International Journal of Applied and Pure Science and Agriculture

ISSN Online - 2394-5532 Impact Factor : 4.446 by SJIF ISSN Print - 2394-823X

Chemical and organic fertilization on Tomato (*Lycopersiconesculentum* Mill.) quality under greenhouse conditions

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Abstract

Experiments were conducted during two successive seasons 2015/2016 in a cooled plastic tunnel at Shambat Research Station, Sudan, to determine the optimum dose of nitrogen, phosphorus, potassium and organic (Shmookh Eltabeeh) fertilizers on tomato fruits quality under green house conditions using two tomato ("Athyla" and PGT107) hybrids. A split plot design replicated three times was used. The fertilizer treatments were (T_1: 13.4 g N + 5.0 g P+ 26.7 g K, T_2: 26.6 g N + 10.0 g P + 53.3 g K and T_3: 40.1 g N + 20.0 g P + 80.0 g K/ m^2) in each group, the each of these was mixed with 2kg organic/m^2, 2kg/m^2 organic alone and control (without fertilizer) used as a sub plot. Hybrids were assigned to be the main plots. The seedlings were transplanted on one side of 80 cm ridges and 40 cm plant spacing. The organic fertilizer was incorporated in soil before planting, whereas the NPK doses were added as powder weekly after two weeks from transplanting. Fruit quality was accessed as percentage of marketable fruits/m^2, fruit diameter, total soluble solid "TSS", fruit acidity and ascorbic acid content. The means were compared using Duncan Multiple Range Test (DMRT) at $P \leq$ = 0.05. The results showed that T_2 from NPK combination with or without organic fertilizer gave significant positive effects on all quality parameters tested in both seasons. The results also showed that there was no significant difference between the two hybrids in response to NPK combination with or without organic. The quality values were decreased with increased fertilizer dose above T_2 showing that excessive NPK fertilization (T_3 with or without organic) for high quality tomato under evaporative cooling system is not recommended.

Keywords: Tomato (Lycopersicon esculentum Mill.), Green house, Chemical fertilizer, Organic, Marketable, Quality

I. INTRODUCTION

Tomato (*Lycopersiconesculentum* Mill.) plant is native to South America (Peru and Ecuador) and was first domesticated in Mexico. It is one of the most popular and widely consumed vegetable crops all over the world, and high-quality yield is an essential prerequisite for its economical success. Tomato has been recently gaining attention in relation to the prevention of some human diseases. This interest is due to the presence of carotenoids particularly lycopene, a source of vitamine A, which is an unsaturated alkali compound, that appears to be an active compound in the prevention of cancer, cardiovascular risk and in slowing down cellular aging[1], [2] and [3]. It is also rich in vitamin C, which is commonly deficient in the diet, and vitamin B. The fruit is now consumed in various ways, either as a raw material for the preparation of food, sauces and beverages and it is an important part of the diet for people in many countries [4].

Tomato is considered as one of the most important vegetables in Sudan, it is second to onion in production. It occupies about 28% of the total area of vegetables grown in Sudan [5]. Tomato yield is very low during summer months because of high temperature and low relative humidity; this is why its prices are high during summer. Thus, it was cultivated in cooled green houses in March to produce in early July.

Greenhouse production is a very dynamic economic sector and must cope with rapid changes in market trends and consumer preferences. Consequently, choosing the right variety in greenhouse production is a critical stage in the production process [6].

Greenhouse tomato varieties are indeterminate and require constant maintenance and physical support of the plants for long term fruit production. Indeterminate tomato varieties need additional fertilizers as they continue to grow to produce fruits compared to determinate tomato varieties that stop active vegetative growth and increase production of fruits [7].

Fertilizer is a major part of the crop production expenses for tomato; however, it is critical for successful crop yields and high fruit quality [8], [9] and [10]. Nitrogen, phosphorus and potassium are critical for tomato growth and development [11]. Nitrogen is associated with vegetative and biomass accumulation, phosphorus is to seed and root development, while potassium is associated with fruit development and quality.

II. OBJECTIVES OF THE STUDIES

The objectives of this study were to investigate the effect of chemical and organic fertilizers on percentage of marketable fruit/m^2, fruit diameter and fruit quality parameters to determine the optimum dose of fertilizers to be applied at Khartoum state, Sudan for protected tomato production.

