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Research Article

Effect of Different Rates of Nitrogen and Phosphorus Fertilizers on Yield and Quality of Greenhouse Tomato Under the UAE Condition

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Abstract

Tomatoes are the major vegetable crops in the United Arab Emirates (UAE). Nitrogen (N) and phosphorus (P) are essential macronutrients for tomatoes growth, it is important to meet plant demand for N and P fertilizer and reduce surplus fertilizer applications. A greenhouse experiment was conducted at Al-Kiwtate Research Station in the UAE to study the effect of different levels of N and P fertilizer on the yield, physio-chemical properties of tomatoes and soil nutrient residues. The experiment was laid out in a factorial arrangement within randomized complete block design with two factors and four replications. All possible combinations of four N rates (0, 300, 600 and 900 kg N ha^{-1}) and three P rates (0, 200, 400 kg P ha^{-1}) were applied in corresponding to the growing stages. Tomato responded significantly to N-P fertilizer. The total yield increased with increasing levels of applied N up to 600 kg ha^{-1} and P 200 kg ha^{-1} and beyond this level tomato yield displayed significant decline. Application of N rate up to 900 kg ha^{-1} and P 200 Kg ha^{-1} had affected adversely the total yield, average fruit weight and number of fruit per plant. Increasing N fertilizer rate revealed significant increments in fruit nitrate concentration, acidity and citric acid comparing to the control. Both soil electrical conductivity (EC) and nitrate accumulations increased with increasing N application rate.

Keywords: *Fertilizer Application; Greenhouse Tomato; Yield Parameter; Physio-Chemical Properties; Soil Residues*

Abbreviations

N: Nitrogen; P: Phosphorus; UAE: United Arab Emirates; EC: Electrical Conductivity

Introduction

Tomatoes (*Lycopersicon esculentum* Mill.) are one of the most consumed vegetable in the world. Tomatoes are a good source of lycopene, β-carotene, folate, potassium, ascorbic acid (vitamin C), tocopherol (vitamin E) chlorogenic acid, flavonoids, rutin, phenolics, and xanthophylls [1,2]. Recent studies suggest that tomatoes contain the antioxidant lycopene, which clinically approved to reduce the risk of cancer [3].

In the UAE, tomatoes have high market values and are on the top of consumed vegetable which encouraged farmers to widely grow tomatoes in their open field and the greenhouses as well. To increase productivity farmers tend to increase fertilizers application without considering that most of the plant are not able to take up all nutrients applied. It has been estimated that 50 - 70% of the nitrogen (N) provided to the soil is lost [4]. Many studies reported that tomatoes are amongst plants that unable to recover all quantity of applied N [5]. N recovery from N fertilization by tomato has been found to be range from 32 to 53% in Florida [6]. While other study reported a recovery rate of 13 to 30% with 90 and 180 kg N ha^{-1} in greenhouses in Georgia [7].

N and phosphorus (P) are essential macronutrients for crop growth [8]. Both considered as a skeleton for organic compounds, including proteins, amino acids, and enzymes responsible for growth and development. N deficiency in the soil can decrease the production of number of fruits, fruit size, storage quality, color, and taste of tomato [9,10]. On the other hand, high N application can promote excessive vegetative growth which can delay the setting and maturity of tomato fruits, thereby reducing tomato production [11]. However, the residual N left after harvest in the soil can causing groundwater contamination and degrading water quality [12]. The problem can be severe in sandy soils which have higher water infiltration and lower NO_3 retaining capacity compared with clay soils.

In spite of the tomato plants requirements of P is relatively smaller than those amounts of N and K [13]; the phosphorus still have a major role in many vital growth functions and promote early plant establishment. Optimum level of P throughout root zone is essential for root development and improve nutrients and water utilization by the plant [14]. The balance combination of both N and P applications has significant impact on growth and yield parameters of tomato [15].

Hence, a sandy textured soil with very low organic matter content is predominate in the UAE it is important to target N and P fertilizer to meet plant demand, prevent nutrient deficiencies, reduce the risk of soil and water pollution and decrease production costs [16].

