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Role of Foliar Application of Organic Liquid Fertilizers Fortified with Phosphorus and Calcium in Tomato Yield and Fruit Quality

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Abstract:**This study was conducted in Al-Nakhil Station - Al-Najaf governorate/Iraq during the growing season of 2021. The study aimed to identify the role of foliar application with organic liquid fertilizers rich in phosphorous and calcium in some indicators of yield and fruit quality of the limited-growth hybrid tomato (OULA F1). The field trial comprised two factors represented by phosphorous and calcium fertilizers and was setup as a factorial experiment with three replications according to a Randomized Complete Block Design (RCBD). The first factor included spraying of phosphorous as NPK with three concentrations (0, 1, 2) ml.L^{-1}, and the second factor was three concentrations of calcium spray (0, 1.25, 2.5) ml.L^{-1}. Two-way ANOVA was performed and the averages of the treatments were compared according to the LSD test at a probability level of 0.05. The results showed the superiority of spraying treatment with organic liquid fertilizer rich in phosphorous at a concentration of (2 ml.L^{-1}) for the measured indicators (fruit set percent, fruit number per plant, and total yield) reached the maximum average (69.37%, 36.32 fruits.$plant^{-1}$, 44.37 t.ha^{-1}), respectively, except for fruit weight was the highest (80.56 g.$fruit^{-1}$) at a concentration (1 ml.L^{-1}). Further, tomato plants sprayed with organic calcium fertilizer at (2.5 ml.L^{-1}) resulted in the maximum average for yield parameters (fruit set 74.24%, fruit number 37.77 fruits.$plant^{-1}$, fruit weight 82.38 g.$fruit^{-1}$, total yield 47.88 t.ha^{-1}), compared to the control treatment (without spray). There were significant variations between tomato treatments in terms of fruit quality indicators, where the high concentration of organic NPK fertilizer fortified with P has improved percentages of N, P, and K in tomato fruits as well as vitamin C content in fruits (1.53%, 0.43%, 2.09%, and 21.87 mg. 100 ml^{-1} fresh juice), consecutively, in comparison with non-sprayed plants. However, the fruit Ca and fruit firmness reached the highest average (0.80% and 2.92 kg.cm^2) at the concentration (1 ml.L^{-1}) of P fertilizer. In addition, all fruit minerals N, P, K, and Ca, as well as fruit firmness and vitamin C content were significantly enhanced when organic Ca fertilizer was applied at a concentration of (2.5 ml.L^{-1}) and realized the highest average (1.59%, 0.41%, 2.03%, 0.83%, 3.61 kg.cm^2, 25.30 mg. 100 ml^{-1} fresh juice), respectively, as compared to the control. Significant effects were found in most of the measured indicators for fruit yield and quality regarding the interaction between the experiment factors.

Keywords: Tomato Quality and Yield, Organic Fertilizer, Phosphorus, Calcium.

1. INTRODUCTION

The genus Lycopersicon consists of annual and perennial herbaceous plants including Tomato (*Lycopersicon esculentum* Mill.). It belongs to the Solanaceae family, native to South America (Peru, Bolivia, and Ecuador). This crop is considered the second most significant vegetable after potato in many countries of the world, because of its high nutritional value. This is due to the minerals of tomato fruits such as potassium, phosphorous, calcium, iron, acids, compounds, and pigments. Likewise, ascorbic acid (vitamin C), citric and malic acid, vitamins such as vitamin A and E, as well as phenolic compounds, and some pigments such as carotene and lycopene (Gerszberg et al., 2015).

Globally, the tomato crop occupies a high rank in terms of production and consumption, as the cultivated area globally reached about 5.05 million hectares, with a productivity of 36,979.8 kg per hectare. Locally, it is one of the major vegetable crops grown in all governorates of Iraq that produced 754.8 thousand tons in 2020 (FAOSTAT, 2022).