III. MATERIALS AND METHODS

An experiment was carried out in two successive summer seasons (2104/2015 and 2015/20 16) in cooled plastic house at Shambat Research Station, Agricultural Research Corporation (ARC), Sudan. The site of experiment is at (Lat. 150 40′ N, Long.320 32′ E, and of 380 meters above sea level). The experimental units were arranged in split plots design with three replications. Two hybrid, namely Athyla and PGT107 was assigned to the main plot whereas, the fertilizer treatments assigned to the sub plot. The fertilizer treatments were as follows:

T_1 : 13.4 g N + 5.0 g P + 26.7 g K/ m^2
T_2 : 26.7 g N +10.0 g P + 53.3 g K/ m^2
T_3 : 40.1 g N + 20.0 g P + 80.0 g K/ m^2
T_4 : Organic fertilizer 2.0 Kg /m^2.
T_5 : 13.4g N + + 5.0 g P+ 26.7 g K + 2kg organic/ m^2
T_6 :26.7 g N + 10.0 g P + 53.3 g K +2kg organic / m^2
T_7: 40.1 g N + 20.0 g P + 80.0 g K +2kg organic / m^2
T_8: Control (without fertilizers)

The experimental area in the greenhouse was prepared in bed 80cm wide “mustaba”. The spacing between plants was 40 cm and 80cm interspacing “in mustaba”. The plot size was 5.2m X 0.8m.

The condition was controlled by evaporative cooling to provide temperature 28^{o}C$\pm$ 3) and relative humidity about 70 %$\pm$ 5 at mid day. Organic fertilizer was added 2kg /m^2 before transplanting. Chemical composition of the organic fertilizer used is shown in table (1).

Table (1): Chemical composition of organic fertilizer

Organic fertilizer	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)	O.C. (%)
	1.3 - 1.5	1.9 – 2.2	4 - 7	3 – 5	1 -1.5	2.5- 3.5	20 – 24

Nursery raised seedlings of both cultivars were planted on one side of 80 cm ridges and 40 cm plant spacing. Each experimental unit consisted of two north - south ridges (1.6m in width) and 5.2m in length. NPK combinations were added in equal doses weekly after two weeks from transplanting. Irrigation was done by using drip system and applied every day for 15 – 20 minutes. Chemical pests and diseases control, weeding and pruning of side branches were done when

Volume 03, Issue 9, [September- 2017] ***e-ISSN: 2394-5532, p-ISSN: 2394-823X***

necessary. The crop harvest started after two months and half from transplanting and continued for two months. Fruit picking was done at 3 – 4 days interval during the first month and weekly for the second month. The data collected were marketable fruits/m^2 (as percentage), fruit diameter and fruit chemical quality tests for the fruits (TSS, fruit acidity and ascorbic acid content).

Data were subjected to analysis of variance by computer program Gen Stat. The means were separated using Duncan's Multiple Range Test (DMRT) at the 5 % level.

IV. RESULTS AND DISCUSSION

As shown in Table (2) the percentage of marketable fruit /m^2 was significantly affected by different doses of fertilizers whereas, there were no significant between the two hybrids in response to NPK combination with or without organic fertilizers. The highest percentage of marketable fruit was obtained from treatment T_2 (26.7 g N + 10.0 g P + 53.3 g K/ m^2) in both seasons, with the two hybrids. These results were in line with [12] and [13] who reported that potassium (K) is the nutrient having the strongest influence on quality attributes that determine fruit marketability. The role of potassium in plant metabolism, growth, development and its significance in production of marketable fruit and on fruit firmness is remarkable.