However, no detailed work of the effect of N and P fertilizers on greenhouse tomato in the country is available. Therefore the experiment was conducted to examine the effect of different levels of N and P fertilizer on the growth, yield and fruit qualities of tomatoes and to come up with the optimal N and P fertilizer rate that sustain tomato yield while reduce the loss of fertilizer for green house tomato in the UAE.

Materials and Methods

The experiment was conducted at Al-Kiwtate Research Station in the UAE during 2014 and 2015. Tomato seeds of elbida e.z variety were sown in potting soils in greenhouse. Four week old seedlings were transplanted into greenhouse in the beginning of November, 2014. Tomato seedlings were planted in 6 X 2 plots, consisted of 2 rows of 12 plants each and the distance between rows is 0.5m. The planting density was 20,000 plant ha^{-1}. The experiment was laid out in a factorial arrangement within a randomized complete block design with two factors and four replications. The experiment included 12 fertilizer treatments consisted of all possible combinations of four nitrogen rates (0, 300, 600 and 900 kg N/ha) and three phosphorus rates (0, 200, 400 kg P_2O_5/ha) with a constant rate of potassium application at 900 kg K_2O/ha to all plots. Nitrogen was applied as urea (N 46%), phosphorus as triple super phosphate (P_2O_5 50%) and potassium as potassium sulphate (K_2O 50%).

N and K fertilizers were applied via irrigation three times per week. Fertilizers were split into three application rates in corresponding to three growing stages; i.e. from transplant to flowering (lasted 35 days) used 15% of the total supply, from flowering to beginning of harvest (45 days) used 25% of the total supply and from initial harvest till the end of growing season (150 days). P was added by hand twice, before seedling transplanting and after one month from planting.

Recommended cultural practices such as irrigation, removal of weeds and plant protection were adopted uniformly according to standard crop management. Weeds were manually controlled.

Matured tomato fruits were harvested twice a week and total fruit number and fruit weight were determined. Yield data were summed up of the total fruit weight from consecutive harvests and converted into tons per hectare basis. The assessment of fruit number and average fruit weight (g) per plant were done twice at the third and final harvests, respectively.

Fruit physio-chemical properties were determined for fruits from the second harvest. Fruit firmness was determined by a fruit pressure tester and values were expressed in pounds. Total soluble solid was checked by a digital refractometer and values were expressed as degree Brix. Titratable acidity was determined using the method of [17].

The statistical analysis was performed using the Statistical Analysis System (SAS). The effect of the treatments was evaluated through the analysis of variance (ANOVA). The Least Significant Difference (LSD) was used to compare differences among treatments at $p \leq 0.05$. The regression procedure was used to determine the linear and/or quadratic effects of N fertilizer.

Before transplanting of tomato, soil samples were randomly collected at depth 0 - 30 cm from each experimental plot and were analyzed for the initial physical and chemical characteristics. Soil samples were also collected after final harvest to evaluate the fertilizer residues in soil of each treatment.

The initial soil in the experimental field had a texture of sandy soil (sand 99.1%, silt 0.76% and clay 0.04%), with pH 8.1, electrical conductivity (EC) 1.5 dSm^{-1}, 1.0% organic matter content, 18.5% water holding capacity and CEC 2.3 meq/100g. Fertility levels including Total-N, nitrate and available phosphorus, potassium were 127.5, 44.7, 22.6 and 154.7 ppm, respectively.

Results and Discussion

Tomato yield

Tomato responded significantly to N-P fertilizer. The total yield increased with increasing levels of applied N up to 600 kg ha^{-1} and P 200 kg ha^{-1} ($p < 0.05$), hence beyond this level tomato yield displayed significant decline (Figure 1). The interactive effects between N and P levels gave the highest yield when 600 kg ha^{-1} N was combined with 200 kg ha^{-1} P (yield 233.9 t ha^{-1}) followed by 600 N and 400 P kg ha^{-1}. This increment was about two folds higher than yields from the control plot without both N and P applications. The result suggests that increasing crop fertilization to an optimum level enables the plants to produce their potential yield.

