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Effect of foliar spraying with ascorbic acid and nano-silicon on the quantitative and qualitative yield of the potato cultivar Burren grown in southern Iraq

Omar A. Ibrahim *, Abdulla A. Abdulla

Department of Horticulture and Landscape Engineering, College of Agriculture, University of Basrah, Iraq.
***Corresponding author e-mail: omar.ibrahem@uobasrah.edu.iq**
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Abstract

The study was conducted at the Agricultural Research Station of the College of Agriculture, University of Basrah, in Karma Ali area during the agricultural season 2022-2023 to study the effect of foliar spraying with different concentrations of ascorbic acid (0,50,100) mg L^{-1} and different concentrations of nano silicon (0,37.5,75) mg L^{-1} and the interaction between them on the quantitative and qualitative yield of the Burren potato cultivar. The results showed that spraying with ascorbic acid at a concentration of 100 mg L^{-1} was significantly excelled in increasing the total yield and marketable yield, reducing the non-marketable yield, increasing the percentage of dry matter, starch, and specific gravity of tubers, and both concentrations were significantly excelled in increasing the tubers' vitamin C content. Also, plants sprayed with nano-silicon were significantly excelled at a concentration of 75 mg L^{-1} in increasing the total yield and marketable yield, the percentage of dry matter, starch, and specific gravity, and the tubers' vitamin C content, and both concentrations were significantly excelled in the percentage of total soluble solids. The interaction between the two study factors showed a significant effect on all quantitative and qualitative yield traits studied.

Keywords: Potato plant, ascorbic acid, nano-silicon, quantitative yield, qualitative yield.

Introduction

Potato *Solanum tuberosum* L. is one of the most important vegetable crops in the world in terms of cultivated area and production due to its high nutritional value [1]. The cultivated area in Iraq in 2019 amounted to about 56,392 dunums with a total productivity of 392,348 tons and a production rate of 6.957 tons $dunum^{-1}$ [2] One of the means that contribute to increasing productivity is reducing the environmental and biological stresses to which the plant is exposed by using antioxidants, including ascorbic acid (vitamin C) $C_6H_8O_6$, which acts as an enzyme cofactor in the enzymatic reactions of carbohydrate and protein metabolism and enters into the processes of respiration and photosynthesis [3] and in stimulating cell elongation and division and its resistance to environmental stresses such as salt stress [4] .

[6,7] obtained a significant increase in the total yield, marketable yield and percentage of dry matter in tubers when spraying potato plants with ascorbic acid at a concentration of 100 mg L^{-1}, and a significant decrease in the unmarketable yield compared to the control treatment for both growth seasons, and no significant effect was shown in the percentage of total soluble solids (TSS).

[8] noted that when spraying potato plants of the Valor cultivar with different concentrations of ascorbic acid (0, 150, 300, 450) mg L^{-1} caused a significant increase in the total yield, percentage of dry matter and starch in tubers for both seasons of the experiment compared to the control treatment. [9] indicated that spraying potato plants with ascorbic acid at a concentration of 300 mg L^{-1} led to a significant increase in the total yield, marketable yield, dry matter and starch percentage, and total soluble solids percentage in tubers compared to the control treatment for both seasons of the experiment.

Silicon is also one of the beneficial mineral elements that play an important role in reducing salt stress [10]. It is one of the beneficial elements and has important roles in many physiological processes, including improving the effectiveness of photosynthesis, increasing the effectiveness of roots to absorb the elements necessary for plant growth, reducing the toxicity of sodium ions, increasing the ratio of potassium ions to sodium ions, increasing the effectiveness of antioxidant enzymes, reducing the toxicity of heavy elements [11] and eliminating insects [12].

[13] obtained when spraying potato plants with potassium silicate $K_2 SiO_3$ at a concentration of 10 ml L^{-1} and with different spraying numbers (1, 2, 3) sprays in addition to the control treatment, the spraying excelled on the total yield, the percentage of marketable yield, the dry weight of tubers and the percentage of starch for both seasons of the experiment compared to the control treatment. [14] noted that when spraying potato plants of the Burren cultivar with nano-silicon SiO_2 NP_3 at a concentration of 50 mg L^{-1} caused a significant increase in the total yield and the weight of the marketable tuber compared to the control treatment. [15] showed that spraying potato plants with nano-silicon SiO_2 NP_3 at concentrations of (0, 25, 50) mg L^{-1} caused both concentrations a significant increase in the yield of the single plant and the percentage of dry matter, starch and total soluble solids in tubers compared to the control treatment. [16]indicated that spraying potato plants with potassium silicate at a concentration of 10 ml L^{-1} and adding compost to the soil caused a significant increase in the total yield, dry matter percentage and starch in tubers compared to the control treatment without adding compost and the treatment with compost alone for both seasons of the experiment.[17] concluded that spraying potato plants of the spunte cultivar with different concentrations of potassium silicate (0, 500, 100) mg L^{-1} led to a significant increase in the total yield, starch percentage and moisture content in tubers compared to the control treatment.As [18] noted that spraying tomato plants with nano silica at a concentration of (0, 150, 300) kg Si ha^{-1} caused both concentrations to significantly increase in the yield.Given the lack of previous studies under the local conditions of

