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EFFECT OF NITROGEN , PHOSPHORUS AND POTASSIUM LEVELS AND FOLIAR SPRAY WITH CITRIC AND SALICYLIC ACIDS ON GROWTH, YIELD AND FRUIT QUALITY OF TOMATO PLANTS

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ABSTRACT: A field experiment was carried out during summer seasons of 2019 and 2020 at a Private Farm, Abo-Hammad Dictrict, Sharkia Governorate, Egypt, to study the effect of N, P, K levels (25% NPK of the recommended rate (RR), 50% NPK (RR), 75% NPK (RR) and 100% NPK (RR) and foliar spray with citric (2g/l) and salicylic acids (0.2 g), beside sprayed with water (control) on growth, yield and fruit quality of tomato cv.186 grown in clay soil conditions and using drip irrigation sybranches. The interaction between fertilizing tomato plants with 75% RR of N,P and K (90, 60 and 90 kg of N,P and K, respectively) and spraying with salicylic acid at 0.2 g/l significantly increased dry weight of shoots, N,P and K total uptake , number of fruits/ plant , average fruit weight, yield/ plant and total yield/fad., TSS and dry matter in fruits**.** However, the interaction between fertilizing with 75% RR of N, P and K without spraying increased acidity in fruits. Whereas, the interaction between fertilizing with 100% RR of N,P and K and spraying with salicylic acid at 0.2 g/l increased vitamin C contents in fruits.

Key words: Tomato, mineral fertilizers, citric and salicylic acids, foliar application, yield and fruit quality.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important fruit vegetable belong to the family Solanaceae which is grown throughout the world. In terms of human health, tomato is a major component in the daily diet and serves as an important source of nutrients including antioxidants like lycopene, a carotenoid phytonutrient that act as an anti-carcinogen and improves skin's ability to protect against harmful ultra violet (UV) rays. It is rich in vitamins, minerals and dietary fiber **(Olaniyi *et al*., 2010**).

Fertilizer is a major part of the crop expenses for tomato production, and it is critical for successful crop yields and high fruit quality. Fertilizer requirements of tomato are quite high due to its high yielding potential per unit area and time. Accordingly, mineral nutrition with suitable levels of nitrogen (N), phosphorus (P) and potassium (K) had a key role for improving the growth and fruit yield of tomato, as well as influencing the tomato plant's ability to with stand negative effects from pests, water, temperature, and other stresses. Nevertheless, N along with P and K, are, still, classified as primary macronutrients or major nutritive elements, which are needed in relatively large quantities and are often deficient in crops not receiving fertilizer application (**Marschner, 1995**).

Fertilizing tomato plants with the moderate levels of N, P and K recorded the best results for increasing dry weight (**Iqbal *et al*., 2011; El-Hamdi *et al.*, 2011; Etissa *et al*., 2013**) and N, P and K uptake (**Fouda and Abd-Elhamied 2017)** on tomato, yield and its components (**Akhtar *et al*., 2010; Parisi *et al*., 2015; Du *et al*., 2021**) and fruit quality **(Mesallam *et al*., 2017**).

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Citric acid as antioxidants due to their molecules auto (ox-redox) properties act as cofactors for some specific enzymes *i.e.*, dismutases, catalases, peroxidases and those catalyzed breakdown of the toxic H_2O_2, OH and O_2 radicals (**Fathy , *et al*. 2003**).

Spraying plant with citric acid significantly incrassated dry weight, N, P and K uptake, yield and fruit quality **(Glala *et al*., 2005; Ali *et al*., 2009; El- Desouky *et al*., 2011** on tomato and **El-Afifi *et al*., 2017**) on sweet pepper.

Salicylic acid (SA) is an endogenous plant growth factor of phenolic nature that possesses an aromatic ring with a hydroxyl group or its hormone plays a vital role in plant growth, ion uptake and transport (**Hayat *et al*., 2010**). SA treatments were generally effective on vegetative growth, photosynthetic ability and thereby helping in effective flower formation and fruit development and ultimately enhance productivity of the crops (**Yildirim and Dursun 2008**).

Spraying tomato plants with SA significantly increased dry weight (**Salehi *et al*., 2011; Kazemi, 2014** on tomato and **Raghami *et al*., 2016)** on eggplant, N, P and K uptake **(Emara (2019)** on tomato**,** productivity **(Javaheri *et al*., 2012; Hafeznia *et al*., 2014; Singh *et al*., 2017; Abd El-Hady *et al*., 2021)** and fruit quality **Raghami *et al*., 2016; Faid *et al*., 2020)**.

Therefore, the aim of this work to study the effect of N, P and K levels and foliar spray with citric and salicylic acids on yield and fruits quality of tomato plants during summer plantations.

MATERIALS AND METHODS

A field experiment was carried out during summer seasons of 2019 and 2020 at a Private Farm, Abo-Hammad Dictrict, Sharkia Governorate, Egypt, to study the effect of N, P , K levels and foliar spray with citric and salicylic acids on growth, yield and fruit quality of tomato cv. T186 grown in clay soil conditions and using drip irrigation system .

The physical and chemical properties of the experimental soil are presented in Table 1.

This experiment was included twelve treatments, which were the combination between four levels of NPK mineral fertilizers and two stimulants as foliar spray, beside unsprayed treatment as follow:

NPK Levels

25% NPK of the recommended rate (RR), 50% NPK (RR), 75% NPK (RR) and 100% NPK (RR).

Foliar Spray Treatments

Spraying with water (control) , spraying with citric acid at 2 g/l and spraying with salicylic acid at 0.2 g/l.

These treatments were arranged in split plot design system with three replications, NPK mineral fertilizers levels were randomly arranged in the main plots, while foliar spray with citric acid and salicylic acids were randomly distributed in sub-plots.

