 3.15%) for both seasons, respectively, compared to measurement treatment T_0 (2.65 and 2.69%), (0.26 and 0.24%) and (3.00 and 2.99%) for the two seasons, respectively. Perhaps the superiority of the treatment of the triple interaction of the study factors ($I_1E_2T_2$) in the percentages of nutrients in industrial potato leaves for both seasons is due to the effect of the study factors, as irrigation scheduling is an important factor in plant growth and the effect is significant and negative in the absorption of nutrients inside the plant whenever we go to Increasing the plant's exposure to water stress (the farther the irrigation periods are, the greater the negative effect of stress), which causes a decrease in the amount of water and nutrients absorbed into the plant tissues, and then a decrease in their percentage on the basis of dry weight. There is a significant effect in alleviating the effect of water stress in industrial potatoes when the ground application of the soil improvement Eco Gel (100 kg ha^{-1}) in the root area, as the soil improver works to gradually provide the appropriate moisture needed by the plant due to its slow retention and release of water to the soil Which provides the appropriate amounts of water for plant growth, and contributes to increasing the readiness and availability of nutrients, in addition to the fact that spraying with trehalose sugar led to an increase and improvement in the photosynthesis process (25) and maintain ion pumps that help to remove sodium from the chloroplasts, increasing potassium ion absorption and decreasing sodium ion absorption (22), Trehalose sugar is a source of energy and an osmotic protector for proteins and membrane structures and increases the plant's tolerance to stress, i.e. mitigating From the effect of water stress compared to natural irrigation conditions. As for the reason for the superiority of the irrigation interval under natural irrigation conditions in giving the highest percentages of nutrients, it may be due to the fact that irrigation scheduling at field capacity increases the soil solution from the readiness of nutrients, which facilitates their absorption and representation and increase their percentage in the plant.

Table 1A. The effect of triple interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress on the percentages of nitrogen, phosphorous and potassium elements in industrial potato leaves for the fall 2020-2021 and spring 2021 seasons

treatment	N in leaves (%)		P in leaves (%)		K in leaves (%)	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I x E x T			
$I_0 E_0T_0$	2.63	2.65	0.24	0.20	3.03	2.94
$I_0 E_0T_1$	2.73	2.78	0.33	0.37	3.15	3.13
$I_0 E_0T_2$	2.74	2.85	0.35	0.37	3.18	3.16
$I_0 E_1T_0$	2.70	2.73	0.28	0.27	3.06	3.02
$I_0 E_1T_1$	2.76	2.82	0.37	0.38	3.17	3.09
$I_0 E_1T_2$	2.78	2.85	0.39	0.40	3.18	3.16
$I_0 E_2T_0$	2.72	2.79	0.31	0.34	3.10	3.11
$I_0 E_2T_1$	2.84	2.81	0.40	0.42	3.20	3.20
$I_0 E_2T_2$	2.91	2.97	0.43	0.48	3.31	3.29
$I_1 E_0T_0$	2.60	2.59	0.19	0.14	2.93	2.91
$I_1 E_0T_1$	2.69	2.73	0.30	0.28	3.01	3.03
$I_1 E_0T_2$	2.72	2.80	0.33	0.35	3.04	3.09
$I_1 E_1T_0$	2.66	2.70	0.26	0.25	2.96	2.98
$I_1 E_1T_1$	2.74	2.79	0.35	0.35	3.10	3.10
$I_1 E_1T_2$	2.74	2.84	0.37	0.37	3.13	3.13
$I_1 E_2T_0$	2.70	2.77	0.31	0.32	3.05	3.06
$I_1 E_2T_1$	2.78	2.83	0.38	0.38	3.15	3.17
$I_1 E_2T_2$	2.81	2.88	0.41	0.40	3.18	3.20
$I_2 E_0T_0$	2.55	2.54	0.17	0.10	2.88	2.89
$I_2 E_0T_1$	2.64	2.66	0.22	0.22	2.93	2.91
$I_2 E_0T_2$	2.70	2.79	0.33	0.32	3.00	3.06
$I_2 E_1T_0$	2.66	2.71	0.28	0.26	2.97	2.96
$I_2 E_1T_1$	2.72	2.77	0.34	0.33	3.06	3.07
$I_2 E_1T_2$	2.73	2.82	0.36	0.37	3.10	3.11
$I_2 E_2T_0$	2.68	2.76	0.30	0.30	3.00	3.02
$I_2 E_2T_1$	2.75	2.82	0.37	0.37	3.12	3.15
$I_2 E_2T_2$	2.77	2.84	0.39	0.38	3.14	3.16
$L.S.D._{0.05}$	0.014	0.015	0.014	0.024	0.021	0.027

