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Original article

Evaluation of Nitrogen, Phosphorus, and Potassium in Tomato (Solanum lycopersicum L.), Leaves Impacted by Two Different Fertilizer Sources

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ABSTRACT

Background and aims. One of the most significant vegetable plants in the world is tomato. Tomato has been developed to increase productivity, nutrient status, and resistance to both biological and abiotic stress factors because of its significance as a food crop. High productivity and desired tomato fruit quality are influenced by nutrient management and fertilizer application. The study was aimed to investigate the use of organic and mineral fertilizer sources by determination of nitrogen, phosphorus, and potassium in tomato leaves to reduce adding high quantities of mineral fertilizers and utilizing organic fertilizer as a partial substitute. **Methods**. Two field experiments were carried out included four rates of organic fertilization as a poultry manure fertilizer (0, 15, 30, 45 t.ha^{-1}) and four rates of mineral fertilization 0, 50, 75, and 100 % of the recommended rate, which are 165 N, 144 P_2O_5, and 200 K_2O kg. ha^{-1} was utilized in the study. The dry leaves were crushed and the percentage of total nitrogen, phosphorus, and potassium (%) content were estimated using the Kjeldahl method, colorimetric method, and a flame photometer, respectively. **Results**. The current study shows that treatments with 30, and 45 t.h^{-1} of organic fertilizer gave the highest value in the percentage of nitrogen, and phosphorous, respectively, compared to other treatments. On the contrary, the potassium percentage decreased by increasing the rates of organic fertilization. 100% of the recommended amount of compound mineral fertilizer recorded the highest percentage of nitrogen, phosphorus, and potassium in the tomato dry leaves. **Conclusion**. combinations of organic and inorganic fertilizers sources enhance nutrients absorbed by tomato plants that could be detectable by measuring element concentrations in the leaves.

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INTRODUCTION

The world's most popular vegetable is a cultured tomato (Solanum lycopersicum L.), which serves as a fundamental component in a wide range of raw, cooked, and processed cuisines, and was initially thought of as an ornamental crop [1]. It comes from the Solanaceae family, which also contains a number of other important and abundant species [2]. For domestic use or export, tomatoes are grown all over the world [3]. The USA now observes National Tomato Day on April 8 each year to honor tomatoes [4]. Based on the most recent Faostat data, the world harvested186.821 million tonnes of tomatoes on 5,051,983 hectares in 2020, attaining an average output of 37.1 tonnes/hectare [5]. Although mineral nutrition is generally the most significant component affecting crop output, applying all necessary minerals through chemical fertilizers had a negative impact on soil fertility, resulting in unsustainable yield [6]. Application of organic and inorganic fertilizers to the soil is considered a successful agricultural strategy and technique since it improves soil fertility and the productivity of crops. From 1961 to 2019, the quantity of commercial and chemical

fertilizers used by agriculture worldwide increased significantly, going from 10 million to almost 110 million tonnes for nitrogen (N), 10 million to almost 45 million tonnes for phosphorus (as P_2O_5), and less than 10 million to more than 35 million tonnes for potassium (as K_2O) (Fig. 1) [5].
It's critical to employ fertilizers in tomato crops effectively in order to prevent any environmental harm while also lowering production expenses [7]. (Hochmuth et al., 2004). Foliar analysis is thought to be highly useful for identifying nutritional problems [8], It evaluates the nutritional state of a crop better than soil testing, which simply assesses the nutrients that are currently available in the analyzed soil [9]. Researchers and growers are now using ecologically friendly fertilizers as a result of environmental contamination and the expensive expense of mineral fertilization.

