ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. IX, Issue 5/ August 2021

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Role of organic and mineral liquid fertilizer on growth, some mineral and biochemical composition of tomato growing in hydroponic and field conditions

SADEQ J. H. DWENEE
IBRAHIM B. RAZZAQ
HAMID SH. MUGHEIR
AHMAD I. ABDALHADI
SAHAR ABD-ALATEEF KHUDEER
SUHAM M. BAJAEE
Ministry of Science and Technology
Directorate of Agricultural Research

Abstract:

The experiment was carried out during two agricultural seasons (2017) and (2018) to evaluating the use of mineral solutions (M), solutions containing organic extracts and mineral supplements (MC) and organic extracts (C) in the growth of tomato plants under hydroponic conditions in the first season and under field conditions in Second season. The results of hydroponic experiment showed superiority of (M) for wet weight of fruits of tomato , percentage of soluble solids in fruits , average number of fruits and vegetative weight of plant by 18.8, 101.9 and 15.2, 25.6 and 20.5, 154.7 and 22.6, 116.2 (%) as compared to treatments (MC) and (C) respectively. The results of second season in field condition showed superiority of (M•C) treatment in the wet weight indices of tomato fruits , percentage of soluble solids in fruits , average number of fruits and vegetative weight of plants by 12.4, 24.3 and 10.8, 18.6 and 11.6, 38.1 and 30 6, 80.5 (%) as compared to (M•) and (C) respectively. The results showed superiority of (C) in the potassium concentration in the vegetative parts compared to (M.C) and (M•) by 5.5, 8.4 and 14.3, 15.8 (%) for hydroponic conditions and field conditions respectively.

Keywords: Tomato, Hydroponic, Liquid fertilizer, Organic extractable

INTRODUCTION:

The increase in population in the world generated increased pressure and demand on plant and animal production in the world (FAO 2010), which as a result led to an increase in the demand for production elements, including fertilizers of all kinds, mineral, organic and liquid. Liquid fertilizers are one of the techniques used for the purpose of providing the plant with its needs of the nutrients necessary for plant growth and improvement in terms of quantity and quality (Al-Nuaimi 1999). The benefit and importance of liquid fertilizers in modern agriculture is that it is easy to add to the plant through modern irrigation systems and that the nutrients are ready for absorption by the plant due to their presence in the soil solution in a formula ready for absorption by the plants. Tomato is an important vegetable crop for food consumption in the world. The area cultivated with this crop in the world is estimated at about 12 million hectares. In Iraq, it amounted to about 303521 dunums (Estefan and Abdulaziz, 1998). Vegetable plants need mineral and organic fertilization in a large amount for the purpose of increasing production and improving quality, as studies have shown that the addition of nitrogen, phosphorus and potassium fertilizers led to a significant increase compared to the control treatment (Shamshad and Butt. 1999, ALmamori & Abdul-Ratha 2020). Kumar et al. 2013 stated that the addition of nitrogen, phosphate and potassium fertilizers at levels of 75, 80 and 180 kg / ha, respectively, increased the yield of tomato fruits per plant from 6.03 to 10.11 kg per plant compared to the addition of individual fertilizers for nitrogen 7.32 kg, phosphorus 7.81 kg and potassium 6.78 Kg per plant for the same levels of fertilizer addition above. Numerous research studies have indicated that adding organic fertilizers to the soil improves the fertile soil properties (Weil 2001) and increases production in quantity and quality. Jassim et, al 2014, stated that the addition of organic fertilizers (compost of corn cob) led to a significant increase in the total yield of tomato, as it reached 17.43 Mg h^{-1} when the organic matter was not added, while the addition of organic matter at the level of 12 Mg h^{-1} led to an increase in the total yield to 34.04 Mg h^{-1}. Al-Shammari et al. 2020 reported that the addition of 10 Mg h^{-1} compost led to a significant decrease in the bulk density values, reaching 12.1 Mg h^{-1}, and an increase in Mean Weight Diameter (M.W.D) and the saturated hydraulic conductivity of 47.1 mm and 3.10 cm $hour^{-1}$, respectively. The addition of mineral and organic fertilizers is one of the determining factors for production and is included in the production cost due to the high prices and their need for manpower and machinery, which are additional costs that make the economic income of tomato production relatively low. Therefore, this research aims to find alternatives from organic and mineral fertilizers to obtain a relatively high feasible economic income.