The recommended rate of N,P and K were 120, 80 and 120 kg/fad., N, P and K were added in the form of ammonium nitrate (3.0% N), calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), respectively. One third of different levels of N, P and K fertilizers were added at the time of soil preparation. The other two thirds were divided into four equal portions and added every two weeks. The first portion was added after 30 days from transplanting.

Citric acid and Salicylic acid (SA-2 hydroxybenzoic acid) were obtained from El-Gomhouria Co. for trading medicines, chemicals and medical appliances, Sharkia Governorate, Zagazig, Egypt. Salicylic acid (SA) was dissolved in absolute ethanol then added drop-wise to water (ethanol/water: 1/1000, *V/V*).

After 30 days from seeds sowing in nursery, at 10th and 12th April during the 1st and 2nd seasons, seedlings of cv. T186 Techno Green were transplanted at 50 cm apart on one side of dripper line. Plot area was 19.2 m^2. It contains two dripper lines, each of 8m length and 1.2 m wide. The distance between two drippers on the line was 50cm. Plants of the 1st line (9.6 m^2) were used for samples to measure vegetative growth, and plant chemical analysis. Meanwhile plants of the 2nd line (9.6 m^2) were used for yield determination.

Table 1. The physical and chemical properties of the experimental soil at 2019 and 2020 seasons

Soil property	1st season	2nd season
Physical properties		
Clay (%)	68.60	67.19
Silt (%)	21.29	23.81
Sand (%)	10.11	9.00
Texture	Clay	Clay
Chemical properties		
E.C. (mmhos/cm)*	2.11	2.42
pH**		
Organic matter (%)	1.99	1.92
Available N (ppm)	9.98	9.92
Available P_2O_5 (%)	0.041	0.044
Available K_2O (%)	0.87	0.83

Samples of the soil were obtained from 25 cm soil surface.

*E.C: Electric conductivity, ** pH (1: 2.5 suspension).

Citric and salicylic acids were sprayed four times at 30, 45, 60 and 75 days after transplanting with aid a manual atomizer to accomplish thoroughly and uniform coverage of the plants foliage, and simultaneously the untreated plants (control) were sprayed with water. In addition, one dripper line was left between each two experimental units as guard area to avoid the overlapping foliar sprayed. The other normal agricultural treatments of growing tomato plants were practiced

Data Recorded

A random sample of three plants from each sup-plot were taken at 90 days after transplanting to determine: Dry weight of branches /plant, dry weight of leaves/plant and shoot dry weight/ plant (branches+ leaves) after dried at (70°c) till constant weight.

Nitrogen, phosphorus and potassium content%

The dry weight of different plant parts, i.e., branches and leaves finely ground and digesting with sulfuric acid and perchloric acid (3:1). nitrogen, phosphorus and potassium were determined as dry weight basis according to the methods described by **Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970),** respectively. N,P and K uptake and total uptake were calculated.

Yield and its component

Fruits of all harvesting were counted, weighted and the following yield parameters were calculated as follows: Number of fruits/ plant, average fruits weight (gm), yield/plant (kg) and total yield/fed.(ton)as well as relative yield (%) was calculated.

Fruit Quality

Five fruits from every plot were taken randomly at full-ripe maturity stage, to determine the following parameters: Total soluble solids (TSS); it was determined in juice by Carle Zeis refractometer. Vitamin C (vit. C); it was assayed in juice (mg/L juice) using 2,6 dichlorophenol indophenol dye (**AOAC, 2019**). Titratable acidity%; it was determined by the titration method with 0.1 sodium hydroxide using phenolphthalin indicator (**AOAC, 2019**). Dry matter (%): a sample of 100 g of fruits were oven dried at 70 ºC till constant weight and dry matter was determined.

Statistical Analysis

Recorded data in both experiments were subjected to the analysis of variance to **Snedecor and Cachran (1980**). Mean separation were done by **Duncan (1958**).

RESULTS AND DISCUSSION

Plant Growth

Effect of N,P and K levels

Data presented in Table 2 show the effect of N,P and K levels on dry weight of tomato plants in summer seasons of 2019 and 2020. Fertilization tomato plants cv.186 at different levels had significant effect on dry weight of branches, dry weight of leaves and dry weight of shoots/ plant at 90 days after transplanting in both seasons. Soil application of tomato plants with 75% of recommended rate (RR) of N, P and K (90, 60 and 90 kg /fad. of N, P and K, respectively) recorded the highest values of dry weight of leaves and dry weight of shoots.

The increases in dry weight of shoots/plant were about 0.07 and 6.6% for fertilizing tomato plants with 75% RR of N,P and K over 100% RR of N,P and K in the 1st and 2nd seasons, respectively.

The increase in plant growth may be attributed to the beneficial effects of N on stimulating the meristmatic activity for producing more tissues and organs, since N plays major roles in the synthesis of structural proteins and other several macro molecules, in addition to its vital contribution in several biochemical processes that related to plant growth (**Marschner, 1995**). Phosphorus is an essential component of the energy transfer compounds, genetic information sybranches, cell membranes and phosphoproteins (**Gardener *et al.*, 1985*).*** On the other hand, they also added that potassium is the prevalent cation in the plant and may be involved in maintenance of ionic balance in the cells, and it bounds ionically to the enzyme pyruvate kinase, which is essential in respiration and carbohydlevels metabolism.