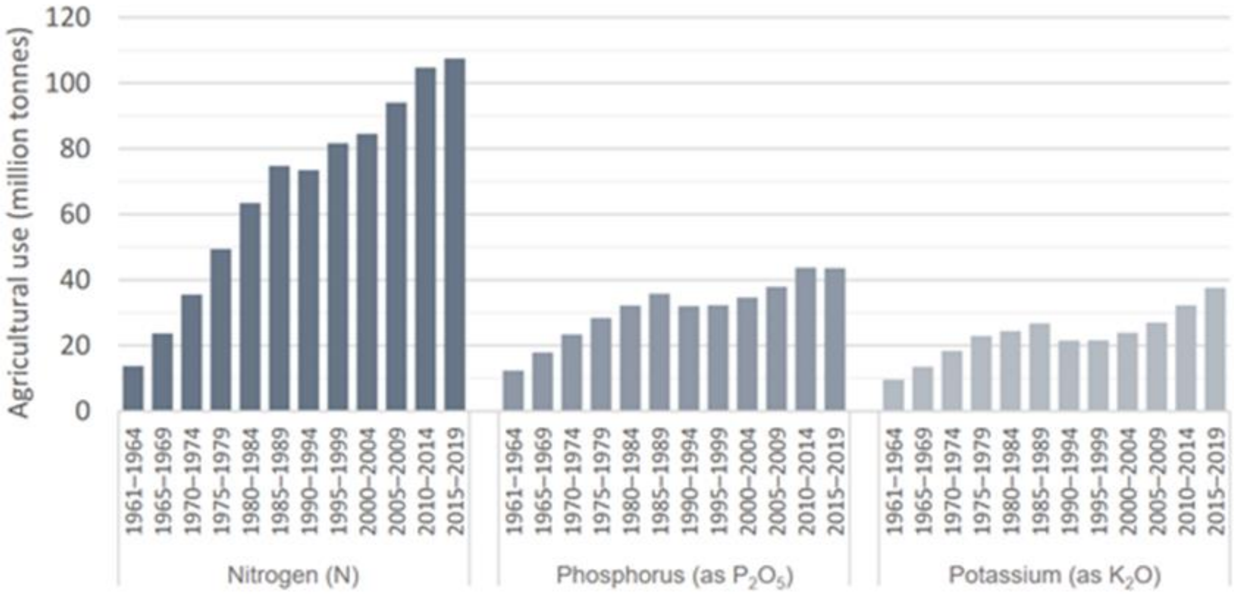

Figure 1. The usage of inorganic fertilizers in agriculture worldwide by nutrient, as N, P_2O_5, and K2O [5].

A study investigated the impacts of different levels of nitrogen inputs (optimal, insufficient, and excessive) and water inputs (optimal, low drought, and high drought) on tomato plants to determine the survival and spread of a tomato leafminer, Tuta absoluta, and tomato growth and performance [10]. The results of their investigation show that, in comparison to optimal N, insufficient N treatments reduced leaf N content and raised the carbon/nitrogen ratio (C/N), but excessive N treatments had no effect on either leaf N content or leaf C/N ratio.
Adekiya et al. [11] conducted a study to assess the mineral percentages in the leaves, of tomato and cucumber crops cultivated in a soilless media in a screen house. The treatments included an inorganic fertilizer, a control, and six concentrations of liquid organic fertilizer (5, 15, 25, 35, 45, and 55 mL). Their finding displayed that in comparison to the control, both organic and inorganic fertilizers, enhanced the nutritional concentration in the leaves of tomato and cucumber plants. In addition, leaf analyses revealed that all of the necessary components for tomato and cucumber crops were within the acceptable ranges in the organic fertilizer treatments, indicating that this organic fertilizer can be utilized as an affordable and accessible replacement for inorganic fertilizer. Another experiment was carried out to evaluate the effect of various combinations of rabbit manure (RM), rock phosphate (RH), feldspar (F), and bio-N-P-K fertilizers on the growth, yield, and quality of tomato plants. Results of the study has mentioned that in comparison to the same treatment without the bio-fertilizer, the application of RM, RH, and F along with the bio-fertilizer inoculation enhanced the concentration of N, P, and K in the tomato leaves by 34%, 35%, and 50%, respectively. This is demonstrated unequivocally that bio fertilization with nitrogen, phosphate, and potassium as well as organic natural minerals (RH and F) results in larger yields and better quality than conventional fertilizer [12]. In a greenhouse experiment, Heeb et al. [13] investigated the effects of several fertilization regimes, including mineral or organic fertilizers, on the yield and nutrient content of tomato plants. They came to the conclusion that because organic fertilizers released nutrients more gradually than mineral fertilizers, the development and yield of the organic nitrogen treatments were constrained by the lower P concentrations in the leaves. This study is aimed to increase the productive capacity of the agricultural soil in Al-Jabal Al-Akhdar region by improving its natural, chemical, and biological properties, through the integrated use of organic and mineral fertilizer sources and reducing the added quantities of mineral fertilizers by adding organic fertilizer as a partial substitute, and the consequent production of food that is safe for human health.