Table (2) Effect of chemical and organic fertilizers on percentage of marketable fruits /m^2 of two tomato hybrids cultivated under cooled plastic house conditions

Treatments	% of Marketable fruits / m^2 Season 2014/2015		Mean (fertilizer)	% of Marketable fruits / m^2 Season 2015/2016		Mean (fertilizer)
	Athyla	PGT107		Athyla	PGT107	
13.4 g N + 5.0 g P+ 26.7 g of K/ m^2	92.4^{ab}	91.4^{ab}	91.9^{b}	93.0^{a}	88.5^{bc}	90.2^{ab}
26.7 g N + 10.0 g P + 53.3 g of K/ m^2	93.5^{a}	94.6^{a}	94.1a	93.4^{a}	93.7^{a}	93.6^{a}
40.1 g N + 20.0 g P + 80.0 g of K/ m^2	89.3^{cd}	88.2^{de}	88.8^{c}	85.1^{cd}	81.7^{de}	83.4^{bc}
Organic fertilizer 2.0 kg /m^2	91.1^{bc}	91.8^{ab}	91.5^{b}	86.3^{bc}	84.6^{cd}	85.5^{bc}
13.4g N +5.0 g P+26.7 g K +2kg organic/ m^2	91.6^{ab}	90.9^{bc}	91.3^{b}	87.8^{bc}	87.6^{bc}	87.7^{b}
26.7g N+10.0 g P+ 53.3 g K +2kg organic/ m	93.1^{a}	92.2^{ab}	92.7^{ab}	91.9^{ab}	91.7^{ab}	91.8^{ab}
40.1g N+20.0 g P+ 80.0g K+2kg organic/ m^2	90.6^{bc}	84.0^{e}	87.3^{c}	84.2^{cd}	83.5^{cd}	83.9^{c}
Control (without fertilizer)	81.7^{f}	80.9^{f}	81.3^{d}	80.1^{d}	72.0^{e}	76.1^{d}
Mean (hybrid)	90.4	89.3		87.7	85.4	
SE ±	0.23			0.62		
CV%	5.20			9.60		

± Means with the same letters in the same column are not significantly different at $P \leq 0.05$

Table (3) shows that the treatment T_2 (26.7 g N + 10.0 g P + 53.3 g K/ m^2) brought the highest fruit diameter with Athyla and PGT107 hybrids, fruits diameter were 6.2 and 6.3 cm, respectively during season one; while in season two the highest fruit diameter achieved by treatmentT_2 with organic for the two hybrids (7.2 and 7.0 cm). Increasing N, P and K concentrations over the recommended level adversely affected fruit size and diameter. As shown in table (3) these results are in contrast to those of [14] and [15] who mentioned that low dose of NPK will result in smaller fruits since the rate of photosynthetic activity of the plant will drop sharply, therefore, growth will be reduced and fruits with small size would be produced.

Volume 03, Issue 9, [September- 2017] ***e-ISSN: 2394-5532, p-ISSN: 2394-823X***

Table (3) Effect of chemical and organic fertilizers on fruit diameter (cm) of two tomato hybrids cultivated under cooled plastic house conditions

Treatments	Fruit diameter(cm) Season 2014/2015		Mean (fertilizer)	Fruit diameter(cm) Season 2015/2016		Mean (fertilizer)
	Athyla	PGT 107		Athyla	PGT 107	
13.4 g N + 5.0 g P+ 26.7 g of K/ m^2	5.2^{b}	6.0^{a}	5.6^{ab}	6.9^{a}	6.1^{de}	6.5^{a}
26.7 g N + 10.0 g P + 53.3 g of K/ m^2	6.2^{a}	6.3^{a}	6.3^{a}	6.8^{a}	6.4^{bc}	6.6^{a}
40.1 g N + 20.0 g P + 80.0 g of K/ m^2	5.2^{b}	5.1^{b}	5.2^{b}	6.7^{ab}	6.1^{cd}	6.4^{a}
Organic fertilizer 2.0 kg /m^2	5.5^{b}	5.4^{b}	5.5^{ab}	6.5^{bc}	6.0^{cd}	6.3^{ab}
13.4g N+5.0 g P+26.7g K+2kg organic/ m^2	5.4^{b}	5.3^{b}	5.4^{ab}	6.6^{bc}	6.5^{bc}	6.6^{a}
26.7g N+10.0 g P+53.3g K+2kg organic / m^2	5.2^{b}	4.9^{b}	5.1^{b}	7.2^{a}	7.0^{a}	7.1^{a}
40.1g N+20.0g P+80.0g K+2kg organic / m^2	4.6^{c}	4.8^{b}	4.7^{b}	6.5^{bc}	5.9^{cd}	6.2^{b}
Control (without fertilizer)	4.4^{c}	4.9^{b}	4.7^{b}	6.0^{cd}	5.7^{d}	5.9^{b}
Mean (hybrid)	5.1	5.3		6.7	6.2	
SE ±	9.30			3.50		
CV%	0.42			0.14		