Table 1B. The effect of binary interactions of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress on the percentages of nitrogen, phosphorous and potassium elements in industrial potato leaves for the fall 2020-2021 and spring 2021 seasons

treatment	N in leaves (%)		P in leaves (%)		K in leaves (%)	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I x E			
$I_0 E_0$	2.70	2.76	0.31	0.31	3.12	3.08
$I_1 E_0$	2.67	2.71	0.27	0.26	2.99	3.01
$I_2 E_0$	2.63	2.66	0.24	0.21	2.93	2.95
$I_0 E_1$	2.74	2.80	0.35	0.35	3.14	3.09
$I_1 E_1$	2.71	2.78	0.33	0.32	3.06	3.07
$I_2 E_1$	2.70	2.76	0.33	0.32	3.04	3.04
$I_0 E_2$	2.82	2.86	0.38	0.41	3.20	3.20
$I_1 E_2$	2.77	2.83	0.37	0.37	3.12	3.14
$I_2 E_2$	2.73	2.81	0.35	0.35	3.09	3.11
$L.S.D._{0.05}$	0.008	0.008	0.008	0.014	0.012	0.016
			I x T			
$I_0 T_0$	2.68	2.72	0.28	0.27	3.06	3.02
$I_1 T_0$	2.65	2.69	0.25	0.24	2.98	2.98
$I_2 T_0$	2.63	2.67	0.25	0.22	2.95	2.96
$I_0 T_1$	2.77	2.80	0.37	0.39	3.17	3.14
$I_1 T_1$	2.73	2.78	0.34	0.34	3.08	3.10
$I_2 T_1$	2.70	2.75	0.31	0.30	3.04	3.04
$I_0 T_2$	2.81	2.89	0.39	0.41	3.22	3.20
$I_1 T_2$	2.76	2.84	0.37	0.37	3.11	3.14
$I_2 T_2$	2.73	2.82	0.36	0.36	3.08	3.11
$L.S.D._{0.05}$	0.008	0.008	0.008	0.014	0.012	0.016
			E x T			
E_0T_0	2.59	2.59	0.20	0.15	2.94	2.91
E_0T_1	2.68	2.72	0.28	0.29	3.03	3.02
E_0T_2	2.72	2.81	0.34	0.34	3.07	3.10
E_1T_0	2.67	2.71	0.27	0.26	3.00	2.99
E_1T_1	2.74	2.79	0.35	0.35	3.11	3.08
E_1T_2	2.75	2.84	0.37	0.38	3.13	3.13
E_2T_0	2.70	2.77	0.31	0.32	3.05	3.06
E_2T_1	2.79	2.82	0.38	0.39	3.16	3.17
E_2T_2	2.83	2.90	0.41	0.42	3.21	3.21
$L.S.D._{0.05}$	0.008	0.008	0.008	0.014	0.012	0.016

Vegetive growth indicators

The results of Table 2A show that there is a significant effect of the triple interaction treatments between trehalose, soil improvement and irrigation interval on some vegetative growth indicators of artificial potatoes for the fall seasons 2020-2021 and spring 2021, as the treatment $I_1E_2T_2$ excelled (under water stress conditions for irrigation interval I_1) in Plant length (70.03 and 62.55 cm plant^{-1}) and total leaves number (47.48 and 42.58 leaf plant^{-1}) for the fall seasons 2020-2021 and spring 2021, respectively, compared to the lowest value in treatment $I_2E_0T_0$ for plant height (54.88 and 48.43 cm plant^{-1}) The number of total leaves (27.91 and 26.43 leaf plant^{-1}) for the two seasons, respectively. As for the tallest plants (74.89 and 65.48 cm plant^{-1}) and the highest number of total leaves (48.28 and 45.36 leaf plant^{-1}) in the treatment $I_0E_2T_2$ (under natural irrigation conditions for the irrigation interval I_0) for the fall seasons 2020-2021 and spring 2021, respectively.

Table 1C. The effect of individual of the nutrition treatments (tocopherol, trehalose) and soil improvement and water stress on the percentages of nitrogen, phosphorous and potassium elements in industrial potato leaves for the fall 2020-2021 and spring 2021 seasons

Treatment	N in leaves (%)		P in leaves (%)		K in leaves (%)	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I			
I_0	2.75	2.81	0.34	0.36	3.15	3.12
I_1	2.72	2.77	0.32	0.32	3.06	3.07
I_2	2.69	2.74	0.31	0.29	3.02	3.03
$L.S.D._{0.05}$	0.006	0.011	0.002	0.004	0.008	0.008
			E			
E_0	2.66	2.71	0.27	0.26	3.01	3.01
E_1	2.72	2.78	0.33	0.33	3.08	3.07
E_2	2.77	2.83	0.37	0.37	3.14	3.15
$L.S.D._{0.05}$	0.004	0.005	0.004	0.008	0.007	0.009
			T			
T_0	2.65	2.69	0.26	0.24	3.00	2.99
T_1	2.74	2.78	0.34	0.34	3.10	3.09
T_2	2.77	2.85	0.37	0.38	3.14	3.15
$L.S.D._{0.05}$	0.004	0.005	0.004	0.008	0.007	0.009