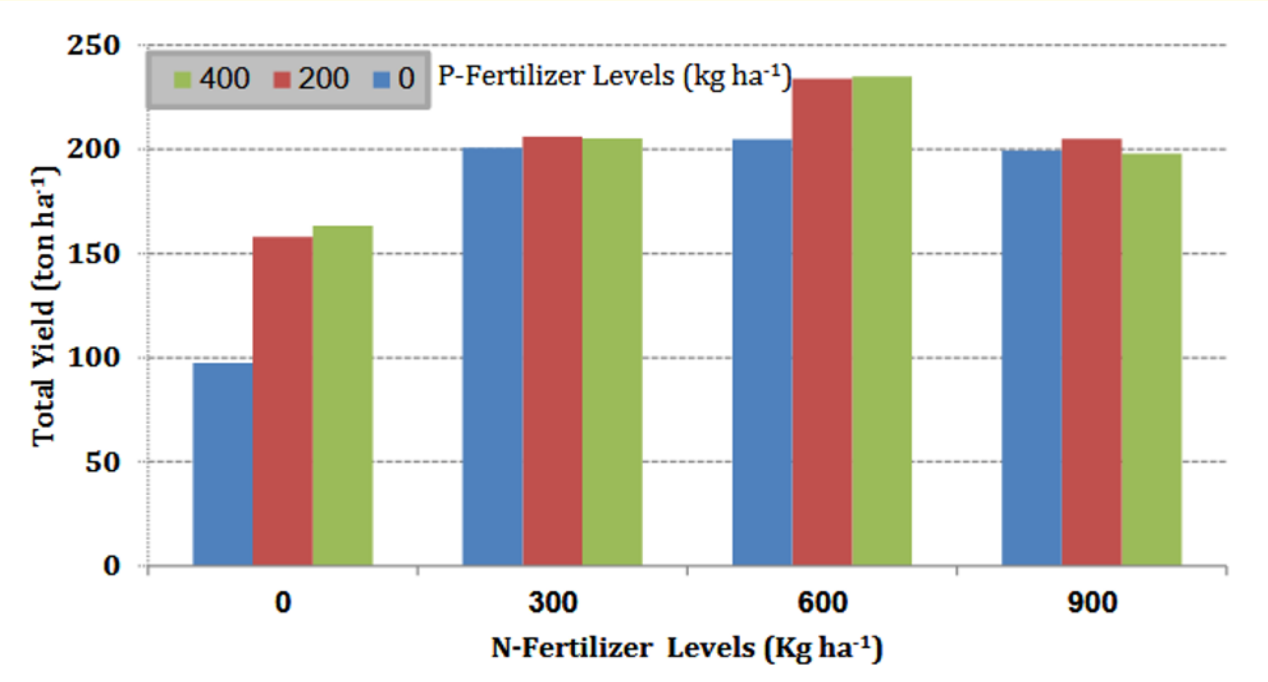

Figure 1: *Tomato Total yield in response to different N and P fertilizer application rates LSD at 5% N = 3.2, P = 2.8, NXP = 5.6.*

The linear and quadratic effects of N and P fertilizer significantly influenced the yield (yield= 122.9 + 2.9 (N)-0.025 (N^2)+1.9 (P)-0.031(P^2), r^2= 0.88). Based on derived equation from fitted quadratic model, fertilizer application level of 500 kg ha^{-1} N with 200 kg ha^{-1} P (expected yield 232.4 t ha^{-1}) could have potential to produce high yielding equal to the level of 600 kg ha^{-1} and P 200 kg ha^{-1}.

Gradual increases were recorded for average fruit weight and number of fruit per plant with increasing N-P levels (Table 1). Both average fruit weight and fruit number at 3rd harvest were highest at N 600 kg ha^{-1} and P at 200 kg ha^{-1}, i.e. 198.4g and 5.7 fruits per plant, respectively. Similar performance was retained with same fertilizer treatment till the end of harvesting season. Application of nitrogen up to 900 kg ha^{-1} had adverse effects on both fruit number and fruit weight while increasing P rate from 120 to 240 kg ha^{-1} produced the same average fruit weight and number but without adverse effects. This implies that 600 - 200 kg ha^{-1} N-P is adequate for improving growth performance of tomato, which was fully reflected in the production of higher number of fruits with bigger size.