Efforts in the past three decades focused on addressing environmental degradation and producing healthy and safe food by relying on organic fertilizers as an alternative to synthetic fertilizers. Foliar spray of nutrients can be utilized as one of the effective means in providing the plant requirement of macro and micronutrients, in addition to addressing soil nutrient deficiencies and increasing the yield, both quantitatively and qualitatively (Haytova, 2013). The exogenous application technique plays a key role in stimulating physiological processes. Phosphorous is one of the basic nutritional elements for photosynthesis, respiration, cell division, and the movement of nutrients within the plant (Jin et al., 2005; Tang et al., 2009). Moreover, it is involved in many compounds and biophysiological processes including the synthesis of phospholipids and nucleotides, which are the building blocks of nucleic acids DNA and RNA, as well as the formation of the energy compounds ATP and ADP (Verma, 2007; Nell et al., 2009).

Calcium is also one of the major nutrients in plants and contributes to several physiological functions, as it is necessary for the assimilation of carbon dioxide in photosynthesis and is the main structure of middle lamella in the cell walls in the form of calcium pectate (Al-Sahaf, 1989). Ca has a prominent role in meristematic cell division and expansion, chromosome stability, mitochondrial production, and cell hydrolysis (Reddy and Reddy, 2004). Calcium also reinforces plant cell wall tissues, making them more resistant to deterioration by the enzyme galacturonase, which causes the softness of fruits during ripening. It also reduces the breakdown of the cell wall caused by microbial enzymes that infect fruits and reduce their marketing or storage quality (Poovaiah et al., 1988).

The objective of this research was to identify the role of foliar application with organic liquid fertilizers rich in phosphorous and calcium in some indicators of yield and fruit quality of the limited-growth hybrid tomato.

2. MATERIALS AND METHODS

Field preparation and plant material

The field experiment was carried out at Al-Nakhil Station located in Al-Najaf governorate/Iraq during the 2021 growing season to cultivate the limited growth hybrid of tomato crop (OULA F1). This research aimed to identify the role of foliar spraying with organic liquid fertilizers fortified with phosphorous and calcium. Ten random soil samples were taken from different spots of the field before planting at different depths (0-30) cm, then mixed to analyze some chemical and physical properties of the field soil (Table 1). The

experiment soil was prepared through plowing, smoothing, and harrowing. Afterward, the field was laid out in terraces (75 cm) wide and (5 m) long per experimental unit with an area of 14 m^2. Each terrace contained two lines and 20 tomato seedlings were planted per experimental unit, with a distance of (50) cm between the two lines and between plants.
The seedlings were sown on 11/4/2021 at the age of four to five true leaves. Before planting, an irrigation water sample was sent to a lab for chemical and physical properties (Table 2), then a drip irrigation system was setup for water supply. All crop management such as irrigation and pest and weed control was performed as recommended.

Foliar application procedures
The experiment included spraying two organic fertilizers, the organic liquid NPK (18:44:0) fertilizer fortified with phosphorous included three concentrations (0 water only, 1, 2) $ml.L^{-1}$ as a first factor. The organic liquid calcium fertilizer (160 g of Ca. L^{-1}) was applied with three concentrations (0 water only, 1.25, 2.5) $ml.L^{-1}$ as a second factor. The foliar spray was applied using a 16-liter hand-held sprayer in the early morning until the plants were completely wet, taking into account the separation of treatments using cardboard as a barrier to avoid contamination among experimental units. Spray procedures were repeated three times during the growing season with an interval of two weeks between one spraying and another. The first spray was 25 days after planting the seedlings (Al-Bayati et al., 2020). One week was left between spraying each fertilizer type. Table 3 shows the compositions of both organic fertilizers used in this research.