It is clear from the results of Table 2B that there are significant differences for the treatments of the binary interaction of the study factors in the indicators of vegetative growth, as the treatment of the interaction $I_1 E_2$ (under water stress conditions for the irrigation interval I_1) excelled in the height of plants (66.78 and 59.37 cm plant^{-1}) and the number of total leaves (44.07 and 41.74 leaf plant^{-1}) for the fall and spring seasons, respectively, compared to treatment $I_2 E_0$, which gave the shortest plants (57.67 and 50.65 cm plant^{-1}) and the lowest number of total leaves (32.46 and 31.84 leaf plant^{-1}) for the two seasons, respectively. The treatment of interference I_0E_2 (under natural irrigation conditions for irrigation interval I_0) was superior to the tallest plants (71.31 and 62.30 cm plant^{-1}) and the highest number of total leaves (44.78 and 42.10 leaf plant^{-1}) for the fall and spring seasons, respectively. The results showed that treatment I_1T_2 (under water stress conditions for irrigation interval I_1) was significant in plant height (67.04 and 58.67 cm plant^{-1}) and total leaves number (44.60 and 41.88 leaf plant^{-1}) for the fall and spring seasons, respectively, compared to treatment I_2T_0 which It gave the shortest plants (57.67 and 51.01 cm plant^{-1}) and the lowest number of total leaves (32.22 and 31.89 leaf plant^{-1}) for the two seasons, respectively. The highest values were found at I_0T_2 treatment (under natural irrigation conditions for irrigation interval I_0) for the tallest plants (72.50 and 63.66 cm plant^{-1}) and the highest number of total leaves (46.18 and 43.65 leaf plant^{-1}) for the fall and spring seasons, respectively. The results showed that the E_2T_2 treatment was significantly superior to the tallest plants (70.77 and 62.66 cm plant^{-1}) and the total number of leaves (47.25 and 42.90 leaf plant^{-1}) for the two seasons, respectively, compared to the treatment E_0T_0, which gave the shortest plants (57.62 and 50.40 cm plant^{-1}) and less. Number of total leaves (30.49 and 29.04 leaf plant^{-1}) for the two seasons respectively, and the two-interaction treatments had no significant effect on the number of main aerial stems for both seasons. The results in Table 2C for the single study factors showed a significant difference for treatment I_1 (under water stress conditions) in plant height (64.00 and 56.09 cm plant^{-1}) and total leaves number (40.14 and 38.48 leaf plant^{-1}) for the two seasons respectively compared to the lowest value For treatment I_2, the height of the plants (61.03 and 53.83 cm plant^{-1}) and the number of total leaves (37.85 and 36.15 leaf plant^{-1}) for the two seasons, respectively. As for treatment I_0 (under natural irrigation conditions), it gave the tallest plants (68.75 and 60.22 cm plant^{-1}) and the highest number of total leaves (42.12 and 40.15 leaf plant^{-1}) for the two seasons, respectively. The irrigation interval treatment had no significant effect on the number of main aerial stems, and the E_2 ground application showed a significant effect as it gave the tallest plants (67.45 and 59.58 cm plant^{-1}) and the highest number of total leaves (43.67 and 41.06 leaf plant^{-1}) for the two seasons, respectively, compared to With the treatment without adding E_0, which gave the shortest plants (61.49 and 53.85 cm plant^{-1}) and the lowest number of total leaves (35.72 and 35.00 leaf plant^{-1}) for the two seasons, respectively, and treatment E_2 significantly outperformed the number of main aerial stems (2.80 stem plant^{-1}) compared to the lowest number of main aerial stems in treatment E_0 (2.41 plant stem plant^{-1}) for the fall season, and the ground addition treatment did not show a significant effect on the number of main aerial stems for the spring season, and the results showed a significant superiority of the treatment of spraying with trehalose T_2 in plant height (67.81 and 59.54 cm Plant^{-1}) and the total number of leaves (44.34 and 41.86 leaf plant^{-1}) for the two seasons, respectively, compared to the treatment of spraying with ordinary water T_0. The length of the plants was (60.11 and 52.89 cm plant^{-1}) and the total number of leaves (33.86 and 33.48 leaf plant^{-1}) for the two seasons respectively, and treatment T_2 was significantly superior In the number of main aerial stems (2.81 stem plant^{-1}) compared to the lowest number of main aerial stems in treatment T_0 (2.32 stem plant^{-1}) for the fall season, and treatment T_1 showed a significant superiority in the number of main aerial stems (3.03 stem plant^{-1}) compared to the treatment T_0 (2.69 stem plant^{-1}) for the spring season. 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 (irrigation interval 8 days and 7 days for the fall and spring seasons respectively), as the hydrogels increased The ability of the soil to retain water and regulate its supply to plants, especially when the period is prolonged (relatively) between irrigation and this is positively reflected in plant growth and improving its performance (2), 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 (20, 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 (18).