Table 2. Effect of N,P and K fertilizer levels and foliar spray with some stimulants on dry weight of branches, leaves and shoots of tomato plant at 90 days after transplanting during 2019 and 2020 summer seasons

Treatments	Dry weight of branches / plant (g)		Dry weight of leaves/ plant (g)		Dry weight of shoots/ plant (g)		Relative ± in shoot dry weight (%)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
Effect of N,P and K fertilizer levels								
25% RR	28.01 c	30.66 d	38.22 d	41.54 d	66.23 c	72.21 d	-17.3	-13.2
50% RR	31.85 b	34.66 c	40.06 c	44.21 c	71.92 b	78.88 c	-10.1	-5.2
75%RR	37.40 a	40.66 a	43.22 b	47.98 a	80.62 a	88.64 a	+0.07	+6.6
100%RR	35.73 a	36.44 b	44.31 a	46.74 b	80.04 a	83.18 b	0.0	0.0
Foliar spray with some stimulants								
Unsprayed	27.73 c	31.50 b	37.26 c	40.41 c	65.00 c	71.91 c	00.0	00.0
CA at 2 g/l	35.38 b	37.00 a	42.26 b	46.09 b	77.65 b	83.09 b	19.5	15.5
SA at 0.2 g/l	36.63 a	38.33 a	44.83 a	48.85 a	81.46 a	87.19 a	25.3	21.2

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5%N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O)

CA= citric acid and SA= salicylic acid

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

These results are true in both seasons of study and matched well with those reported by **Iqbal *et al*. (2011) , El-Hamdi *et al.* (2011) and Etissa *et al*. (2013**) on tomato plants.

Effect of citric and salicylic acids

Results recorded in Table 2 show the effect of foliar spray with citric acid and salicylic acid on dry weight of tomato plants. Foliar spray of tomato plants with citric acid (CA) at 2g /l and salicylic acid (SA) at 0.2 g/l at 30, 45, 60 and 75 days after transplanting increased dry weight of branches, dry weight of leaves and dry weight of shoots/plant at 90 days after transplanting compared to unsprayed plants (control) in both seasons.

Spraying with SA at 0.2 g/l increased dry weight of branches, dry weight of leaves and dry weight of shoots/plant at 90 days after transplanting with no significant differences with CA at 2 g /l with respect to dry weight of branches in the 2nd season.

The increases in dry weight of shoots were about 19.5 and 15.5% for spraying with CA at 2 g/l, 25.3 and 21.2% for spraying with SA at 0.2 g/l over unsprayed plants in the 1st and 2nd seasons, respectively.

Salicylic acid (SA) or ortho-hydroxy benzoic acid and other salicylates are known to affect various physiological and biochemical activities of plants and may play a key role in regulating their growth and productivity (**Hayat *et al.*, 2010)**. It plays a diverse physiological role in plants which include plant growth (**Khan *et al.*, 2003**).

Obtained results agree with those reported by **Yildirim and Dursun (2008), Salehi *et al.* (2011), Javaheri *et al.* (2012), Kazemi (2014)** on tomato and **Raghami *et al.* (2016)** on eggplant regarding SA effect .

As for citric acid, **Ali *et al*. (2009)** found that spraying tomato plants with citric acid was the best treatment for increasing dry weight/ plant than unsprayed plants.

Effect of the interaction

The effect of interaction between N, P and K levels and spraying with citric acid and salicylic acid on dry weight of tomato plants in summer seasons during 2019 and 2020 are presented in Table 3. The interaction between N,P and K at 75% RR and foliar spray with SA at 0.2 g /l increased dry weight of branches, dry weight of leaves and dry weight of shoots/plant.

The increases in dry weight of shoots were about 28.5 and 28.5% for the interaction between fertilizing tomato plants with 75% RR of N,P and K and spraying with SA at 0.2 g/l over 100% RR of N,P and K only in the 1st and 2nd seasons, respectively.

N, P and K Uptake

Effect of N,P and K levels

Data presented in Table 4 show the effect of N, P and K levels on N,P and K uptake of tomato plants in summer seasons of 2019 and 2020 under clay soil conditions . Fertilization tomato plants with 50, 75 and 100% RR of N,P and K increased N,P and K uptake by branches and leaves and total N, P and K uptake by shoots compared to 25% RR of N, P and K. In general, 75% RR of N,P and K increased NP and K uptake by branches and leaves and total uptake of N, P and K by shoots with no significant differences with 100% RR of N, P and K in the same cases.

Phosphorus is the provision of chemical energy and formation of well developed root sybranches depends largely upon phosphorus element as well as decreased pH of soil, where high soil reaction causing inhibition in nutritional uptake for that phosphorus enhancing the uptake of different elements by plants, **(Saga, 1972).**It is of interest to note that the obtained results of minerals uptake showed a trend exactly similar to those observed with dry weights (Table 2).

These results are in harmony with those reported by **El-Hamdi *et al*. (2011) on tomato and Fouda and Abd-Elhamied (2017)** on eggplant.

Effect of citric and salicylic acids

Data in Table 5 show the effect of spraying with citric acid and salicylic acid on N,P and K uptake of tomato plants in summer seasons of 2019 and 2020 under clay soil conditions. Spraying tomato plants with CA at 2g /l and SA at 0.2 g/l increased N,P and K uptake by branches and leaves and total uptake of N, P and K by shoots compared to control (sprayed with

Table 3. Effect of the interaction treatments between N,P and K fertilizer levels and some stimulants on dry weight of branches , leaves and shoots of tomato plant at 90 days after transplanting during 2019 and 2020 summer seasons