MATERIALS AND METHODS:

The research was carried out over the 2016-2017 and 2017-2018 seasons and included two consecutive experiments due to the dependence of the second experiment on the results of the first experiment, as follows:

1-First experiment: 2016-2017 hydroponic:

The hydroponic farm experiment consisted of conducting a steady state hydroponic experiment in the greenhouse of the Agricultural Research Department / Zaafaraniya, where 3 basins were made of cork material and covered with polyethylene tightly, with dimensions of 1.0 * 1.0 meters and a height of 0.2 meters for one basin and topped with a layer of perforated cork with holes to allow the growth of plants with a diameter of 2.0 cm and the number of holes 25 holes equal distances in length and width between the holes. The basins are equipped with 3 air pumps, so that they are distributed evenly on the basins, each pump has three tubes to supply 3 basins with equal ventilation, and each basin takes its ventilation from three pumps in order to ensure that the ventilation is distributed equally to all basins and to overcome the variation that may occur as a result of different pumping air in each pump.

Preparation of nutrient solutions:

1- Mineral nutrient solution (M): The solution containing the nutrients necessary for plant growth was prepared according to the modified Hoagland and included the salts of the nutrients as shown in Table 1

2- Organic extract (C): A nutrient solution was prepared from an extract of corn cob compost by adding 0.1 M sulfuric acid to compost at a ratio of 1:5, and then diluting with a ratio of 1:10 when adding to the basins (Table 2). Buffer solution consisting of a weak acid and its salt was added to maintain the degree of reaction of the nutrient solution.

3- Organic-mineral extract (MC): The solution was prepared from adding mineral supplements from the salts of the elements shown in Table 1 to the organic extract.

Table 1: Mineral contents of the nutrient solution.

	Salt	$\mu M.l^{-1}$
1	$CaCl_2.2H_2O$	200.0
2	K_2SO_4	100.0
3	$MgSO_4.7H_2O$	50.0
4	KH_2PO_4	10.0
5	NH_4NO_3	400.0
6	Fe Na EDTA	10.0
7	H_3BO_3	3.00
8	$CuSO_4.5H_2O$	0.10
9	$MnSO_4.2H_2O$	0.25
10	$Na_2MoO_4.2H_2O$	0.02
11	$ZnSO_4.7H_2O$	0.30

Table 2. The nutrient content of the organic extract

Element	ppm	Element	ppm
N	182.16	Mn	10.15
P	51.28	Fe	25.80
K	71.65	Zn	5.43
Mg	325.62	Na	205.89
Ca	476.81	Cl	171.75
Cu	4.94	B	1.82

Tomato (local variety) were cultivated on 10/19/2016 in the hydroponic system basins, according to the treatment that mentioned in procedures. The salinity of solution (EC) was continuously monitored as well as the pH was adjusted so that the salinity of the solution did not exceed 2.5 dS/m and the degree of reaction was between 6.0-7.0 by neutralizing it with 0.1 standard hydrochloric acid and 0.1 standard sodium hydroxide. The nutrient solution was replaced weekly with new solutions.

2- Second experiment: field cultivating of tomato by drip irrigation.

A plot of land was prepared at the Tuwaitha site within the sustainable agriculture and combating desertification station with an area of 400 square meters, and plowing, leveling and smoothing operations were performed, and then a drip irrigation system was installed to form three lines for each line. Liquid fertilizers that were used in the hydroponic farm technology were distributed randomly. Table 3 shows the physical and chemical characteristics of the soil used in the experiment.

Table 4 shows the components of the mineral liquid fertilizer (M∘) that was prepared based on the results of soil analyzes in Table 3 and added the salts of the elements (B, Zn, Fe, Cu, N, P, K,) and as shown in Table 4 in order to meet the tomato need Of these nutrients according to Tandon 1995. Irrigation with fresh water with electrical conductivity EC 0.8 dS/m and the treatments of liquid mineral fertilizers (M∘), organic extracts (C) and organic extracts fortified with nutrients (M∘C) were added individually and directly to the locally grown plants in order to ensure that the treatments were not mixed. And make sure that solutions are delivered to the plants, as well as to avoid the losses that may occur through the passage of fertilizers through the drip tubes. Table 4 shows the components of the liquid mineral fertilizer that was added to the plants directly for the treatment of mineral fertilization, and which was added to