Industrial potato yield indicators

It is evident from the results of Table 3A that there is a significant effect 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. (5.53 and 5.70 tuber plant^{-1}), tuber weight (113.09 and 112.89 g tuber^{-1}), yield per plant (0.625 and 0.643 kg plant^{-1}) and total yield (33.359 and 34.320 ton ha^{-1}) for the two seasons, respectively, compared to the lowest value in Treatment $I_2E_0T_0$ for the total number of tubers (4.20 and 4.46 tubers plant^{-1}), the yield per plant (0.397 and 0.409 kg plant^{-1}) and the total production (21.182 and 21,862 ton ha^{-1}) for the two seasons respectively, while $I_2E_0T_1$ treatment gave lowest value of tuber weight (94.14 g tuber^{-1}) in the fall season and treatment $I_2E_0T_0$ (91.78 g tuber^{-1}) in the spring season.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 total tubers (6.62 and 6.76 tuber plant^{-1}), the yield per plant (0.653 and 0.687 kg plant^{-1}) and the total production (34.848 and 36.649 ton ha^{-1}) and upon treatment $I_0E_2T_1$ in tuber weight (115.10 and 117.29 g tuber^{-1}) for the fall seasons 2020-2021 and spring 2021, respectively.

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

Indications treatment	Plant length (cm plant^{-1})		Number of main aerial stems (stem plant^{-1})		Total number of leaves (leaf plant^{-1})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I x E x T			
$I_0 E_0 T_0$	59.97	52.55	2.22	2.40	32.78	31.46
$I_0 E_0 T_1$	67.27	57.70	2.67	3.13	41.10	40.36
$I_0 E_0 T_2$	70.02	62.01	2.86	2.91	43.06	42.08
$I_0 E_1 T_0$	62.93	56.16	2.33	2.51	35.50	35.48
$I_0 E_1 T_1$	72.00	63.17	2.94	3.15	45.11	42.22
$I_0 E_1 T_2$	72.58	63.48	2.85	3.10	47.19	43.50
$I_0 E_2 T_0$	65.07	57.05	2.50	2.85	38.06	36.83
$I_0 E_2 T_1$	73.98	64.37	3.22	3.16	48.00	44.10
$I_0 E_2 T_2$	74.89	65.48	2.93	3.33	48.28	45.36
$I_1 E_0 T_0$	58.00	50.21	2.23	2.44	30.78	29.22
$I_1 E_0 T_1$	61.17	54.17	2.44	2.87	36.11	35.36
$I_1 E_0 T_2$	63.97	56.04	2.72	2.91	40.24	41.03
$I_1 E_1 T_0$	59.86	51.79	2.35	3.04	33.36	32.24
$I_1 E_1 T_1$	65.57	57.07	2.83	3.14	42.46	41.26
$I_1 E_1 T_2$	67.11	57.43	2.78	3.13	46.07	42.03
$I_1 E_2 T_0$	62.13	55.20	2.48	2.93	37.58	40.38
$I_1 E_2 T_1$	68.18	60.37	2.67	3.03	47.17	42.26
$I_1 E_2 T_2$	70.03	62.55	3.06	3.08	47.48	42.58
$I_2 E_0 T_0$	54.88	48.43	2.11	2.55	27.91	26.43
$I_2 E_0 T_1$	56.96	50.05	2.13	2.90	31.76	30.13
$I_2 E_0 T_2$	61.18	53.47	2.33	2.91	37.71	38.96
$I_2 E_1 T_0$	58.01	51.49	2.31	2.73	33.40	32.18
$I_2 E_1 T_1$	62.38	54.34	2.17	2.90	40.32	39.16
$I_2 E_1 T_2$	63.14	55.46	2.91	2.74	43.07	40.46
$I_2 E_2 T_0$	60.11	53.10	2.41	2.78	35.37	37.07
$I_2 E_2 T_1$	65.24	58.15	3.05	2.96	45.16	40.16
$I_2 E_2 T_2$	67.38	59.96	2.88	3.08	45.98	40.77
L.S.D.$_{0.05}$	0.340	0.618	N.S	N.S	0.885	0.584

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

Indications treatment	Plant length (cm plant^{-1})		Number of main aerial stems (stem plant^{-1})		Total number of leaves (leaf plant^{-1})	
Seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I x E			
$I_0 E_0$	65.76	57.42	2.58	2.81	38.98	37.97
$I_1 E_0$	61.05	53.47	2.46	2.74	35.71	35.20
$I_2 E_0$	57.67	50.65	2.19	2.79	32.46	31.84
$I_0 E_1$	69.17	60.93	2.70	2.92	42.60	40.40
$I_1 E_1$	64.18	55.43	2.65	3.10	40.63	38.51
$I_2 E_1$	61.18	53.76	2.46	2.79	38.93	37.27
$I_0 E_2$	71.31	62.30	2.88	3.11	44.78	42.10
$I_1 E_2$	66.78	59.37	2.74	3.01	44.07	41.74
$I_2 E_2$	64.24	57.07	2.78	2.94	42.17	39.33