Treatment (kg ha^{-1})		3rd harvest			End of season		
		Average fruit weight (g fruit^{-1})	Average No. of fruit (No. plant^{-1})	Plant height (cm)	Average fruit weight (g plant^{-1})	Average No. of fruit/plant	Plant height (cm)
N	P						
0	0	153.8	2.5	2.6	81.5	1.7	3.7
	200	176.5	3.2	2.8	91.9	2.1	3.9
	400	181.4	3.9	2.8	93.3	2.6	3.9
300	0	190.5	4.9	3.4	104.4	3.4	4.8
	200	198.4	5.7	3.5	109.3	3.8	4.5
	400	196.4	5.4	3.3	110.7	3.7	4.8
600	0	202.7	5.4	3.4	111.5	3.7	4.5
	200	220.6	7.3	3.3	131.6	5.1	4.8
	400	214.8	6.6	3.4	124.3	4.9	4.6
900	0	190.1	4.5	3.4	96.3	2.9	4.5
	200	200.4	5.3	3.4	101.1	3.6	4.8
	400	188.7	4.5	3.5	92.9	3.0	4.6
LSD (5%)		8.78	0.78	NS	7.8	0.6	NS

Table 1: *Average plant height and yield parameters of tomato in response to different N and P fertilizer.*

N fertilization resulted in significant longer plant shoot compared with zero application with no significant differences between N levels at the time of the 3rd harvest as well as at the end of season. The application of P has no significant effect on plant height at the two measuring time.

In greenhouse production the nutrient requirement are higher than those of field crops, mostly due increased yield which in case of tomatoes can be to ten times more in the greenhouses compared to outside field conditions [18]. The results of this trial demonstrated that mineral nutrition of tomato from application of fertilizers can increase tomato yield by several folds compared with no fertilization this finding was consistent with the past research findings of [3,19,20].

Application of N rate up to 900 kg ha^{-1} and P 200 Kg ha^{-1} did not possess further yield benefits and affected adversely the total yield and enhanced merely some quality parameters this finding in line with [21] who find out that the tomato yield at level of 140 N kg ha^{-1} were significantly lower than 100 N kg ha^{-1}. This might be due to the fact that nitrogen stimulated vegetative growth over reproductive growth which decreased yield and delayed fruit setting [22]. On the other hand, tomatoes take up relatively smaller amount of P than the amounts of N and K, as a result, smaller rate of P from fertilizers should be added to soil [13].

Appropriate balances of N, P and K are required to achieve the optimal yields as well as the best benefits. In this study, K application was fixed at 900 kg ha^{-1} for all treatments; based on the results of the optimal N rate, application of K may need to be further investigated and reduced.

Physio-chemical properties

Table 2 shows the effects of fertilizer treatments on some physio-chemical properties of tomatoes. Increasing N fertilizer rate revealed significant increments in nitrate concentration, acidity and citric acid, than the control. The other fruit quality parameters including TSS, sugar and firmness did not show significant response to N treatments. The acidity and nitrate concentration result were comparable to those values reported in the literatures for tomato products [23-25] while TSS and sugar were not comparable to those reports. The observed trend towards increasing citric acid in fruits with increasing N rate are also observed by [26] who reported that the citric acid decrease in fruit of tomatoes grown in soils with N deficiency.

Treatment	Total soluble solid (°Brix)	Nitrate (ppm)	Phosphorus (ppm)	Sugar (%)	Acidity (%)	Citric acid (%)	Firmness
Nitrogen rate (kg ha^{-1})							
0	4.1	1.2	94.1	4.0	0.27	0.34	2.2
300	4.2	1.7	98.8	4.0	0.27	0.35	2.3
600	4.1	1.8	94.2	4.4	0.28	0.36	2.1
900	4.1	1.9	93.3	4.1	0.31	0.40	2.4
LSD (5%)	ns	0.28	ns	ns	0.025	0.03	ns
Phosphorus rate (kg ha^{-1})							
0	4.1	1.6	94.3	4.1	0.27	0.34	2.2
200	4.2	1.8	94.7	4.2	0.28	0.36	2.3
400	4.1	1.6	96.5	4.1	0.29	0.37	2.3
LSD (5%)	ns	ns	ns	ns	ns	ns	ns

Table 2: *Effects of N and P fertilization on Physio-chemical Properties of tomato at the 3rd harvest.*

P fertilizer application had no significant effects on all physio-chemical properties measured in this study. A different response of quality parameters to P application level can be observed with respect to the cited literature [27] which reported increasing in total soluble solids and acidity contents as a result of increasing P application level. In fact, the results from the trial suggested that phosphorus treatments had less effect on qualities of tomato fruits than nitrogen application.