± Means with the same letters in the same column are not significantly different at $P \leq 0.05$

Table (4) showed that there were differences in total soluble solid (TSS) among the different treatments during both seasons. While, there was no difference between hybrids in response to NPK combination with or without organic fertilizers. The highest (TSS) reached from treatment T_2 with organic (26.7 g N + 10.0 g P + 53.3 g K/ m^2 +2kg organic/m^2) with the two hybrids during the both seasons. These results disagreed with [16] who reported that TSS increased with increase the dose of fertilizers, mainly potassium fertilizer. It is also not in line with those of [15] who stated that TSS increased with high level of N and P, while high K reduced it.

Table (4) Effect of chemical and organic fertilizers on total soluble solid (TSS °Brix) of two tomato hybrids under cooled plastic house conditions

Treatments	Total soluble solid (TSS °Brix) Season 2014/2015		Mean (fertilizer)	Total soluble solid (TSS °Brix) Season 2015/2016		Mean (fertilizer)
	Athyla	PGT107		Athyla	PGT107	
13.4 g N + 5.0 g P+ 26.7 g of K/ m^2	4.2^{cd}	4.4^{bc}	4.3^{c}	4.1^{cd}	4.0^{cd}	4.1^{bc}
26.7 g N + 10.0 g P + 53.3 g of K/ m^2	4.8^{ab}	4.5^{bc}	4.7^{b}	4.7^{bc}	4.3^{cd}	4.6^{b}
40.1 g N + 20.0 g P + 80.0 g of K/ m^2	3.6^{de}	3.9^{de}	3.8^{cd}	4.0^{cd}	3.8^{cd}	3.9^{bc}
Organic fertilizer 2.0 kg /m^2	4.0^{cd}	4.3^{bc}	4.2^{c}	4.7^{bc}	4.5^{bc}	4.6^{b}
13.4g N+5.0 g P+26.7g K+2kg organic/ m^2	4.6^{bc}	4.1^{cd}	4.4^{c}	4.8^{bc}	5.0^{ab}	4.9^{ab}
26.7g N+10.0 g P+53.3g K+2kg organic / m^2	5.1^{a}	4.9^{a}	5.0^{a}	5.2a	4.8^{bc}	5.0^{a}
40.1g N+20.0g P+80.0g K+2kg organic / m^2	3.8^{de}	4.0^{cd}	3.9^{d}	3.6^{de}	3.5^{de}	3.6^{c}

Control (without fertilizer)	3.7^{de}	3.1^{e}	3.4^{e}	3.6^{de}	3.3^{e}	3.5^{c}
Mean (hybrid)	4.2	4.2		4.3	4.2	
SE ±	9.00			5.50		
CV%	0.54			0.14		

± Means with the same letters in the same column are not significantly different at P ≤ 0.05

Table (5)illustrates the influence of fertilizers on fruit acidity. The highest acidity obtained from treatment T_3 with organic (40.1 g N + 20.0 g P + 80.0 g K + 2kg organic / m^2) for the two hybrids during both seasons. The results indicate that acidity increased with the increase in the dose of fertilizers, especially with potassium. These results are in confirmatory with the results of [17] who reported that high dose of potassium fertilizer have a positive significant effect on tomato fruit acidity, while it disagrees with that of [18], [19] and [15] who reported that low NPK mainly phosphorus will produce fruits with high acidity.