L.S.D.$_{0.05}$	**0.196**	**0.357**	**N.S**	**N.S**	**0.511**	**0.337**
			I x T			
I_0 T_0	**62.66**	**55.25**	**2.35**	**2.59**	**35.45**	**34.59**
I_1 T_0	**60.00**	**52.40**	**2.35**	**2.80**	**33.91**	**33.95**
I_2 T_0	**57.67**	**51.01**	**2.27**	**2.68**	**32.22**	**31.89**
I_0 T_1	**71.08**	**61.75**	**2.94**	**3.15**	**44.74**	**42.23**
I_1 T_1	**64.97**	**57.20**	**2.65**	**3.01**	**41.91**	**39.63**
I_2 T_1	**61.53**	**54.18**	**2.45**	**2.92**	**39.08**	**36.48**
I_0 T_2	**72.50**	**63.66**	**2.88**	**3.11**	**46.18**	**43.65**
I_1 T_2	**67.04**	**58.67**	**2.85**	**3.04**	**44.60**	**41.88**
I_2 T_2	**63.90**	**56.29**	**2.71**	**2.91**	**42.25**	**40.06**
L.S.D.$_{0.05}$	**0.196**	**0.357**	**N.S**	**N.S**	**0.511**	**0.337**
			E x T			
E_0T_0	**57.62**	**50.40**	**2.18**	**2.46**	**30.49**	**29.04**
E_0T_1	**61.80**	**53.97**	**2.41**	**2.97**	**36.32**	**35.28**
E_0T_2	**65.06**	**57.17**	**2.64**	**2.91**	**40.34**	**40.69**
E_1T_0	**60.27**	**53.15**	**2.33**	**2.76**	**34.09**	**33.30**
E_1T_1	**66.65**	**58.19**	**2.64**	**3.06**	**42.63**	**40.88**
E_1T_2	**67.61**	**58.79**	**2.84**	**2.99**	**45.44**	**41.99**
E_2T_0	**62.44**	**55.11**	**2.46**	**2.85**	**37.00**	**38.09**
E_2T_1	**69.13**	**60.96**	**2.98**	**3.05**	**46.77**	**42.17**
E_2T_2	**70.77**	**62.66**	**2.96**	**3.16**	**47.25**	**42.90**
L.S.D.$_{0.05}$	**0.196**	**0.357**	**N.S**	**N.S**	**0.511**	**0.337**

The results of Table 3B indicate that there are significant differences for the treatments of the binary interaction of the study factors in the yield indicators, as the treatment of the interaction I_1E_2 (under the water stress conditions of the irrigation interval I_1) excelled in the number of total tubers (5.43 tuber plant^{-1}) for the spring season and the yield per plant (0.562 and 0.579 kg plant^{-1}) and the total production (30.001 and 30.887 ton ha^{-1}) for the two seasons, respectively, compared to treatment I_2E_0, which produced the lowest number of total tubers (4.61 tuber plant^{-1}) for the spring season and the yield per plant (0.421 and 0.446 kg plant^{-1}) The total production (22.462 and 23.788 ton ha^{-1}) for the two seasons respectively, and the interaction treatment between irrigation and ground addition of soil improver did not show a significant effect on the total number of tubers in the fall season, but the highest values were found at I_0E_2 treatment (under natural irrigation conditions for interval Irrigation I_0) in the total number of tubers (5.75 tuber plant^{-1}) for the spring season and the yield per plant (0.587 and 0.603 kg plant^{-1}) and the total production (31.356 and 32.184 ton ha^{-1}) for the two seasons respectively, and the treatment showed I_1E_2 (under conditions of Water stress of irrigation interval I_1) significantly superior to tuber weight (107.48 g tuber^{-1}) Compared to treatment I_2 E_0 in the lowest value of tuber weight (97.09 g tuber-1) for the autumn season, while the highest value was found with treatment I_0E_1 (under natural irrigation conditions for the irrigation interval I_0) in tuber weight (109.68 g tuber^{-1}) for the fall season which did not differ significantly with I_1E_2 treatment, and it outperformed treatment I_2E_2 (under water stress conditions for irrigation interval I_2) with the highest value of tuber weight (106.93 g tuber^{-1}) compared to the lowest value of treatment I_1E_0 (94.15 g tuber^{-1}) for the spring season. The results showed that treatment I_1T_2 (under water stress conditions for irrigation interval I_1) was significant in the number of total tubers (5.24 and 5.52 tubers plant^{-1}), the yield per plant (0.569 and 0.585 kg plant^{-1}) and the total production (30.380 and 31.213 ton ha^{-1}) for the two seasons, respectively, when compared with treatment I_1T_0, which gave the lowest number of total tubers (4.42 tuber plant^{-1}) for the fall season and the yield per plant (0.422 and 0.440 kg plant^{-1}) and the total production (22.509 and 23.512 ton ha^{-1}) for the two seasons over The sequence and in the treatment I_2T_0 for the total number of tubers (4.62 tuber plant^{-1}) for the spring season,