Basra city on the possibility of using ascorbic acid and nano-silicon to reduce the damage of salt stress, increase the yield and improve its quality, this study was conducted.

Materials and Methods

The field experiment was carried out at the Agricultural Research Station of the College of Agriculture - University of Basrah in Karmat Ali site, during the winter season 2022-2023 and in sility clay soil, where the soil was plowed before planting by perpendicular plowing, after which smoothing and leveling operations were carried out, then decomposed organic fertilizer was added at a rate of 1.5 tons ha^{-1} [13], then the land was divided into three lines, each line was 27 meters long, and pit was divided into 9 experimental units, the length of the unit was 3 meters and its width was 0.50 meters, and the distance between pits was 0.80 meters. The land was irrigated before planting, and then the tubers were cultivated, Burren cultivar, on October 15, 2022. As for the planting distance between one pit and another, it was 0.25 meters and a planting depth of 15 cm. The tubers were planted with agricultural service operations, such as weeding , replacing the lost holes. In addition to that, The fertilizer recommendation was 720 kg of ammonium sulfate fertilizer and 600 kg of calcium superphosphate fertilizer in addition to 240 kg of potassium sulfate ha^{-1} in one batch after a month of cultivation [19]. After 30 days of cultivation, the treatments were started, which included two factors: ascorbic acid at three concentrations of foliar spray (0, 50, 100) mg L^{-1}, and the second factor, nano-silicon, which was also at three concentrations (0, 37.5, 75) mg L^{-1}. The experiment was implemented as a factorial experiment, according to the randomized complete blocks design (R.C.B.D.) The number of treatments was 9 factorial treatments, which is the interaction between three concentrations of foliar spraying with ascorbic acid and three concentrations of nano-silicon fertilizer and three replicates, so the number of experimental units was 27 experimental units. The averages of the results were analyzed statistically using the Genstat statistical program, and the Least Significant Differences Test (L.S.D) was used to compare the averages at a probability level of 0.05.

The experimental measurements included quantitative yield traits of potato plants, which included total yield t ha^{-1}, marketable yield ton.ha^{-1}, non-marketable yield ton.ha^{-1}, in addition to qualitative traits of tubers, which were the percentage of dry matter, percentage of starch, percentage of total soluble solids, tubers' vitamin C content mg 100 g^{-1}, and specific gravity of tubers.

Table (1): Some chemical and physical characteristics of the study soil

Attribute		Value	Unit
pH		7.7	
ECE		5.22	ds m^{-1}
Available Phosphorus		38.8	mg kg^{-1}
Total Nitrogen		0.23	g kg^{-1}
Ready Potassium		101.20	mg kg^{-1}
solube positive ions	Calcium	16.5	millimoles l^{-1}
	Magnesium	11	
	Sodium	21.3	
	Bicarbonates	13.6	
	Sulfates	18.5	
	Chlorides	28.0	
Soil separators	Sand	593	G kg-1
	Silt	271.5	
	Clay	135.5	
Soil texture		sandy loam	

Study indicators:-

1- The total yield, tons per hectare, was calculated from the yield of the plants of the experimental unit and then converted to the hectare basis according to the following equation:

$$\text{Total yield tons.ha}^{-1} = \frac{\text{Yield of the experimental unit (kg)}}{\text{Area of the experimental unit m2}} * 1000$$

$$\text{2-Marketable yield tons.ha}^{-1} = \frac{\text{Marketable yield of the experimental unit (kg)}}{\text{Area of the experimental unit m2}} * 1000$$

3- The unmarketable yield t/hectare-1 = the total yield - the marketable yield

4- The percentage of dry matter in tubers %: - A known weight of potato tubers was taken for each treatment and dried in an electric oven at a temperature of 65-70°C until the weight was stable and the percentage was extracted according to the following equation:

$$\text{dry matter\%} = \frac{\text{Dry weight of the sample}}{\text{fresh weight of the sample}} * 100$$