Treatments		Dry weight of branches / plant (g)	Dry weight of leaves/ plant (g)	Dry weight of shoots/ plant (g)	Relative ± in shoot dry weight (%)
NPK levels	Stimulants		2019 season		
25%RR	Unsprayed	23.36 f	32.00 g	55.36 g	-21.8
	CA at 2 g/l	28.93 e	40.26 e	69.20 e	-1.00
	SA at 0.2 g /l	31.73 cd	42.40 cd	74.13 cd	6.0
50%RR	Unsprayed	28.36 e	36.60 f	64.96 f	-7.1
	CA at 2 g/l	33.60 c	40.26 e	73.86 d	5.6
	SA at 0.2 g /l	33.60 c	43.33 c	76.93 c	10.0
75%RR	Unsprayed	30.06 de	39.66 e	69.73 e	-0.03
	CA at 2 g/l	40.13 ab	42.13 cd	82.26 b	17.6
	SA at 0.2 g /l	42.00 a	47.86 a	89.86 a	28.5
100RR	Unsprayed	29.13 de	40.80 de	69.93 e	0.00
	CA at 2 g/l	38.86 b	46.40 ab	85.26 b	21.9
	SA at 0.2 g /l	39.20 ab	45.73 b	84.93 b	21.5
			2020 season		
25%RR	Unsprayed	27.00 e	34.34 h	61.34 h	-19.8
	CA at 2 g/l	31.00 d	44.08 ef	75.08 fg	-1.8
	SA at 0.2 g /l	34.00 cd	46.21 cd	80.21 cde	4.9
50%RR	Unsprayed	32.00 d	40.31 g	72.31 g	-5.4
	CA at 2 g/l	36.00 bc	45.10 de	81.10 cd	6.1
	SA at 0.2 g /l	36.00 bc	47.22 c	83.22 c	8.8
75%RR	Unsprayed	34.00 cd	43.52 f	77.52 def	1.4
	CA at 2 g/l	43.00 a	49.26 b	92.26 ab	20.7
	SA at 0.2 g /l	45.00 a	51.15 a	96.15 a	28.5
100RR	Unsprayed	33.00 cd	43.46 f	76.46 ef	0.0
	CA at 2 g/l	38.00 b	45.92 cd	83.92 c	9.8
	SA at 0.2 g /l	38.33 b	50.84 a	89.17 b	16.6

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5%N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O)

CA= citric acid and SA= salicylic acid

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 4. Effect of N,P and K fertilizer levels on N, P and K uptake by branches and leaves and total uptake by shoot (mg) of tomato plant at 90 days after transplanting during 2019 and 2020 summer seasons

Treatments	Branches			Leaves			Total uptake		
	N	P	K	N	P	K	N	P	K
					2019 season				
25% RR	632.97 c	116.95 c	941.5 d	1020.9 c	148.13 d	1409.7 d	1653.9 c	265.08 c	2351.2 c
50% RR	794.20 b	149.49 b	1130.4 c	1152.5 b	161.39 c	1556.7 c	1946.7 b	310.87 b	2687.1 b
75%RR	972.48 a	195.11 a	1486.6 a	1468.2 a	188.04 b	1764.9 b	2440.7 a	383.16 a	3251.5 a
100%RR	928.04 a	180.96 a	1353.1 b	1434.9 a	197.04 a	1898.1 a	2362.9 a	378.00 a	3251.1 a
					2020 season				
25% RR	708.2 d	130.82 d	1127.2 d	1143.7 d	166.60 c	1528.2 d	1851.9 d	297.42 d	2655.3 d
50% RR	868.5 c	166.41 c	1331.9 c	1321.2 c	187.65 b	1801.0 c	2189.7 c	354.04 c	3132.9 c
75%RR	1068.5 a	229.76 a	1750.4 a	1660.1 a	220.90 a	2075.0 b	2728.6 a	450.67 a	3825.5 a
100%RR	949.9 b	178.60 b	1485.5 b	1546.7 b	219.07 a	2121.2 a	2496.5 b	397.66 b	3606.6 b

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5%N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O)

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 5. Effect of foliar spray with some stimulants on N, P and K uptake by branches and leaves and total uptake by shoot (mg) of tomato plant at 90 days after transplanting during 2019 and 2020 summer seasons

Treatments	Branches			Leaves			Total uptake		
	N	P	K	N	P	K	N	P	K
					2019 season				
Unsprayed	650.46 c	120.68 c	927.0 c	969.7 c	140.10 c	1328.6 c	1620.2 c	260.78 c	2255.6 c
CA at 2 g/l	886.12 b	172.91 b	1313.5 b	1352.5 b	179.38 b	1722.6 b	2238.6 b	352.28 b	3036.1 b
SA at 0.2 g/l	959.19 a	188.29 a	1443.2 a	1485.2 a	201.48 a	1920.8 a	2444.4 a	389.76 a	3364.0 a
					2020 season				
Unsprayed	743.4 c	132.85 b	1117.7 c	1157.4 b	157.49 c	1518.9 c	1900.8 c	290.32 c	2636.6 c
CA at 2 g/l	928.4 b	194.71 a	1511.1 b	1548.4 a	205.49 b	1944.0 b	2476.8 b	400.21 b	3455.1 b
SA at 0.2 g/l	1024.5 a	201.63 a	1642.4 a	1548.0 a	232.67 a	2181.1 a	2572.5 a	434.31 a	3823.5 a

CA= citric acid and SA= salicylic acid

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

water) as shown in Table 5. Foliar spray with SA at 0.2 g/l gave the highest values N,P and K uptake by branches and leaves and total uptake of N, P and K by shoots , followed by Ca at 2 g/l in both seasons.

This can be attributed to the role of salicylic acid to improve membrane permeability, absorption and utilization of mineral nutrients, also, SA facilitate absorption and mineral nutrients and transport of assimilates (**Javaheri *et al*., 2012**).