Table 3. Some physical and chemical characteristics soil

EC $dS\ m^{-1}$	pH	O.C	Total N	Ava. K	Sand	Silt	Clay	Texture
1:1		%		ppm	g/kg			
3.38	7.31	0.46	0.063	121.8	62	398	540	S.C
Na	Ca	Mg	K	SO_4	Cl	HCO_3		SAR
Soluble cations and Anions in mmol/kg								
17.23	10.51	4.82	0.87	9.52	14.95	0.02		4.40
DTPA Extractable Trace Elements ppm						Sol. B		Ava. P ppm

Zn	Fe	Mn	Cu	ppm	
1.08	4.81	8.42	1.45	5.18	7.92

Table 4. The components of the mineral fertilizer (M∘) that was added to the plant directly and that was added to the organic extract to compensate the organic extract shortage with mineral fertilizer (M∘C).

Element	mg per 10 ml	Element	mg per 10 ml
N (urea)	10.0	Mn ($MnSO_4.H_2O$)	1.20
P (KH_2PO_4)	2.1	Cu ($CuSO_4$)	0.80
K (KNO_3)	5.4	Zn ($ZnSO_4.H_2O$)	1.80
Fe ($FeSO_4.7H_2O$)	2.7	B (H_3BO_3)	0.40

The organic extract to represent the treatment of the organic extract fortified with nutrients. Treatments were added in the form of doses, each dose of 10 ml, at a rate of two doses per week, the content of each 10 ml of solution of mineral nutrients is shown in Table 4.

Local variety of Tomato were planted on 10/25/2017 and placed near the dripper, each plant separately, and covered with polyethylene caps to protect them from the effect of low temperature with daily ventilation by opening the covers regularly and daily. Liquid fertilizer treatments and organic extracts were added over the growth periods, at a rate of twice a week. Growth continued for 105 days thereafter harvesting and relevant indicators were recorded.

The study indicators were taken as follows:

The vegetative parts and tomato fruits: wet weight of tomato fruits, percentage of dissolved solids in the fruits, average number of fruits and vegetative weight of the plant in addition to measuring the concentration of Zn, Cu, Mn, Fe, P, N and K in plant.

Soil, plant and water analyzes:

- (pH): using a pH meter (HANNA pH 211) in a 1: 1 soil extraction and irrigation water according to the method mentioned in (Page et al. 1982).

-(EC): measured in a 1: 1 soil extraction and water using the WTW Cond 720 according to the aforementioned method (Page et al. 1982).

-Bicarbonate: measured by titration with (0.02N) sulfuric acid (Jackson, 1973).

-K and Na: a flame photometer (JENWAY) according to (Richards, 1954).

- Cl: by the colorimetric method involving color development using mercury thiocyanate and ferric ion, and measurement using a Spectro Photometer (SPECORD 205) as in (Page et al., 1982).

-SO_4: determined by turbidity method by using $BaCl_2$ and using a spectrophotometer (SPECORD 205) according to (Black, 1965).

-O.M: estimated according to the Walkley, Black method mentioned in (Black, 1965).

- Mg, Ca: estimated by the Atomic Absorption Device (AAS Nova 400), according to the method mentioned in (Page et al., 1982).

-Total Nitrogen: estimated using the BUCHI apparatus according to the method described by Bremner mentioned in (Page et al. 1982).

-Available K: extracted with 1.0N ammonium acetate and was estimated by the Flame Photometer (JENWAY) according to (Tandon, 1995).

-Soil texture: estimated according to Day (1965) and Black (1965).

-The elements (Fe, Cu, Zn, Mn, P, B) were estimated according (Page et al. 1982)

RESULTS AND DISCUSSION:

Hydroponics experience.

In this study, the results of the first season of the steady state Hydroponic experiment. (Table 5) show that the addition of the mineral solutions (M), solutions containing organic extracts and mineral supplements (MC) and organic extracts (C) led to clear differences in the growth indicators of tomato. As the results showed a superiority of the treatment (M) for the indicators of wet weight of tomato fruits, the percentage of soluble solids in fruits, the average number of fruits and the vegetative weight of the plant by 18.8, 101.9 and 15.2, 25.6 and 20.5, 154.7 and 22.6, (116.2%) as compared to treatments (MC) and (C) respectively. The results also showed that the (M.C) treatment was superior to the (C) treatment for the indicators of wet weight of tomato fruits, percentage of soluble solids in fruits, average number of fruits and vegetative weight of the plant by 70.05, 9.02, 111.85 and 76.33 (%), respectively.