Firmness parameter show no difference between different fertilizer treatments pointing out that N and P applications did not influence this parameter and that it was mostly influenced by their genetic characteristic and time of harvesting as suggested by [28]. The results show a non-significant interaction between nitrogen and phosphorus indicating that the application rate of phosphorous was not significantly affected by the nitrogen level applied.

Soil nutrient residues

The influences of fertilizer rates on nutrient residues in soil and Electrical conductivity (EC) are presented in table 3. At all N levels applied, soil nitrate and total N concentration was significantly in order of 900 > 600 > 300 > 0 kg ha^{-1}. These results indicated that tomato plants had surplus uptakes of N at rate of 900 kg ha^{-1} that resulted in the highest nitrate accumulation in soils. High nitrate contents in soils receiving N 900 kg ha^{-1} showed that this high rate might have detrimental effects on soil and the environment. Nitrate concentration in soil without any N fertilizer application was lower than the nitrate level before transplanting indicated that there was high nitrate depletion by the plants.

Treatment	EC (ds m^{-1})	Nitrate (ppm)	Total Nitrogen (ppm)	Available Phosphorus (ppm)
Nitrogen rate (kg ha^{-1})				
0	2.3	32.5	88.5	20.2
300	3.9	45.7	143.0	19.0
600	5.2	72.9	159.7	19.2
900	5.3	124.3	198.8	23.9
LSD (5%)	1.2	5.0	6.4	NS
Phosphorus rate (kg ha^{-1})				
0	4.1	66.3	141.8	8.7
200	4.2	69.3	147.6	21.8
400	4.4	71.0	153.0	31.2
LSD (5%)	NS	NS	6.6	3.6

Table 3: *Soil chemical properties in response to different N and P fertilizer rates post-cropping of tomato.*

Soil EC is a measurement of total soluble salts presented in soil that came from fertilization and other activities. High EC in soils after harvest showed nutrient residues accumulated in soils from fertilization. The changes of EC in soil of each N treatment followed the same pattern of soil nitrate accumulations indicating that high EC attributed to N residues from relevant N application.

Increased P application level had also increased significantly the residual phosphorus in the soil, using 400 kg ha^{-1} phosphorous had almost doubled and tripled the P residues comparing to 200 kg ha^{-1} and control, respectively. There were no significant interactions between N and P fertilizers treatments on soil nutrients and EC tested in soils after harvest. In other words, N or P fertilizer was the main source of N or P accumulation in sandy soil in the UAE condition.

The results highlighted the finding of [28] that nitrate concentration, and EC of the soil can be considered reliable diagnostic indicators to develop a recommended N level in greenhouse tomato crops. However, during the tomato cropping duration, large amounts of residual nitrate built up in the soil after crop harvest as a result of increasing N application level and that increased the potential for nitrate leaching from the soil causing environmental hazards [13]. Taking into consideration that the sandy soil is the dominant soil in the UAE, thus the problem can be severer due to the higher filtration rate and lower nitrate retaining capacity as compared to clay soil.

Conclusion

The results of this research pointed out that the fertilizer level of 600 N combined with 200 kg ha^{-1} P seems to allow a good balance among productivity, physio-chemical properties and reduce nutrient residual. Balanced fertilizer management is crucial to ensure better crop establishment, growth, yield and fruit quality. Therefore adequate amount of P fertilizer should be combined with the N fertilizer to achieve the optimal benefits in field grown tomatoes. The rate and type of nutrients applied in the form of fertilizers should be adjusted after analyzing the nutrient contents of soil and taking in consideration the cultivar potential yield. A further study is important to confirm the ability to decrease fertilizer application rate to 500 kg ha^{-1} N without affecting yield and more importantly to reduce the potential for salt and nutrient residual accumulations for safer tomato production.

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Conflict of Interest

The authors are hereby declare that there is no financial interest or any conflict of interest exists in this research.

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