Field layout and measured parameters
A factorial experiment was laid out according to the Randomized Complete Block Design (R.C.B.D.) with three replications. At the harvest stage, fruit samples were collected for yield and quality parameters as follows:

Quantitative parameters of tomato fruits

1- Fruit set percent (%) was calculated by dividing the final number of flowers over the total number of fruits per treatment according to:

$$\text{Fruit set (\%)} = \frac{\text{No.of fruit set per experimental unit}}{\text{No.of total flowers per experimental unit}} \text{ X } 100$$

The final number of flowers was calculated daily and cumulatively for five plants randomly selected per experimental unit from the beginning of the flowering to the end of the growing season, then the average was extracted.
2- Fruit number per plant ($fruit.plant^{-1}$) was calculated for five plants, and divided by the number of plants for each cumulative harvest, then calculated the average.
3- Fruit weight ($g.fruit^{-1}$) was measured for five plants, taken randomly from each experimental unit cumulatively, then taking the average.
4- Total yield ($t.ha^{-1}$) was estimated by harvesting tomato fruits at the red ripe stage. Fruit yield from each plant was recorded from the first harvest to the last one cumulatively per experimental unit. The total yield expressed in ton per hectare was calculated according to:

$$\text{Yield } (t.ha^{-1}) = \frac{\text{Yield of experimental unit (kg)}}{\text{Area of experimental unit } (m^2) \text{x } 1000} \text{ X } 10000\ (m^2)$$

Qualitative parameters of tomato fruits

1- Percentage of N, P, K, and Ca in fruits (%) were estimated at the red ripe stage. N was determined by macro-Kjeldahl (Jackson, 1958). P was estimated by spectrophotometer while K and Ca were determined by flame photometer as described by (Al-Sahaf, 1989).

2- Fruit firmness ($Kg.cm^{-2}$) was measured with help of a pressure tester. Fruit firmness was determined from the shoulder region of the fruit at the beginning of the ripe stage for ten fruits from each experimental unit.

3- Vitamin C content in fruits ($mg.100ml^{-1}$ fresh juice) was estimated (AOAC, 1999).

Statistical analysis

Data of various indicators were analyzed by statistical software Statistix 10 (Analytical Software, Tallahassee, FL). Analysis of variance (ANOVA) procedure was employed to determine the differences among treatments and means were compared using the Least Significant Difference Test (LSD) hen F test was found significant at 0.05.

Table 1. Some chemical and physical properties of field soil pre-planting at a depth of 0-30 cm.

Soil Parameter		Unit	Value
Texture: Sandy	Clay	$g.kg^{-1}$	13.24
	Silt	$g.kg^{-1}$	72.11
	Sand	$g.kg^{-1}$	914.65
Cation Exchange Capacity (CEC)		$Cmol.kg^{-1}$	4.70
pH		---------	7.04
Electric Conductivity (EC)		$dS.m^{-1}$	6.40
N		ppm	7.27
P		ppm	4.86
K		ppm	128.85
Ca		ppm	1152.00
Na		ppm	546.90
Organic matter (OM)		%	1.58

Table 2. Some chemical and physical analyses of irrigation water used in the experiment.

Water Parameter	Unit	Value
pH	---------	8.00
Electric Conductivity (EC)	$dS.m^{-1}$	4.52
K	ppm	81.30
Na	ppm	750.00
Ca	ppm	1008.00
Mg	ppm	802.60
Cl	ppm	1210.60
SO_4	ppm	238.08
CO_3	ppm	12.20
HCO_3	ppm	82.66

Table 3. Compositions of organic fertilizers (NPK rich in phosphorous) and calcium used in the experiment.

Fertilizer	Element	Concentration
Organic liquid NPK	N P K	18% 44% 0
Organic liquid Ca	Ca	160 $g.L^{-1}$