Table 5. The effect of the mineral solutions (M), solutions containing organic extracts and mineral supplements (MC) and organic extracts (C) on some growth indicators of tomato in the hydroponic experiment

Indicators	M	MC	C	L.S.D 0.01
wet weight of fruits (gm)	629.6	530.2	311.8	30.94
percentage of soluble solids in fruits %	22.48	19.51	17.90	2.107
average number of fruits	20.24	16.80	7.93	3.263
vegetative weight (gm)	439.3	358.3	203.2	40.44

The previous results show that the reason for the superiority of the mineral solutions treatment is due to its high content of nutrients necessary for plant growth, as shown in Table 3, as it is the only source for supplying the plant with nutrients due to the absence of soil as another source to supply the plant with nutrients, and this result is consistent with many studies that have indicated the positive effect of nutrients on growth of plants grown in hydroponic systems (HuiPing, M., et al 2008, Sharma et al., 2018 and Anna Rita, and P. Gherbin. 2006).

Table 6 shows the effect of adding mineral solutions (M), solutions containing organic extracts and mineral supplements (MC) and organic extracts (C) on some nutrients content of the vegetative part of the tomato. The results show the superiority of (M) treatment over the (MC) and (C) treatment in the indicators of potassium, nitrogen, phosphorous and manganese elements, with an increase of 5.50 and 8.40, 38.1 and 93.3, 23.4 and 82.7, 14.3 and 196.8 (%) for the treatment (MC) and (C) treatment respectively.

This result is coincided with the growth indicators shown in Table 4, as the nutrients Mn, P, N, K have a direct and important effect on the growth of crops and increase the productivity (Al-Nuaimi 1984) with noting that there are no significant differences in the superiority of the iron and copper index between the two treatments of (MC) and (M). This result can be explained by the fact that the presence of organic compounds such as sugars, organic and humic acids, alcohols and phenols in the organic extract contributes to the increase in the entry movement of nutrients with relatively high atomic weights such as Cu, Fe and Zn by their association with chelating bonds, and it may also be due to the presence of organic compounds with relatively high molecular weights in the root zone contributed to the increase in the interstitial distances of the root cells and the entry of heavy elements such as Cu, Fe and Zn into the plant with the obsolete Apoplast pathway, as indicated by Aubry et al., 2019 and (Al-Nuaimi 1984).

Table 6. The effect of the (M), (C) and (MC) on the mineral content of tomato plant in the hydroponic experiment.

Parameters	(M)	(MC)	(C)	Mean	L.S.D 0.01
K%	1.924	1.822	1.770	1.842	0.121
P%	0.293	0.211	0.152	0.222	0.046
N%	3.383	2.744	1.852	2.663	0.306
Cu ppm	13.14	14.89	7.24	11.76	4.76
Mn ppm	120.52	105.30	40.61	88.81	13.85
Fe ppm	137.38	140.53	62.28	113.40	7.54
Zn ppm	34.81	38.23	21.91	31.65	3.3.8

Field experiment

Table 7 shows the effect of adding mineral solutions (M), organic extracts (C), and solutions containing organic extracts and mineral supplements (MC) on indicators of wet weight of tomato fruits, percentage of soluble solids in fruits, average number of fruits and vegetative weight of the plant. The results showed superiority of (M.C) treatment over (M) and (C) treatment by 12.4, 24.3 and 10.8, 18.6 and 11.6, 38.1 and 30.6, 80.5 (%) for the above-mentioned indicators, respectively.

The results show the superiority of the MC, M and C treatment over the comparison treatment (Cont.) For the wet weight index of tomato fruits by 73.5, 54.4 and 39.6 (%) and for the percentage of soluble solids in fruits by 35.1, 21.9 and 13.9% and for the average number of fruits by 85.4, 66.1, and 34.2 (%), and for the vegetable weight index, by 144.8, 87.5, and 35.6 (%), for the treatment MC, M, and C, respectively.