METHODS

Two field experiments were carried out in the experimental farm of the Horticulture Department - Faculty of Agriculture - Omar Al-Mukhtar University. Soil samples from the experiment site were collected at a depth of 20 cm before the start of the experiment and were analyzed at the soil laboratory of the Soil and Water Department at the University to identify some of the natural and chemical properties of the soil of the experiment site (Table 1).

Table 1. Characteristics and properties of the experiment site's soil.

Measurements		
Particle Size distribution	Sand (%)	16.21
	Silt (%)	54.4
	Clay (%)	33.51
Organic Matter (%)		2.57
E.C (Mmhos/ cm)		1.20
Total Nitrogen (%)		0.22
Soil pH		7.90
CO_3^{--}%		1.35
P ppm		117
K ppm		282

The experiment included 16 treatments representing all possible interactions between the land additions of four rates of organic fertilization as a poultry manure fertilizer (0, 15, 30, 45 $t.ha^{-1}$) and four rates of mineral fertilization 0, 50, 75, and 100 % of the recommended rate, which are 165 N, 144 P_2O_5, and 200 K_2O $kg.ha^{-1}$. The land was prepared for cultivation by plowing it well in two perpendicular directions, then dividing it into lines, and adding the aforementioned rates of organic fertilizers in the cultivation lines, then the lines were backfilled, then drip irrigation lines were extended over the lines of cultivation. As for nitrogen, potassium, and phosphate fertilizers, they were added in three equal batches; one month after planting, the second after another month, and then after another 15 days. Urea fertilizer (48% N), monocalcium phosphate (48% P_2O_5) and potassium sulfate (48% K_2O) were used as sources of nitrogen, phosphorus, and potassium, respectively. The decomposing poultry manure was also used as a source of organic fertilizer, which was obtained from a neighboring farm. The seedlings, which were obtained from a private nursery, were planted in rapid production trays on lines 100 cm apart and at a distance of 50 cm between the plants inside the line.
Each experimental unit includes 2 lines of 4 meters in length and one meter in width with a total area of 8 square meters. A separating line will be left between each two adjacent experimental units to protect from the side effects of adjacent treatments. All other agricultural operations such as hoeing, weed control, drip irrigation, and control of insect and disease pests were carried out, as is recommended in the commercial production of tomatoes, when necessary.

Experiment design

A randomized complete block, split-plot design with three replications was used for the study, where the organic fertilizer rates (0, 15, 30, 45 $tons.h^{-1}$) were distributed on the main plots, while the secondary plots were randomly assigned to the complex mineral fertilization rates (0%, 50%, 75%, 100%) of the recommended NPK levels.

Recorded data

Determination of nitrogen (%). The dry leaves were crushed and the percentage of total nitrogen content was estimated using the Kjeldahl method [14].
Determination of phosphorous (%). To estimate the percentage of phosphorus in the leaves, the colorimetric method was used by means of a spectrophotometer at a wavelength of 470 nm [15].
Determination of potassium (%). The potassium concentration in dry leaves was estimated using a flame photometer according to the steps mentioned [15].