3. RESULTS

The results in Table (4) indicated that there were significant differences among the tomato treatments regarding fruit yield and its components. Consequently, spraying with organic NPK fertilizer rich in phosphorous at a concentration of (2 $ml.L^{-1}$) revealed the highest mean for fruit set percent, fruit number per plant, and total yield (69.37%, 36.32 $fruit.plant^{-1}$, and 44.37 $t.ha^{-1}$), respectively, whereas fruit weight had the highest mean (80.56 $g.fruit^{-1}$) when plants sprayed with P at (1 $ml.L^{-1}$). In contrast, non-sprayed tomato plants (control) gave the lowest mean for fruit set (67.53%), fruit number (33.65 $fruits.plant^{-1}$), fruit weight (73.38 $g.fruit^{-1}$), and total yield (38.15 $t.ha^{-1}$). The same table showed that spraying plants with organic calcium fertilizer at a concentration of (2.5 $ml.L^{-1}$) has improved yield characteristics giving the maximum mean for fruit set (74.24%), fruit number (37.77 $fruits.plant^{-1}$), fruit weight (82.38 $g.fruit^{-1}$), and total yield (47.88 $t.ha^{-1}$), compared to the control treatment. Moreover, the same yield characteristics appeared in the minimum mean (63.95%, 31.21 $fruits.plant^{-1}$, 73.31 $g.fruit^{-1}$, and 35.22 $t.ha^{-1}$), consecutively, related to the control plants. According to the results, a significant improvement in tomato yield characteristics was observed for the interaction between both fertilizers. the combination of (P 2 $ml.L^{-1}$ x Ca 2.5 $ml.L^{-1}$) enhanced the tomato fruit indicators providing the highest mean for (41.39 $fruits.plant^{-1}$), fruit weight (87.64 $g.fruit^{-1}$), and total yield (55.59 $t.ha^{-1}$) except for fruit number resulted in the highest mean fruit set (74.85%) by the treatment combination of (P 1 $ml.L^{-1}$ x Ca 2.5 $ml.L^{-1}$). However, the non-sprayed tomato plants regarding the interaction treatment (P0 x Ca0) gave the lowest mean for fruit set (61.08%), fruit number (27.36 $fruits.plant^{-1}$), fruit weight (65.35 $g.fruit^{-1}$), and total yield (27.20 $t.ha^{-1}$).

Table 4: Fruit yield parameters of tomato plants influenced by spraying with organic liquid fertilizers rich in phosphorous and calcium.

	Fruit Quantitative parameters			
Treatments ($ml.L^{-1}$)	**Fruit Set (%)**	**Fruit Number ($fruit.plant^{-1}$)**	**Fruit Weight ($g.fruit^{-1}$)**	**Total Yield ($t.ha^{-1}$)**
	Effect of organic NPK fertilizer rich in phosphorous			
P 0 (Control)	67.53	33.65	73.38	38.15
P 1	68.83	35.40	80.56	43.81
P 2	69.37	36.32	79.12	44.37
LSD (0.05)	1.21	0.90	1.73	1.16
	Effect of organic calcium fertilizer			
Ca 0 (Control)	63.95	31.21	73.31	35.22
Ca 1.25	67.53	36.38	77.37	43.23

Ca 2.50		74.24	37.77	82.38	47.88
LSD (0.05)		1.21	0.90	1.73	1.16
		Effect of the interaction			
P 0	Ca 0	61.08	27.36	65.35	27.20
	Ca 1.25	68.38	38.76	78.28	46.41
	Ca 2.50	73.13	34.82	76.50	40.83
P 1	Ca 0	62.82	31.93	77.92	38.13
	Ca 1.25	68.82	37.17	80.78	46.07
	Ca 2.50	74.85	37.11	83.00	47.23
P 2	Ca 0	67.96	34.34	76.66	40.33
	Ca 1.25	65.39	33.21	73.06	37.20
	Ca 2.50	74.24	41.39	87.64	55.59
LSD (0.05)		2.09	1.55	2.99	2.01