Table 7. The effect of the (M), (C) and (MC) on some growth indicators of tomato in the field experiment

Parameters	MC	M	C	Con.	L.S.D 0.01
wet weight index of tomato fruits for each plant (gm)	1458.6	1297.4	1173.1	840.5	120.6
soluble solids in fruits (%)	24.58	22.18	20.72	18.19	2.37
average number of fruits for each plant	15.53	13.89	11.22	8.36	2.26
vegetative weight of the plant (gm)	802.7	614.8	444.7	327.9	167.2

The results, in Table 8, also showed a significant superiority of M.C treatment over M and C treatment with respect to Control for indicators of the content of the vegetative part of potassium (89.7%, 65.9% and 63.8%), phosphorous (108.6%, 75.3% and 40.9%), nitrogen (64.2%, 43.7% and 23.2%), copper (159.9%, 110.2% and 64.6%) and manganese (177.6%, 157.3% and 24.2%), iron (132.7%, 110.7% and 36.0%), and zinc (115.6%, 84.8% and 46.2%).

This result shows a difference from what was obtained from the results in the hydroponics experiment, as the MC treatment have superiority over the rest of the treatments with complete compatibility with all the studied indicators. This may due to the fact that the organic extracts in addition to being contain different concentrations of nutrients, as explained previously, they contain Sulfuric acid with a concentration of 0.1M, which was used in the preparation of the organic extract, as mentioned previously in the materials and methods of work, which when added to the soil, reduces soil reaction (pH) within the spot that was added to it, which increases the availability of the nutrients, especially trace elements whose availability is affected by the soil reaction pH (Al-Nuaimi 1999, Al-Ghariri 1998). This is an advantage of acid prepared nutrition solution that the prepared organic extract is distinguished by adding sulfuric acid to the corn cob compost, which is added to the soil exclusively and near the cradle of plants through drippers, and it is not recommended to add it to the leaves as a spray because the sulfuric acid may cause the burning of plant leaves which confirms the importance of adding mineral solutions in conjunction with organic extracts in the field,

Table 8. The effect of the (M), (C) and (MC) on mineral content of tomato in the field experiment

parameters	MC	M	C	Con.	Mean	L.S.D 0.01
K %	2.75	2.406	2.38	1.45	2.25	0.342549
P %	0.194	0.163	0.13	0.093	0.15	0.031
N %	2.48	2.17	1.86	1.51	2.01	0.253
Cu ppm	7.64	6.18	4.84	2.94	5.40	1.291
Mn ppm	84.83	78.62	37.95	30.56	57.99	6.033
Fe ppm	78.81	71.35	46.06	33.87	57.52	6.564
Zn ppm	29.84	25.57	20.24	13.84	22.37	4.877

This integration increases the availability of the nutrients that already exist in the soil and improves the fertile soil characteristics by the effect of organic extracts that contain many organic acids, sugars, carbohydrates and proteins, as well as providing the plant with the nutrients accompanying the organic extract furthermore the mineral contained of the components of the organic extract (Power, 1994, Brady and Wiel, 1999) and as indicated in Table 2 above.

The results of the averages of Tables 6 and 8 show the superiority of all the averages of the study indicators for the content of the vegetative part of the nutrients in the experiment of the hydroponic over the experiment of the field with the exception of the index of the content of the vegetative part of the element of potassium, which can be attributed to the exposure of plants to saline stress and as shown in Table 3 which shows Field soil characteristics as tomato plants collect potassium in their vegetative parts as a means of resistance to the stress they were exposed to as a result of exposure to salt stress, and this is in agreement with Surya Kant and Uzi Kafkafi 2002, which showed that plants accumulate potassium in their tissues when exposed to abiotic stresses or perhaps the decrease in potassium concentration in the aquatic farm experiment was due to the dilution factor of the potassium element in plant tissue, which occurred as a result of the increase in vegetative growth and the average number of fruits due to the availability of ideal conditions for growth of nutrients and controlled growth conditions.

CONCLUSIONS AND RECOMMENDATIONS:

From the results presented above, it is possible to conclude and recommend the following:

1- The use of organic extracts supplemented with nutrients led to an increase in the yield and quality of tomato fruits compared to traditional methods of liquid fertilizers.

2- The method of preparing the organic extract with 0.1M sulfuric acid and adding it to the soil near the cradle of plants led to an increase in the availability of the nutrients already present in the soil.

3- The necessity of using organic extracts and adding them to liquid mineral fertilizers because of their positive effect on increasing the availability of plant nutrients and improving the soil fertility.

4- Conducting economic feasibility studies to exploit the organic extracts that are usually produced as waste in organic fertilizer manufacturing plants, use them in aquatic farm systems, and prepare liquid mineral fertilizers.

5- Expanding the use of organic extracts supplemented with nutrients in the cultivation of economic crops such as wheat, yellow corn, and others.

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