Similar findings were obtained by **Abd El-Gawad and Bondok (2015)** and **Emara (2019)**. They showed that spraying tomato plants with SA significantly increased N, P and K uptake by plants than unsprayed plants . Also **El- Desouky *et al.* (2011)** showed that spraying tomato plants with citric acid at 2.5 or 5 g / liter significantly increased nitrogen , phosphorus and potassium contents in leaves than unsprayed plants**.**

Effect of the interaction

Data recorded in Table 6 show the effect of the interaction between N, P and K levels and spraying with citric and salicylic acids on N,P and K uptake of tomato plants in summer seasons of 2019 and 2020 under clay soil conditions. N, P and K uptake and total uptake, the interaction between 75% RR of N,P and K and spraying with SA at 0.2 g /l significantly increased N,P and K uptake by branches and leaves and total uptake of N,P and K by shoots in both seasons.

Yield and its Components

Effect of N, P and K levels

Data tabulated in Table 7 indicate the effect of N, P and K levels on yield and its components of tomato plants in 2019 and 2020 summer seasons. Data show that early and total yield and its components increased with increasing N,P and K up to 100% RR of N,P and K. This means that 100% RR of N, P and K increased number of fruits/plant, average fruit weight, yield/plant and total yield/fad., in both seasons.

The increments in yield of tomato may be due to the increases in the dry weight (Table 2) and also due to the increase in fruit number and average fruit weight (Table 7). In other words, the positive effect of mineral N, P and K application on tomato fruit yield may be directly correlated with improving plant growth, dry matter production, and yield components.

Plants need nitrogen, phosphorus and potassium as a certain mineral nutrients to grow and to produce yield, being required in the largest quantities and generally become deficient first in the soil. Availability of nutrient has been reported to be directly related to high yield (**Roberts, 2001**). The role of phosphorus is improving yield of plant is as a constituent of ATP and activates growth of plant and activates amino acid to synthesis of protein **(Devline and Withan, 1972)**. Also, phosphorus plays a great role in cell division and cell elongation as well as the synthesis of nucleic acids (**Rizk and Shafeek, 2000)**.

These results agree with those reported by **Akhtar *et al* (2010), Parisi *et al*. (2015) and Du *et al*. (2021)** on tomato.

Effect of citric and salicylic acid

Spraying tomato plants with CA at 2g /l and SA at 0.2 g/l increased yield and its components compared to unsprayed (spraying with water in both seasons (as shown in Table 7). Foliar spray with SA at 0.2 g/l significantly increased number of fruits/plant, average fruit weight, yield/plant and total yield/fad., in both seasons, followed by foliar spray with CA at 2 g/l.

The increases in total yield were about 4.7 and 18.1% for spraying with CA at 2 g /l , 8.5 and 25.2% for spraying with SA at 0.2 g /l over unsprayed plants in the 1st and 2nd seasons, respectively.

The beneficial effect of SA as foliar application on tomato yield may be correlated with improving dry weight production (Table 2) and minerals uptake (Table 5).

In this concern, **Vicente and Plasencia (2011)** suggested that the growth-promoting effects of SA could be related to changes in the hormonal status. Also, thermogenesis, flower induction, nutrient uptake, and then increased total yield (**Larque-Saavedra, 1979)**. Obtained results were similar to those reported **Javaheri *et al.* (2012), Hafeznia *et al.* (2014), Singh *et al*. (2017) and Abd El-Hady *et al*. (2021)** all on tomato plants they indicated that highest yield and its components were recorded when plants sprayed with SA than unsprayed plants.

Table 6. Effect of the interaction treatments between N,P and K fertilizer levels and some stimulants on N, P and K uptake by branches and leaves and total uptake by shoots (mg) of tomato plant at 90 days after transplanting during 2019 and 2020 summer seasons