5- Percentage of starch in tubers: Calculated according to the following equation:

% starch = 17.55 + 0.891 (percentage of dry matter - 24.182) [20]

6- Vitamin C content of tubers (mg 100 gm-1 fresh weight) was estimated according to the method described in [20]

7- Percentage of total soluble solids TSS was estimated by Hand Refract meter

8- Specific density of tubers = $\frac{1.0988 + (\%\ dry\ matter - 24.182)}{211.o4}$ [21]

Results and Discussion

It is clear from Table (2) that the study factors ascorbic acid and nano silicon and the interaction between them had a significant effect on the total yield and the marketable yield, as the plants were sprayed with ascorbic acid at a concentration of 100 mg L^{-1} significantly excelled in increasing the total yield by an increase rate of 12.31% and the marketable yield by an increase rate of 17.32% compared to control treatment , while it caused a significant decrease in the unmarketable yield by a decrease rate of 27.73% compared to control treatment. The spraying treatment at a concentration of 50 mg L^{-1} did not differ significantly from them for all the traits under study. The increase in the total and marketable yield may be due to the role of ascorbic acid in accelerating cell division and expansion [4] and stimulating active growth as it enters as an enzyme companion in the enzymatic reactions of carbohydrate and protein metabolism [3]. As for the decrease in the unmarketable yield, it may be due to the role of ascorbic acid in increasing the tuber weight, which was positively reflected in reducing the unmarketable yield. These results are consistent with [7,8,9].

The same table shows that spraying with silicon led to a significant increase in the total and marketable yield, and the effect increased with increasing the spray concentration, as the high concentration of 75 mg L^{-1} was significantly excelled and by an increase rate of 75.59, 49.54% in the total yield and (86.81, 55.34) % in the marketable yield compared to control treatment and the concentration of 37.5 mg L^{-1}, respectively. In turn, the spray concentration of 37.5 mg L^{-1} was significantly excelled compared to control treatment and by an increase rate of 17.65, 20.25% for both traits, respectively, while spraying with nano-silicon did not significantly affect the unmarketable yield. The significant superiority may be attributed to the role of nano-silicon in increasing plant hormones that encourage growth and the absorption of elements necessary for growth such as potassium and calcium and reducing the concentrations of sodium ions[22], in addition to increasing the effectiveness of Antioxidant enzymes increase the tolerance of plants to environmental stresses, including salt stress to which plants were exposed [10], in addition to the role of silicon in increasing vegetative growth indicators and leaf content of total chlorophyll and carotene pigments [23], which was positively reflected in increasing the total yield and marketable yield. These results are consistent with [24,14,15].

The interaction between the two study factors showed a significant effect, as plants sprayed with ascorbic acid at a concentration of 50 mg L^{-1} and nano-silicon at a concentration of 75 mg L^{-1} gave the highest values for the total yield and the marketable yield, which reached 33.94 and 31.887 tons ha^{-1}, respectively, while plants sprayed with ascorbic acid at a concentration of 50 mg L^{-1} and not sprayed with nano-silicon gave the lowest values, which reached 15.286 and 13.131 tons ha^{-1}, respectively. As for the non-marketable yield, plants sprayed with ascorbic acid and not sprayed with nano-silicon gave the lowest yield, which reached 1.623 tons ha^{-1}, while plants not sprayed with both factors gave the highest non-marketable yield, which reached 2.361 tons ha^{-1}.

Table (2): Effect of foliar spraying with ascorbic acid and silicon Nano and the interaction between them in some quantitative yield traits of potato plants.

Treatments	Total yield (ton.ha^{-1})	Marketable yield (yield ton.ha^{-1})	Unmarketable yield yield ton.ha^{-1}
0	20.713	18.406	2.304
50	21.965	19.877	2.091
100	23.263	21.594	1.665
0	16.753	14.709	2.042
37.5	19.711	17.688	2.018
75	29.476	27.478	1.996
LSD 0.05	2.01	1.632	N.S
0-0	18.995	16.633	2.361
37.5-0	21.38	19.086	2.293
75-0	21.765	19.501	2.26
0-50	15.286	13.151	2.133
37.5-50	16.655	14.593	2.071
75-50	33.945	31.887	2.055
0-100	15.98	14.345	1.633
37.5-100	21.09	19.395	1.69
75-100	32.72	31.044	1.673
LSD 0.05	4.175	3.545	0.435