Data analysis

All of the data were examined in Minitab (version 17.0 for Windows; Minitab, LLC.) [16]. Levene's test and the Kolmogorov-Smirnov normality test were used to determine the homogeneity of the variances and their normality, respectively (P >0.05). Some data were transformed to conform to the assumptions of normality and equality of variance before analysis using square root or log transformation.

RESULTS AND DISCUSSION

Effect of organic fertilizer levels on the percentage of nitrogen, phosphorus and potassium in dry leaves (%)

Results of the current study revealed that there were no significant differences in the percentage of nitrogen between the organic fertilization treatments in both growing seasons (P >0.05), although the treatment with 30 $t.h^{-1}$ of organic fertilizer gave the highest value in the percentage of nitrogen, but not significant compared to other treatments (Table 2). Moreover, the results indicated that the organic fertilizer had a significant effect on the percentage of phosphorus in the dry leaves of tomato plants during the two study seasons, as the highest level of organic fertilizer (45 $t.h^{-1}$) recorded the highest percentage of phosphorous in the leaves compared to the control treatment, followed by the treatments of 30 and 15 $t.h^{-1}$., respectively, with no significant differences between them. On the contrary, the potassium percentage decreased by increasing the rates of organic fertilization. As the treatment with 45 $t.h^{-1}$ recorded the lowest potassium content compared to other treatments. Similar findings were made by Adekiya et al. [11], who discovered that organic fertilizers improved the nutritional concentration in tomato and cucumber plant leaves when compared to the control. Additionally, leaf analyses showed that all of the elements required for tomato and cucumber crops were within the permissible ranges in the organic fertilizer treatments, suggesting that organic fertilizer can be used as an accessible and economical alternative to inorganic fertilizer. On the other hand, our results differ from Heeb et al. [13] who came to the conclusion that the development and yield of the organic nitrogen treatments were constrained by the lower P concentrations in the leaves as the result of slow and gradual availability of nutrients from the organic sources as compared to the inorganic fertilizers.

Table 2. Effect of different organic fertilizer levels on some chemical components of tomatoes leaves.

Treatment	Minerals in dry leaves (%)^{z}		
Organic Fertilizer ($t.h^{-1}$)^{y}	N%	P%	K%
First Season			
Control	1.264a^{x}	7.924c	4.98a
First level	1.153a	7.941b	3.67b
Second level	1.316a	8.031b	3.11b
Third level	1.297a	8.97a	2.91b
Second season			
Control	1.378a	8.216c	4.272a
First level	1.146a	8.311b	3.597ab
Second level	1.476a	8.321b	3.205b
Third level	1.242a	8.620a	2.817b

^{z}All data were subjected to analysis of variance using ANOVA in Minitab (version 16.0 for Windows; Minitab, LLC.).
^{y}Four levels of organic fertilizer were evaluated: Zero, 15, 30, and 45 $t.h^{-1}$.
^{x}Means followed by the same letter are not significantly different at P <0.05.
^{abc}Within the whole table: Means of minerals in tomato dry leaves impacted by the four levels of organic fertilizer which evaluated in the study; where "a" represents the highest value and "c" the lowest value at P<0.05.

Effect of compound mineral fertilizer levels on the percentage of nitrogen, phosphorus and potassium in dry leaves (%)