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

Indications treatment	Plant length (cm plant^{-1})		Number of main aerial stems (stem plant^{-1})		Total number of leaves (leaf plant^{-1})	
seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021
			I			
I_0	68.75	60.22	2.72	2.95	42.12	40.15
I_1	64.00	56.09	2.62	2.95	40.14	38.48
I_2	61.03	53.83	2.48	2.84	37.85	36.15
L.S.D.$_{0.05}$	0.082	0.178	N.S	N.S	0.657	0.291
			E			
E_0	61.49	53.85	2.41	2.78	35.72	35.00
E_1	64.84	56.71	2.61	2.93	40.72	38.72
E_2	67.45	59.58	2.80	3.02	43.67	41.06
L.S.D.$_{0.05}$	0.113	0.206	0.156	N.S	0.295	0.194
			T			
T_0	60.11	52.89	2.32	2.69	33.86	33.48
T_1	65.86	57.71	2.68	3.03	41.91	39.45
T_2	67.81	59.54	2.81	3.02	44.34	41.86
L.S.D.$_{0.05}$	0.113	0.206	0.156	0.203	0.295	0.194

while the highest values were found in the treatment I_0T_2 (under natural irrigation conditions for the irrigation interval I_0) in the number of total tubers (5.72 and 5.84 tuber plant^{-1}) and yield per plant (0.607 and 0.621 kg plant^{-1}) and total production (32.403 and 33.155 ton ha^{-1}) for the two seasons respectively, and treatment I_1T_2 (under water stress conditions for irrigation interval I_2) was significantly superior to the value of tuber weight (108.31 g tuber^{-1}) As measured by the lowest value of treatment I_2T_0 (94.85 g tuber^{-1}) for the fall season, while treatment I_0T_1 (under natural irrigation conditions for the irrigation interval I_0) gave the highest tuber weight (110.10 g tuber^{-1}) for the fall season, while treatment I_2T_2 (under water stress conditions for the irrigation interval I_2) gave the highest tuber weight (107.44 g tuber^{-1}) compared to treatment I_1T_0 which gave the lowest tuber weight (93.97 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 total number of tubers (5.84 and 6.00 tuber plant^{-1}), the yield per plant (0.628 and 0.649 kg plant^{-1}) and the total production (33.508 and 34.663 ton ha^{-1}) for the two seasons, respectively, compared to the lowest values In the treatment E_0T_0 the total number of tubers (4.29 and 4.57 tuber plant^{-1}), the yield per plant (0.406 and 0.422 kg plant^{-1}) and the total production (21.697 and 22,541 ton ha^{-1}) for the two seasons respectively, and the treatment E_2T_1 was significantly superior with the highest weight tuber (112.29 and 112.79 g tuber^{-1}) for the two seasons respectively when compared with treatment E_0T_0 which gave the lowest marketable tuber weight (94.98 and 92.35 g tuber^{-1}) for the two seasons respectively. The results in Table 3C show that the single study factors had a significant effect, and the I_0 irrigation interval treatment was superior by giving it the highest number of total tubers (5.14 and 5.33 tuber plant^{-1}) and the treatment I_1 (under water stress conditions) was superior in the yield per plant (0.509 and 0.529 kg plant^{-1}) and total production (27.173 and 28.255 ton ha^{-1}) for the two seasons respectively, compared to the lowest value in treatment I_2, the number of total tubers (4.80 and 4.98 tuber plant^{-1}) and the yield per plant (0.493 and 0.513 kg plant^{-1}) and production Total (26.317 and 27.388 ton ha^{-1}) for the two seasons respectively, and I_0 treatment (under natural irrigation conditions) had the highest yield per plant (0.543 and 0.549 kg plant^{-1}) and total production (28.966 and 29.305 ton ha^{-1}) for the two seasons respectively, And the results did not show a significant effect of irrigation interval I treatment on tuber weight for both seasons, and the results showed a significant effect of E_2 ground application by its superiority in the total number of tuber (5.31 and 5.48 tuber plant^{-1}) and tuber weight (106.41 and 105.92 g tuber^{-1}) and yield per plant (0.565 and 0.582 kg plant^{-1}) and total production (30.180 and 31.069 ton ha^{-1}) For two seasons in succession, compared to the treatment without adding E_0, which gave the lowest number of total tubers (4.51 and 4.83 tubers plant^{-1}) and the lowest value for tuber weight (98.54 and 95.98 g tuber^{-1}) and yield per plant (0.445 and 0.463 kg plant^{-1}) and production Total (23.751 and 24,743 ton ha^{-1}) for the two seasons respectively, and the results showed a significant superiority of spraying with trehalose T_2 in the number of total tubers (5.34 and 5.54 tuber plant^{-1}) and tuber weight (107.47 and 106.68 g tuber^{-1}) and the yield per plant (0.573 and 0.590 kg plant^{-1}) and total production (30.599 and 31.511 ton ha^{-1}) for the two seasons, respectively, compared to treatment T_0, which gave the lowest number of total tubers (4.45 and 4.71 tuber plant^{-1}) and the lowest value for tuber weight (96.84 and 94.55 g tuber^{-1}), yield per plant (0.430 and 0.446 kg plant^{-1}) and total production (22.963 and 23.789 ton ha^{-1}) for the two seasons, respectively.