Table (3) shows that the spraying treatments with ascorbic acid have significantly affected all the qualitative traits studied except for the percentage of total soluble solids, where the spraying concentration with 100 mg L^{-1} significantly increased the percentage of dry matter in tubers compared to control treatment and the spray concentration with 50 mg L^{-1} by an increase of 7.71, 13.49% and in the percentage of starch by an increase of 10.97, 20.02% and in the specific density by an increase of 0.50, 0.85% and in the content of vitamin C in tubers by an increase of 23.73, 4.73% respectively. The significant increase of ascorbic acid when using the appropriate concentration in increasing and improving the qualitative traits of tubers may be attributed to its role in increasing cell division and the effectiveness of a number of enzymes and maintaining chloroplasts as it is one of the antioxidants. [25] and thus increasing the efficiency of the photosynthesis process and increasing the production of nutrients manufactured in the leaves and their transfer to the tubers, which was positively reflected in increasing the qualitative traits. These results are consistent with [7,8,9].

The same table shows that spraying with nano-silicon had a significant effect on all the qualitative traits of the studied tubers, as both concentrations were significantly excelled compared to control treatment, and the effect increased significantly with increasing spray concentration, with an increase rate of 7.28, 14.50% in the percentage of dry matter, 10.71, 21.31% in the percentage of starch, 10.48, 30.49% in the tubers' vitamin C content, and 0.45, 0.91% in the specific density of tubers, respectively. Both concentrations were also significantly excelled compared to control treatment in the percentage of total soluble solids, with an increase rate of 30.14, 29.57%, and the two concentrations did not differ significantly between them. The significant increase in the qualitative traits of potato tubers when spraying with the appropriate concentration of nano-silicon may be attributed to its positive role in reducing environmental stresses, including The salt stress that plants were exposed to increase the effectiveness of the root system, reduced the rate of transpiration, and improved the effectiveness of the photosynthesis process [11], thus increasing the production of nutrients manufactured in the leaves and their transfer to the tubers, which was positively reflected in improving the qualitative traits of the tubers. These results are consistent with [24,16,15,17].

As for the interaction between the two study factors, it had a significant effect on all the studied qualitative traits of tubers, as plants not sprayed with ascorbic acid and sprayed with nano-silicon at a concentration of 37.5 mg L^{-1} gave the highest values for the percentage of dry matter, starch, percentage of total soluble solids and specific density of tubers, which reached (16.64%, 10.83%, 4.76% and 1.0633%), respectively, while plants sprayed with ascorbic acid at a concentration of 100 mg L^{-1} and nano-silicon at a concentration of 75 mg L^{-1} gave the highest content of vitamin C in tubers, which reached 21.5 mg 100 g^{-1} fresh weight, while plants not sprayed with both factors gave the lowest values for the percentage of dry matter, starch, percentage of total soluble solids, amount of vitamin C and specific density, which reached (13.06%, 7.65%, 3.4%, 12.26 mg/100 g^{-1} fresh weight and 1.0463%) respectively.

Table (3): Effect of foliar spraying with ascorbic acid and nano-silicon and their interaction on some qualitative traits of potato tubers

Treatments	Dry matter (%)	Starch (%)	TSS (%)	Vitamin C (mg/100g)	Specific Gravity
0	14.9	9.29	4.22	14.65	1.0551
50	14.11	8.59	4.28	17.31	1.0514
100	16.05	10.31	4.26	18.13	1.0604
0	14	8.49	3.55	14.69	1.0506
37.5	15.02	9.4	4.62	16.23	1.0556
75	16.05	10.31	4.6	19.17	1.0604
LSD 0.05	0.16	0.14	N.S	0.49	0.0007
0-0	13.02	9.39	4.5	15.25	1.0463
37.5-0	13.06	9.13	4.76	16.63	1.0556
75-0	16.05	10.36	4.63	19.14	1.0633
0-50	13.02	7.86	4.1	16.7	1.0476
37.5-50	13.76	8.92	4.06	15.83	1.0503
75-50	15.7	10.55	4.63	19.4	1.0563
0-100	15.93	9.96	4.73	17.63	1.0586
37.5-100	16.35	10.39	4.39	20.43	1.061

75-100	16.35	10.58	4.41	21.5	1.0616

In order to increase the productivity of the potato cultivar Burren and improve its quality, it is necessary to spray the plants with ascorbic acid at a concentration of 100 mg L^{-1} and nano silicon at a concentration of 75 mg L^{-1} under the conditions of Basrah city, which suffers from salt stress in its soil.

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