The main significant effects of each organic NPK fertilizer fortified with P and Organic Ca fertilizer were evident among tomato plants in terms of fruit quality parameters, but there was no significant interaction for all qualitative parameters (Table 5). At (2 $ml.L^{-1}$) organic P fertilizer, N, P, and K in tomato fruits as well as vitamin C content in fruits increased significantly providing the maximum value (1.53%, 0.43%, 2.09%, and 21.87 mg. 100 ml^{-1} fresh juice), consecutively in comparison with the control plants. Furthermore, the fruit Ca and fruit firmness was significantly improved in the sprayed plants at (1 $ml.L^{-1}$) organic P fertilizer giving (0.80% and 2.92 $kg.cm^2$) as compared to the control plants. The same qualitative parameters have decreased for the control plants (0.94% fruit N, 0.21% fruit P, 1.55% fruit K, 0.71% fruit Ca, 2.32 $kg.cm^2$ fruit firmness, and 17.68 mg. 100 ml-1 fresh juice Vit C). The results of the same table indicated that sprayed plants at (2 $ml.L^{-1}$) organic Ca have significantly enhanced all tomato fruit parameters (1.59% fruit N, 0.41% fruit P, 2.03% fruit K, 0.83% fruit Ca, 3.61 $kg.cm^2$ fruit firmness, and 25.30 mg. 100 ml^{-1} fresh juice Vit C) which were significantly higher than those of the control plants. However, tomato fruit quality declined in respect to the non-sprayed plants (0.85%, 0.21%, 1.65%, 0.71%, 1.93 $kg.cm^2$, and 16.31 mg. 100 ml^{-1} fresh juice), respectively. Significant interaction effects were found in the measured indicators of fruit minerals which realized the highest value (1.98% fruit N, 0.51% fruit P, and 0.90% fruit Ca) in comparison with the control interaction which resulted in a lower value (0.49% fruit N, 0.11% fruit P, and 0.69% fruit Ca). The interaction effect of the other fruit quality indicators such as fruit K, fruit firmness, and Vit C were not reached the significance level.

Table 5: Physicochemical parameters of tomato fruits influenced by spraying with organic liquid fertilizers rich in phosphorous and calcium.

Fruit qualitative parameters

Treatments ($ml.L^{-1}$)	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Firmness ($kg.cm^{-2}$)**	**Vit C ($mg.100ml^{-1}$ fresh Juice)**
	Effect of organic NPK fertilizer rich in phosphorous					
P 0 (Control)	0.94	0.21	1.55	0.71	2.32	17.68
P 1	1.18	0.32	1.95	0.80	2.92	21.01
P 2	1.53	0.43	2.09	0.79	2.80	21.87
LSD (0.05)	0.17	0.04	0.28	0.06	0.43	2.56

		Effect of organic calcium fertilizer					
Ca 0 (Control)		0.85	0.21	1.65	0.71	1.93	16.31
Ca 1.25		1.20	0.35	1.91	0.76	2.50	18.95
Ca 2.50		1.59	0.41	2.03	0.83	3.61	25.30
LSD (0.05)		0.17	0.04	0.28	0.06	0.43	2.56
		Effect of the interaction					
P 0	Ca 0	0.49	0.11	1.33	0.70	1.45	14.06
	Ca 1.25	1.13	0.27	1.76	0.71	2.08	18.70
	Ca 2.50	1.20	0.27	1.57	0.72	3.44	20.28
P 1	Ca 0	0.77	0.17	1.77	0.69	2.05	16.55
	Ca 1.25	1.17	0.35	1.82	0.84	2.65	19.55
	Ca 2.50	1.59	0.45	2.26	0.89	4.06	26.92
P 2	Ca 0	1.30	0.34	1.86	0.73	2.30	18.31
	Ca 1.25	1.30	0.43	2.15	0.73	2.78	18.61
	Ca 2.50	1.98	0.51	2.26	0.90	3.32	28.70
LSD (0.05)		0.29	0.07	N.S.	0.10	N.S.	N.S.