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

Indications treatment	Total number of tubers (tuber plant^{-1})		tuber weight (g tuber^{-1})		Yield per plant (kg plant^{-1})		Total production (ton ha^{-1})	
seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021	2021-2020	2021
				I x E x T				
$I_0 E_0T_0$	4.45	4.66	94.48	92.87	0.418	0.433	22.337	23.102
$I_0 E_0T_1$	4.69	5.05	101.23	94.84	0.475	0.478	25.335	25.538
$I_0 E_0T_2$	5.00	5.12	106.61	104.19	0.533	0.533	28.428	28.440
$I_0 E_1T_0$	4.45	4.73	100.56	95.08	0.447	0.450	23.841	24.000
$I_0 E_1T_1$	5.39	5.53	113.96	107.55	0.614	0.595	32.751	31.738
$I_0 E_1T_2$	5.56	5.63	114.53	114.43	0.636	0.644	33.935	34.378
$I_0 E_2T_0$	4.54	4.86	103.07	95.04	0.467	0.462	24.955	24.667
$I_0 E_2T_1$	5.58	5.63	115.10	117.29	0.642	0.660	34.266	35.235
$I_0 E_2T_2$	6.62	6.76	98.67	101.57	0.653	0.687	34.848	36.649
$I_1 E_0T_0$	4.23	4.60	95.65	92.39	0.404	0.424	21.573	22.658
$I_1 E_0T_1$	4.41	4.80	96.60	95.43	0.425	0.457	22.686	24.409
$I_1 E_0T_2$	4.83	5.40	101.03	94.63	0.487	0.509	26.009	27.173
$I_1 E_1T_0$	4.36	4.73	95.33	94.58	0.414	0.447	22.097	23.862
$I_1 E_1T_1$	5.26	5.53	108.43	106.56	0.570	0.588	30.418	31.386
$I_1 E_1T_2$	5.37	5.48	110.82	110.03	0.595	0.602	31.771	32.146
$I_1 E_2T_0$	4.66	5.00	97.96	94.95	0.456	0.473	24.336	25.275
$I_1 E_2T_1$	5.44	5.60	111.40	110.73	0.605	0.620	32.306	33.066
$I_1 E_2T_2$	5.53	5.70	113.09	112.89	0.625	0.643	33.359	34.320
$I_2 E_0T_0$	4.20	4.46	94.80	91.78	0.397	0.409	21.182	21.862
$I_2 E_0T_1$	4.33	4.50	94.14	95.98	0.407	0.431	21.734	23.035
$I_2 E_0T_2$	4.48	4.88	102.32	101.72	0.458	0.496	24.471	26.467
$I_2 E_1T_0$	4.50	4.63	94.21	95.70	0.424	0.443	22.620	23.649
$I_2 E_1T_1$	5.04	5.26	108.06	107.11	0.544	0.563	29.043	30.062
$I_2 E_1T_2$	5.26	5.35	107.70	108.70	0.567	0.581	30.252	31.004
$I_2 E_2T_0$	4.66	4.76	95.53	98.53	0.444	0.469	23.724	25.027
$I_2 E_2T_1$	5.35	5.50	110.36	110.36	0.590	0.606	31.507	32.364
$I_2 E_2T_2$	5.38	5.53	112.49	111.91	0.605	0.619	32.317	33.022
$L.S.D._{0.05}$	0.263	0.176	5.408	3.322	0.025	0.023	1.121	1.175

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 improvement 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 (15). 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 (28) 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 (3), 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 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 (16, 28), 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).