The results shown in Table (3) indicated that there were no significant differences between compound mineral fertilization treatments in the percentage of nitrogen and phosphorus during the first season, although the highest percentage of nitrogen was at the level of 75% of the recommended amount of compound mineral fertilizer, however, this increase is not sufficient to reach the significant level. Yet, significant differences were recorded during the second season for both nitrogen and phosphorus (P <0.05), where the highest percentage of nitrogen and phosphorus were in the dry leaves when treated with 100% and 50% compound mineral fertilizer, respectively. In addition, results of the statistical analysis showed that the effect of the compound mineral fertilization led to the emergence of a significant difference in the percentage of potassium in the dry leaves, where the highest value was in the first season when treated with 50% of the recommended amount of compound mineral fertilizer, and on the contrary, the highest value for the percentage of potassium during the season, it was when treated with 75% and 100% of the recommended amount of compound mineral fertilizer. This finding concurred with that of Han et al. [10], in which insufficient N treatments reduced leaf N content as compared to the optimum level. Our findings imply that the significantly elevated levels of the elements in the leaf tissue could be linked to the plant's high nutrient absorption as a result of the nutrient's increasing prevalence in the soil due to of the application of the inorganic fertilizer containing it.

Table 3. Effect of different levels of compound mineral fertilization on some chemical components of leaves and fruits of tomatoes.

Treatment	Minerals in dry leaves (%)^z		
NPK %^{y}	N%	P%	K%
First Season			
Control	1.078b^x	7.928a	3.581b
First level	1.362a	8.211a	4.800a
Second level	1.490a	7.836a	3.652b
Third level	1.500a	8.118a	3.633b
Second Season			
Control	1.135bc	8.234ab	3.578ab
First level	1.488ab	8.505a	3.107b
Second level	1.633ab	8.157ab	3.457ab
Third level	1.986a	7.272b	3.749a

^{z}All data were subjected to analysis of variance using ANOVA in Minitab (version 16.0 for Windows; Minitab, LLC.).
^{y}Four levels of compound mineral fertilization were evaluated: Zero, 50, 75, and 100 % of the recommended amount of compound mineral fertilizer.
^{x}Means followed by the same letter are not significantly different at P <0.05.
^{abc}Within the whole table: Means of minerals in tomato dry leaves impacted by the four levels of organic fertilizer which evaluated in the study; where "a" represents the highest value and "c" the lowest value at P<0.05.

Effect of interaction between organic fertilization and compound mineral fertilization on some chemical components of leaves of tomato plant

Results shown in Tables (4 and 5) indicated that there were significant differences in the nitrogen, phosphorus and potassium content of dry tomato leaves as the result of the interaction effect between the two treatments during the two growing seasons (*P* <0.05). The highest nitrogen percentage was recorded in the first growing season when the treatment of overlapping 15 t.h^{-1} organic fertilizer with 75% compound mineral fertilizer, while in the second study season the highest nitrogen percentage was 30 t.h^{-1}organic fertilizer with 50% compound mineral fertilizer.
While, the highest value of phosphorus in the dry leaves in the first season was when the treatment of overlapping with 45 t.h^{-1} organic fertilizer with 100% compound mineral fertilizer, while the treatment with 45 t.h^{-1} with 50% compound mineral fertilizer recorded the highest percentage of phosphorus during the second growing season. For the potassium, the interaction treatment between 0 t.h^{-1} (control) with 100% compound mineral fertilizer gave the highest potassium content in the leaves in both seasons of the study.
Conversely, high treatments of organic fertilizer (30 and 45 t.h^{-1}) with 50% and 100% compound mineral fertilizers gave the lowest potassium content in the leaves. This finding agreed with that of Youssef and Eissa [12], who noted that when RM, RH, and F were applied in addition to the bio-fertilizer inoculation, the concentration of N, P, and K in the tomato leaves increased by 34%, 35%, and 50%, respectively, as compared to the same treatment without the bio-fertilizer.

Table 4. Effect of the interaction between organic fertilization and compound mineral fertilization on some chemical components of tomato leaves the first season.