Treatments		Branches			Leaves			Total uptake		
		N	P	K	N	P	K	N	P	K
NPK levels	**Stimulants**	**2019 season**								
25%RR	**Unsprayed**	**505.5 f**	**85.04 f**	**646.9 i**	**804.3 f**	**102.40 g**	**961.1 f**	**1309.8 g**	**187.43 h**	**1607.9 j**
	CA at 2 g/l	657.9 e	121.71 e	1008.7gh	1048.7 e	162.17 e	1553.2 d	1706.6 f	283.87 f	2561.9 h
	SA at 0.2 g/l	735.5 d	144.11 cd	1169.1 ef	1209.8 c	179.82 cd	1714.8 b	1945.3 de	323.93 e	2883.8 f
50%RR	Unsprayed	658.2 de	121.08 e	934.3 h	934.2 ef	134.09 f	1289.9 e	1592.4 f	255.17 g	2224.2 i
	CA at 2 g/l	849.7 c	162.74 c	1182.3 e	1214.7 c	162.31 e	1588.9 cd	2064.4 cd	325.03 e	2771.3 fg
	SA at 0.2 g/l	874.7 c	164.64 c	1274.6 d	1308.7 c	187.78 c	1791.1 b	2183.4 c	352.40 d	3065.7 e
75%RR	Unsprayed	716.5 de	139.19de	1070.5fg	1071.8 d	157.40 e	1511.6 d	1788.3 ef	296.60 f	2582.1 h
	CA at 2 g/l	1025.0 b	209.53 b	1629.4 b	1523.3 b	177.59 cd	1694.4 bc	2548.3 b	387.13 c	3323.8 d
	SA at 0.2 g/l	1176.0 a	236.60 a	1759.8 a	1809.4 a	229.13 a	2088.7 a	2985.4 a	465.73 a	3848.5 a
100%RR	Unsprayed	721.7 de	137.41de	1056.3 g	1068.4 d	166.51 de	1551.9 d	1790.1 ef	303.93 ef	2608.2 gh
	CA at 2 g/l	1011.9 b	197.65 b	1433.6 c	1623.4 b	215.43 b	2053.8 a	2635.2 b	413.10 b	3487.3 c
	SA at 0.2 g/l	1050.6 b	207.80 b	1569.4 b	1612.9 b	209.18 b	2088.6 a	2663.5 b	416.97 b	3657.9 b
		2020 season								
25%RR	Unsprayed	580.5 i	97.92 e	810.9 i	888.3 h	108.40 i	1057.9 i	1468.8 f	206.30 i	1868.8 h
	CA at 2 g/l	697.5 h	133.78 d	1195.9gh	1220.3 f	183.70 fg	1665.9 g	1917.8 e	317.50gh	2861.8 f
	SA at 0.2 g/l	846.6 efg	160.76cd	1374.7def	1322.5 ef	207.69 e	1860.7 e	2169.1 d	368.47 f	3235.4 de
50%RR	Unsprayed	755.2 gh	138.39 d	1107.7 h	1091.6 g	153.61 h	1507.3 h	1846.8 e	291.97 h	2615.0 g
	CA at 2 g/l	910.8 def	180.84bc	1421.6cd	1444.4 c	192.41 f	1857.1 e	2355.2 c	373.27 ef	3278.7 d
	SA at 0.2 g/l	939.6 de	180.00bc	1466.4cd	1427.6 cd	216.93 d	2038.5 d	2367.2 c	396.90 de	3504.9 c
75%RR	Unsprayed	822.8 fg	151.88 d	1295.8efg	1325.9 de	182.98 g	1758.5 f	2148.7 d	334.87 g	3054.3 ef
	CA at 2 g/l	1113.7 b	268.75 a	1900.5 a	1874.9 a	220.02 cd	2100.1 cd	2988.6 a	488.77 b	4000.6 b
	SA at 0.2 g/l	1269.0 a	268.65 a	2055.0 a	1779.6 a	259.69 a	2366.5 b	3048.6 a	528.37 a	4421.6 a
100%RR	Unsprayed	815.1 g	143.20 d	1256.4fg	1323.8def	184.98 fg	1751.9 fg	2138.9 d	328.17 g	3008.3 f
	CA at 2 g/l	991.8 cd	195.46 b	1526.6bc	1653.9 b	225.84 c	2152.8 c	2645.7 b	421.30 cd	3679.4 c
	SA at 0.2 g/l	1042.7 bc	197.13 b	1673.4 b	1662.3 b	246.38 b	2458.8 a	2705.0 b	443.50 c	4132.2 b

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5%N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O)

CA= citric acid and SA= salicylic acid

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 7. Effect of N,P and K fertilizer levels on yield and its components of tomato plant during 2019 and 2020 summer seasons

Treatments	Number of fruits/ plant		Average fruit weight (g)		Yield / plant (kg)		Total yield /fad. (ton)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
Effect of N,P and K fertilizer levels								
25% RR	21.46 c	19.31 d	71.51 d	89.39 d	1.535 c	1.730 d	10.581 c	11.950 d
50% RR	26.38 b	25.50 c	99.35 c	110.15 c	2.623 b	2.813 c	18.251 b	19.258 c
75%RR	32.76 a	30.68 b	118.57 a	118.69 a	3.884 a	3.650 b	27.008 a	25.116 b
100%RR	32.58 a	33.71 a	120.08 a	116.75 a	3.912 a	3.937 a	27.205 a	27.104 a
Effect of foliar spray with some stimulants								
Unsprayed	27.43 b	25.20 c	100.73 c	102.58 c	2.860 c	2.642 c	19.882 c	18.227 c
CA at 2 g/l	28.66 a	27.74 b	101.49 b	110.75 b	2.997 a	3.135 b	20.824 b	21.521 b
SA at 0.2 g/l	28.79 a	28.96 a	104.91 a	112.90 a	3.109 a	3.320 a	21.578 a	22.823 a

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5% N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O)
CA= citric acid and SA= salicylic acid
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

As for citric acid effect**, El- Desouky *et al*. (2011)** showed that spraying tomato plants with citric acid at 2.5 or 5 g/liter significantly increased average fruit weight, fruit diameter and fruit length and total yield (kg/plant) than unsprayed plants**.** Also **El- Afifi *et al*. (2017**) indicated that, fruit length, fruit diameter, number of fruits/ plant, average fruit weight and total yield/fad., significantly increased with spraying citric acid at 2000 ppm than unsprayed sweet pepper plants.

Effect of the interaction

Data in Table 8 show that, the interaction between 75% or 100% RR of N, P and K and spraying with SA at 0.2 g/l increased number of fruits/plant, average fruit weight, yield/plant, total yield /fad in both seasons, except number of fruits/ plant in the 2nd season, with respect the interaction between 100% RR of N, P and K and spraying with SA at 0.2 g/l and average fruit weight with respect to the interaction between 75% RR of N, P and K and spraying with SA at 0.2 g / l. This means that the interaction between 75%% RR of N, P and K and spraying with SA at 0.2 g/l increased number of fruits/plant, average fruit weight, yield / plant and total yield/ faddan.

The stimulative effect of the interaction between mineral N, P and K levels and spraying with SA or citric acid may be due to their vital role in enhancing nutrients uptake and total uptake (Table 6) and hence the photosynthetic rate which may reflect a favorable effect on plant growth and total yield.