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

Indications treatment	Total number of tubers (tuber plant^{-1})		tuber weight (g tuber^{-1})		Yield per plant (kg plant^{-1})		Total production (ton ha^{-1})	
seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021	2021-2020	2021
				I x E				
I_0 E_0	4.71	4.94	100.77	97.30	0.475	0.481	25.367	25.693
I_1 E_0	4.49	4.93	97.76	94.15	0.439	0.464	23.423	24.747
I_2 E_0	4.34	4.61	97.09	96.50	0.421	0.446	22.462	23.788
I_0 E_1	5.13	5.30	109.68	105.69	0.565	0.563	30.175	30.038
I_1 E_1	5.00	5.25	104.86	103.72	0.526	0.546	28.095	29.132
I_2 E_1	4.93	5.08	103.33	103.84	0.512	0.529	27.305	28.238
I_0 E_2	5.58	5.75	105.62	104.63	0.587	0.603	31.356	32.184
I_1 E_2	5.21	5.43	107.48	106.19	0.562	0.579	30.001	30.887
I_2 E_2	5.13	5.26	106.12	106.93	0.547	0.565	29.183	30.138
L.S.D.$_{0.05}$	N.S	0.101	3.122	1.918	0.010	0.012	1.093	1.056
				I x T				
I_0 T_0	4.48	4.75	99.37	94.33	0.444	0.448	23.711	23.923
I_1 T_0	4.42	4.77	96.31	93.97	0.425	0.448	22.669	23.932
I_2 T_0	4.45	4.62	94.85	95.34	0.422	0.440	22.509	23.512
I_0 T_1	5.22	5.40	110.10	106.56	0.577	0.578	30.784	30.837
I_1 T_1	5.03	5.31	105.48	104.24	0.533	0.555	28.470	29.621
I_2 T_1	4.90	5.08	104.19	104.48	0.514	0.534	27.428	28.487
I_0 T_2	5.72	5.84	106.60	106.73	0.607	0.621	32.403	33.155
I_1 T_2	5.24	5.52	108.31	105.85	0.569	0.585	30.380	31.213
I_2 T_2	5.04	5.25	107.51	107.44	0.544	0.565	29.013	30.164
L.S.D.$_{0.05}$	0.152	0.101	3.122	1.918	0.010	0.012	1.093	1.056
				E x T				
E_0T_0	4.29	4.57	94.98	92.35	0.406	0.422	21.697	22.541

E_0T_1	4.48	4.78	97.32	95.42	0.436	0.456	23.252	24.327
E_0T_2	4.77	5.13	103.32	100.18	0.493	0.513	26.303	27.360
E_1T_0	4.43	4.70	96.70	95.12	0.428	0.446	22.852	23.837
E_1T_1	5.23	5.44	110.15	107.07	0.576	0.582	30.737	31.062
E_1T_2	5.40	5.48	111.02	111.05	0.599	0.609	31.986	32.509
E_2T_0	4.62	4.87	98.85	96.17	0.456	0.468	24.338	24.989
E_2T_1	5.45	5.57	112.29	112.79	0.613	0.629	32.693	33.555
E_2T_2	5.84	6.00	108.08	108.79	0.628	0.649	33.508	34.663
$L.S.D._{0.05}$	0.152	0.101	3.122	1.918	0.010	0.012	1.093	1.056

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

Indications treatment	Total number of tubers (tuber plant^{-1})		tuber weight (g tuber^{-1})		Yield per plant (kg plant^{-1})		Total production (ton ha^{-1})	
seasons	2021-2020	2021	2021-2020	2021	2021-2020	2021	2021-2020	2021
				I				
I_0	5.14	5.33	105.36	102.54	0.543	0.549	28.966	29.305
I_1	4.90	5.20	103.37	101.36	0.509	0.529	27.173	28.255
I_2	4.80	4.98	102.18	102.42	0.493	0.513	26.317	27.388
$L.S.D._{0.05}$	0.141	0.258	N.S	N.S	0.008	0.006	0.440	0.505
				E				
E_0	4.51	4.83	98.54	95.98	0.445	0.463	23.751	24.743
E_1	5.02	5.21	105.96	104.42	0.534	0.546	28.525	29.136
E_2	5.31	5.48	106.41	105.92	0.565	0.582	30.180	31.069
$L.S.D._{0.05}$	0.087	0.058	1.803	1.107	0.005	0.004	0.300	0.301
				T				
T_0	4.45	4.71	96.84	94.55	0.430	0.446	22.963	23.789
T_1	5.05	5.26	106.59	105.09	0.541	0.555	28.894	29.648
T_2	5.34	5.54	107.47	106.68	0.573	0.590	30.599	31.511
$L.S.D._{0.05}$	0.087	0.058	1.803	1.107	0.005	0.004	0.300	0.301

This action of both trehalose and the soil improvement 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 improvement addition) led to an increase in the absorption of water and nutrients (Table 1 A, B and C) and this was reflected in the improvement of the vegetative growth of the plant (Table 2 A, B and C), which led to an increase in the efficiency of The process of photosynthesis, processing and accumulating nutrients, and then transferring them to the tubers, which caused an increase in yield and its components (3A, B and C).

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