Treatments		Minerals in dry leaves (%)^z		
Organic Fertilizer (t.h^{-1})^y	NPK %^{x}	N%	P%	K%
Control	Control	1.340abcd^w	7.632^{ab}	3.62^{bc}
	First level	1.675^{abc}	8.052^a	2.78^{bc}
	Second level	1.255^{abcd}	7.645^{ab}	4.73^b

	Third level	0.785d	8.365a	5.23a
First level	Control	0.745d	8.582a	4.23bc
	First level	0.897cd	8.510a	3.56bc
	Second level	1.917a	8.420a	3.59bc
	Third level	1.052bcd	6.252b	3.29bc
Second level	Control	1.163abcd	7.717ab	3.31bc
	First level	1.898a	8.375a	2.92cd
	Second level	1.445abcd	7.640ab	3.13bcd
	Third level	0.760d	8.392a	3.06bc
Third level	Control	1.065bcd	7.780a	3.17bcd
	First level	0.977bcd	7.907a	2.39d
	Second level	1.342abcd	7.637ab	3.14bc
	Third level	1.802ab	9.062a	2.94cd

zAll data were subjected to analysis of variance using ANOVA in Minitab (version 16.0 for Windows; Minitab, LLC.).
yFour levels of organic fertilizer were evaluated: Zero, 15, 30, and 45 $t.h^{-1}$.
xFour levels of compound mineral fertilization were evaluated: Zero, 50, 75, and 100 % of the recommended amount of compound mineral fertilizer.
wMeans followed by the same letter are not significantly different at $P<0.05$.
abcdWithin the whole table: Means of minerals in tomato dry leaves impacted by the four levels of organic fertilizer which evaluated in the study; where "a" represents the highest value and "c" the lowest value at $P<0.05$

Table 5. Effect of the interaction between organic fertilization and compound mineral fertilization on some chemical components of tomato leaves the second season.

Treatments		Minerals in dry leaves (%)z		
Organic Fertilizer ($t.h^{-1}$)y	NPK %x	N%	P%	K%
Control	Control	1.527abcdew	8.483a	3.840bc
	First level	1.803abc	8.217ab	3.710bc
	Second level	1.403abcde	7.563ab	4.117b
	Third level	0.780de	8.600a	5.420a
First level	Control	0.650e	8.180ab	3.903bc
	First level	0.813de	8.757a	3.683bc
	Second level	2.033ab	8.577a	3.487bc
	Third level	1.087cde	6.530bc	3.313bc
Second level	Control	1.223bcde	7.977ab	3.457bc
	First level	2.287a	8.337a	2.920cd
	Second level	1.673abcd	8.227ab	3.123bcd
	Third level	0.720e	8.543a	3.320bc
Third level	Control	1.140bcde	8.297ab	3.110bcd
	First level	1.047cde	8.510a	2.117d
	Second level	1.423abcde	8.260ab	3.100bc
	Third level	1.357bcde	5.413c	2.943cd

zAll data were subjected to analysis of variance using ANOVA in Minitab (version 16.0 for Windows; Minitab, LLC.).
yFour levels of organic fertilizer were evaluated: Zero, 15, 30, and 45 $t.h^{-1}$.
xFour levels of compound mineral fertilization were evaluated: Zero, 50, 75, and 100 % of the recommended amount of compound mineral fertilizer.
wMeans followed by the same letter are not significantly different at $P<0.05$.
abcdeWithin the whole table: Means of minerals in tomato dry leaves impacted by the four levels of organic fertilizer which evaluated in the study; where "a" represents the highest value and "c" the lowest value at $P<0.05$.

CONCLUSION

It was observed that when organic fertilizers were mixed with less than the highest rate of mineral fertilizers examined in the current study as an integrated treatment, similar or very close percentages of the elements in the leaves were obtained from the use of the highest rate of mineral fertilizers alone. This reflects that combinations of organic and inorganic fertilizers sources enhance growth or production as a result in a large amount of the nutrient absorbed and allocated to a demand center that could be detectable by measuring elements in the leaves concentrations. These findings will help decrease fertilizer use below the recommended dose, hence lowering the environmental pollution.

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Conflict of interest

The authors affirm that they do not have any competing interests with this publication

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