4. DISCUSSION

It is noticed that spraying with organic fertilizer enriched with high P realized a significant increase in the percentage of fruit set, due to the importance of phosphorus in increasing the number of flowers and fruit set and filling (Winsor and Adams, 1987; Hasan, 1998). Moreover, phosphorous is one of the basic nutritional elements for plants and plays a key role in the process of photosynthesis, respiration, and energy transfer, as well as the processes of growth, formation, division of plant cells, and the movement of nutrients within the plant (Tang et al., 2009). Also, P contributes to protecting flowers from abscission and increasing the rate of fruit set and seeds (Al-Sahaf 1989). Further, the increase in the components of tomato fruit yield when spraying with organic fertilizer may be attributed to the positive effect of P element, as it involves in the increase of carbon metabolism products, numerous compounds, and biological processes, for instance, synthesis of phospholipids, which play a substantial role in the construction and synthesis of nucleotides, as well as the formation of energy compounds ADP and ATP (Taiz & Zeiger, 2010). Similar findings were confirmed by (Azarpour et al. 2012; Iledun et al. 2020) who have reported a significant enhancement of fruit quality as a result of adding different levels of P such as increasing the number and weight of fruit, plant yield, and total production. Besides, the increase of fruit minerals (N, P, and K) may be attributed to the positive effect of the organic nutrients rich in phosphorous due to its availability in a ready-absorption form by the leaves and then being transferred from the leaves (source) to the fruits (sink), and this agrees with (Bahia, 2001). Al-Dulaimi et al., (2009) confirmed that supplying phosphorous via foliar or soil application has improved vegetative and root growth, which was positively reflected in increasing the absorption of elements and their transfer to the fruits. In general, the increase in the vegetative growth indicators of the plant caused an increase in the products of CO_2 metabolism that are transmitted to the fruits, which reflected an increase in the carbohydrates involved in the formation of ascorbic acid (Ademoyegun et al., 2011). The same results were noticed by Jasim et al., (2014), who found a significant increase in vitamin C in tomato fruits, and Maluki et al. (2016) in giving the highest degree of fruit firmness.

It is noteworthy that the increase in the plant yield and total yield may be ascribed to the role of calcium in increasing the percentage of fruit set, which increased the number of fruits per plant and fruit yield per plant, hence an increase in the total fruit yield as shown in (Table 4). These results are in agreement with the results of (Mona et al. 2005; Kazemi, 2014; Tejashvini et al., 2018; Sajid et al., 2020). Correspondingly, the increase in yield components may be attributed to the role of mineral nutrients, the most important of which is Ca, which has a crucial effect in activating and stimulating the processes of pollination, fertilization, germination, and growth of the pollen tube (Brewbaker and Kwack, 1963). Our results are consistent with those (Afsana et al., 2017; Tejashvini et al., 2018). Ca also plays a vital role in the metabolism and absorption of nutrients (Kamal, 2000) in which calcium increases the presence of galacturonic acid in the cell wall, thus increasing the formation of calcium pectate that involves in the composition of the middle lamella in the cell wall (Pagel and Heitefuss, 1989). Spraying with organic calcium at a concentration of 2.5 ml.L^{-1} resulted in increasing the absorption of calcium and potassium elements as they entered into the composition of the middle lamella, which plays a direct effect on enhancing the fruit firmness. Similar findings were reported by (Rab et al., 2017). Moreover, Ca was found to increase cell membrane integrity since it binds to the polar head groups of phospholipids. Obviously, many studies emphasize the role of calcium in maintaining the metabolism of carbohydrates, protein, meristematic activity, cell division, and cell elongation. Therefore, the application of Ca improved fruit quality content, in which fruit firmness is an important quality indicator relevant to the storage and marketing of fruit. The current data in this research agree with that found by (Tejashvini et al., 2021) who showed that tomato sprayed with Ca has improved vitamin C content in tomato fruits.

5. CONCLUSION

The results of the experiment showed that spraying the organic NPK fertilizer fortified with P at (2 ml.L^{-1}) has improved the fruit yield indicators, and positively affected the qualitative fruit characteristics by showing the best results. The experiment exhibited the positive role of spraying with organic calcium fertilizer at (2.5 ml.L^{-1}) and was found effective for better yield and quality production of tomatoes. The interaction between both factors also showed an improvement in most of the measured indicators through the combination of (P 2 ml.L^{-1} x Ca 2.5 ml.L^{-1}). It is recommended for testing other varieties of tomato to determine their suitability with these concentrations in the conditions of Najaf Governorate.

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