Fruit Quality

Effect of N,P and K levels

Data presented in Table 9 show the effect of nitrogen phosphorus and potassium levels on chemical composition of tomato fruits, i.e., total soluble solids (TSS), vitamin C, and acidity in tomato fruits. The obtained results in Table 9 show that, fertilizing tomato plants with 75% RR of N, P and K significantly increased TSS (brix), acidity (%) and dry matter contents, whereas 100% RR of N, P and K significantly increased vitamin C in fruits in both seasons. Increasing NPK rate up to 75% produced significant positive linear trend regarding total protein in fruits, TSS, dry matter and Vit. C concentration.

Table 8. Effect of the interaction treatments between N,P and K fertilizer levels and some stimulants on yield and its components of tomato plant during 2019 and 2020 summer seasons

Treatments		Number of fruits/ plant	Average fruit weight (g)	Yield / plant (kg)	Total yield /fad. (ton)
NPK levels	**Stimulants**		**2019 season**		
25%RR	**Unsprayed**	20.36 f	69.74 i	1.420 f	9.840 j
	CA at 2 g/l	22.16 e	69.36 i	1.537 ef	10.559 i
	SA at 0.2 g/l	21.86 e	75.43 h	1.649 e	11.343 h
50%RR	**Unsprayed**	25.74 d	95.07 g	2.447 d	17.100 g
	CA at 2 g/l	26.73 d	100.22 f	2.679 c	18.653 f
	SA at 0.2 g/l	26.69 d	102.77 e	2.743 c	19.000 f
75%RR	**Unsprayed**	31.69 c	118.40 c	3.752 b	26.000 e
	CA at 2 g/l	32.93 ab	117.13 d	3.857 ab	26.809 cd
	SA at 0.2 g/l	33.66 a	120.17 ab	4.045 a	28.215 a
100RR	**Unsprayed**	31.94 bc	119.72 b	3.824 ab	26.587 de
	CA at 2 g/l	32.83 ab	119.25 bc	3.915 ab	27.275 bc
	SA at 0.2 g/l	32.98 ab	121.26 a	3.999 a	27.753 ab
			2020 season		
25%RR	**Unsprayed**	17.95 i	84.79 f	1.522 f	10.639 f
	CA at 2 g/l	19.54 h	87.92 e	1.718 ef	11.818 f
	SA at 0.2 g/l	20.45 g	95.45 d	1.952 e	13.393 e
50%RR	**Unsprayed**	24.89 f	95.62 d	2.380 d	16.452 d
	CA at 2 g/l	25.42 f	116.88 b	2.971 c	20.277 c
	SA at 0.2 g/l	26.19 e	117.95 b	3.089 c	21.044 c
75%RR	**Unsprayed**	26.98 d	114.12 c	3.079 c	21.248 c
	CA at 2 g/l	31.02 c	120.95 a	3.752 b	25.685 b
	SA at 0.2 g/l	34.05 b	121.00 a	4.120 a	28.416 a
100RR	**Unsprayed**	30.99 c	115.81 bc	3.589 b	24.569 b
	CA at 2 g/l	34.98 a	117.24 b	4.101 a	28.304 a
	SA at 0.2 g/l	35.16 a	117.21 b	4.121 a	28.439 a

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5% N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) , CA= citric acid at and SA= salicylic acid

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 9. Effect of N,P and K fertilizer levels on fruit quality of tomato plant during 2019 and 2020 summer seasons

Treatments	TSS brix		Acidity (%)		Vit. C (mg /100 ml juice)		Dry matter (%)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
Effect of N,P and K fertilizer levels								
25% RR	4.50 d	3.97 c	0.336 d	0.353 d	12.86 d	13.62 d	4.27 d	4.04 d
50% RR	5.35 c	4.72 b	0.410 c	0.431 c	14.22 c	14.93 c	5.05 c	5.30 c
75%RR	5.69 a	5.01 a	0.476 a	0.496 a	16.11 b	16.92 b	5.37 a	5.69 a
100%RR	5.52 b	4.98 a	0.436 b	0.457 b	17.92 a	18.92 a	5.25 b	5.59 a
Effect of foliar spray with some stimulants								
Unsprayed	4.94 c	4.31 c	0.448 a	0.445 b	13.24 c	13.82 c	4.59 b	4.72 c
CA at 2 g/l	5.37 b	4.80 b	0.427 b	0.472 a	15.53 b	16.56 b	5.14 a	5.33 b
SA at 0.2 g/l	5.49 a	4.90 a	0.370 c	0.385 c	17.07 a	17.92 a	5.22 a	5.43 a

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5% N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O)
CA= citric acid at and SA= salicylic acid
Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

These results are in harmony with those reported by **Parisi *et al*. (2015)** and **Du *et al.* (2021)** on tomato.

Effect of citric and salicylic acids

The effect of citric and salicylic acids as foliar spray on fruit quality of tomato are presented in Tables (9). Foliar spray with SA at 0.2 g /l increased TSS, vitamin C and dry matter in fruits in both seasons, without significant differences with citric acid at 2 g /l with respect to dry matter (%) in the 1st season. Citric acid at 2 g /l increased acidity in the 2nd season.

Increasing such constituents in tomato fruits consider very important since, tomato is one of the highly important foods in human nutrition for its highly nutritive value. It is rich in vitamins A and C, in addition to its value to human healthy, contributed to tomato acidity. Hence, the applied treatments improved the quality of tomato fruits by increasing their concentrations of total soluble solids, Vitamin C and the titratable acidity **(El-Desouky *et al.* 2011)**.

These results are in harmony with those reported by **Raghami *et al.* (2016) and Faid *et al*. (2020)** they indicated that spraying with SA was the best for enhancing fruit quality than unsprayed plants.

As for citric acid, **Ali *et al*. (2009)** found that spraying tomato plants with citric acid increasing fruit quality such as TSS and vitamin C in fruits than unsprayed plants, also, **El- Desouky *et al.* (2011)** showed that spraying tomato plants with 2.5 or 5 g/liter significantly increased vitamin C, total soluble solids and titratable acidity as well as N, P and K contents in fruits than unsprayed plants**.**

Effect of the interaction

Data recorded in Table 10 show the effect of interaction between N,P and K levels and spraying with citric and salicylic acids on tomato fruit quality during 2019 and 2020 summer season . The interaction between 75% RR of N,P and K and foliar spray with SA at 0.2 g/l increased TSS and dry matter in fruits, whereas the interaction between100% RR of N,P and K and spraying with SA at 0.2 g /l increased vitamin C in fruits in both seasons . Fertilizing with 75% RR of N,P and K without spraying increased acidity in fruits in both seasons.

Table 10. Effect of the interaction treatments between N,P and K fertilizer levels and some stimulants on fruit quality of tomato plant during 2019 and 2020 summer seasons

Treatments		TSS brix	Acidity (%)	Vit. C mg /100 ml juice	Dry matter (%)
NPK levels	**Stimulants**		**2019 season**		
25%RR	**Unsprayed**	4.17 h	0.386 f	10.80 g	3.83 h
	CA	4.53 g	0.330 g	13.22 ef	4.44 g
	SA	4.80 f	0.296 h	14.58 d	4.54 fg
50%RR	**Unsprayed**	4.97 f	0.429 d	12.45 f	4.61 f
	CA	5.50 cd	0.416 de	14.22 de	5.25 c
	SA	5.59 bcd	0.385 f	16.00 c	5.28 c
75%RR	**Unsprayed**	5.42 de	0.525 a	13.71 de	5.05 d
	CA	5.71 bc	0.500 b	16.53 c	5.45 b
	SA	5.95 a	0.407 def	18.10 b	5.61 a
100RR	**Unsprayed**	5.20 e	0.454 c	16.01 c	4.86 e
	CA	5.77 ab	0.463 c	18.16 b	5.44 b
	SA	5.61 bcd	0.394 ef	19.59 a	5.46 b
LSD at 0.05 level		0.22	0.022	0.99	0.16
			2020 season		
25%RR	**Unsprayed**	3.61 h	0.350 f	11.34 h	3.54 i
	CA	4.03 g	0.402 e	14.21 f	4.26 h
	SA	4.28 f	0.308 g	15.31 d	4.31 h
50%RR	**Unsprayed**	4.29 f	0.433 d	12.74 g	4.82 g
	CA	4.89 cd	0.459 c	15.26 de	5.50 de
	SA	4.98 bc	0.400 e	16.80 c	5.60 cd
75%RR	**Unsprayed**	4.59 e	0.520 a	14.39 ef	5.35 e
	CA	5.14 ab	0.546 a	17.35 c	5.78 b
	SA	5.29 a	0.423 de	19.01 b	5.95 a
100RR	**Unsprayed**	4.76 de	0.479 c	16.81 c	5.16 f
	CA	5.13 ab	0.481 c	19.40 b	5.77 bc
	SA	5.06 bc	0.410 de	20.57 a	5.85 ab
LSD at 0.05 level		0.18	0.032	0.88	0.17

RR= The recommended rate of N,P and K were 120, 80 and 120 kg/fad. N,P and K in the form of ammonium sulphate (20.5%N) , calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), CA= citric acid at 2 g/l and SA= salicylic acid at 0.2 g/l

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

From the foregoing results, it could be concluded that during summer plantation, fertilizing tomato plants cv.186 with 75% RR of N,P and K (90, 60 and 90 kg of N,P and K, respectively) and spraying with salicylic acid at 0.2 g/l increased dry weight of shoots, N,P and K total uptake , number of fruits/ plant , average fruit weight, yield/ plant and total yield /fad., TSS and dry matter in fruits.

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تأثير مستويات النيتروجين والفوسفور والبوتاسيوم والرش الورقى بحمضى الستريك والسالسيلك على النمو والمحصول وجوده ثمار نباتات الطماطم

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اجرى هذ العمل خلا موسمى صيف 2019، 2020 بمزرعه خاصه ، مركز أبو حماد ، محافظه الشرقيه ، مصر وذلك لدراسة معدلات النيتروجين والفوسفور والبوتاسيوم (25، 50، 75 و100% من الموصى به) والرش بحمضى الستريك 2 جرام/لتر، حمض السالسيلك بتركيز 0.2 جم/لتر)، بجانب معامله الرش بالماء (معامله المقارنه) على النمو والمحصول وجوده ثمار الطماطم صنف 186 النامية فى الارض الطينية وتحت نظام الرى بالتنقيط. سجل معامله التفاعل بين تسميد نباتات الطماطم بمعدل 75% من الموصى به من النيتروجين والفوسفور والبوتاسيوم (90، 60 ، 90 كجم من النيتروجين والفوسفور والبوتاسيوم على التوالى) والرش بحمض السالسيلك بتركيز 0.2 جم/لتر لزياده الوزن الجاف للمجموع الخضرى، الممتص الكلى من النيتروجين والفوسفور والبوتاسيوم، عدد الثمار على النبات، متوسط وزن الثمرة، محصول النبات والمحصول الكلى للفدان، محتوى الثمار من المواد الصلبة الذائبة والمادة الجافة، علاوة على ذلك سجلت معامله التفاعل بين التسميد بمعدل 75% من الموصى به من النيتروجين والفوسفور فقط لزياده محتوى الثمار من الحموضة. بينما سجلت معامله التفاعل بين التسميد بمعدل 100% من الموصى به من النيتروجين والفوسفور والبوتاسيوم والرش بحمض الساليسلك بمعدل 2 جم / لتر لزياده محتوى الثمار من فيتامين ج.

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