Table (5) Effect of chemical and organic fertilizers on fruits acidity of two tomato hybrids under cooled plastic tunnel

Treatments	Fruit acidity Season 2014/2015		Mean (fertilizer)	Fruit acidity Season 2015/2016		Mean (fertilizer)
	Athyla	PGT107		Athyla	PGT107	
13.4 g N + 5.0 g P+ 26.7 g of K/ m^2	4.3^{cd}	4.6^{bc}	4.5^{b}	3.9^{cd}	4.0^{bc}	4.0^{bc}
26.7 g N + 10.0 g P + 53.3 g of K/ m^2	4.2^{cd}	4.5^{bc}	4.4^{b}	4.2^{bc}	4.6^{bc}	4.2^{b}
40.1 g N + 20.0 g P + 80.0 g of K/ m^2	5.0^{ab}	4.7^{bc}	4.9^{ab}	5.0^{ab}	4.8^{ab}	4.9^{ab}
Organic fertilizer 2.0 kg /m^2	3.9^{de}	3.3^{f}	3.5^{c}	3.9^{cd}	4.5^{bc}	4.2^{b}
13.4g N+5.0 g P+26.7g K+2kg organic/ m^2	4.2^{cd}	4.1^{cd}	4.2^{b}	3.5^{cde}	3.1^{de}	3.3^{c}
26.7g N+10.0 g P+53.3 g K+2kg organic / m^2	5.0^{ab}	4.6^{bc}	4.8^{b}	4.9^{ab}	4.5^{bc}	4.7^{b}
40.1g N+20.0 g P+80.0 g K+2 kg organic / m^2	5.1^{a}	4.9^{ab}	5.0^{a}	5.2^{a}	5.0^{ab}	5.1^{a}
Control	3.6^{de}	3.9^{de}	3.8^{c}	2.9^{e}	3.4^{cd}	3.2^{c}
Mean (hybrid)	4.4	4.3		4.5	3.9	
SE ±	13.17			11.6		
CV%	0.99			0.27		

± Means with the same letters in the same column are not significantly different at P ≤ 0.05

Although there were differences between the two seasons in ascorbic acid content, the highest amount of ascorbic acid was found from the moderate treatment T_2 with organic (26.7 g N + 10.0 g P + 53.3 g K + 2kg organic / m^2 .) for the two hybrids during both seasons Table (6). The results also showed that there was no difference between the two hybrids in response to NPK combination with or without organic. These results are not in line with [17] and [20] who reported that there are a positive correlation between increase of fertilizer dose and ascorbic acid content. Generally tomato fruit quality was increased significantly by increasing potassium application [21].

Table (6) Effect of chemical and organic fertilizers on ascorbic acid content of two tomato hybrids under cooled plastic tunnel condition

Treatments	ascorbic acid(mg) Season 2014/2015		Mean (fertilizer)	ascorbic acid(mg) Season 2015/2016		Mean (fertilizer)
	Athyla	PGT107		Athyla	PGT107	
13.4 g N + 5.0 g P+ 26.7 g of K/ m^2	37.0^{ab}	35.0^{bc}	36.0^{b}	47.7^{bc}	42.0^{cd}	44.9^{c}
26.7 g N + 10.0 g P + 53.3 g of K/ m^2	36.5^{b}	36.0^{b}	36.3^{b}	47.3^{bc}	43.7^{cd}	45.5^{c}
40.1 g N + 20.0 g P + 80.0 g of K/ m^2	35.8^{b}	31.0^{cd}	33.4^{bc}	47.6^{bc}	47.1^{bc}	47.4^{b}
Organic fertilizer 2.0 kg /m^2	24.8^{ef}	21.5^{e}	23.2^{d}	49.0^{bc}	46.3^{bc}	47.7^{b}
13.4g N+5.0 g P+26.7g K+2kg organic/ m^2	24.5^{ef}	34.0^{bc}	29.3^{cd}	50.7^{b}	42.3^{cd}	46.5^{b}
26.7g N+10.0 g P+53.3g K+2kg organic / m^2	39.5^{a}	38.5^{a}	39.0^{a}	56.7^{a}	51.7^{b}	54.2^{a}
40.1g N+20.0g P+80.0g K+2kg organic / m^2	34.4^{bc}	35.2^{bc}	34.8^{bc}	48.5^{bc}	42.0^{cd}	45.3^{c}
Control (without fertilizer)	25.0^{de}	27.0^{d}	26.0^{cd}	41.0^{d}	41.3^{d}	41.2^{d}
Mean (hybrid)	32.2	32.3		48.6	44.6	
SE ±	7.00			4.40		
CV%	2.27			1.16		

± Means with the same letters in the same column are not significantly different at $P \leq 0.05$

V. CONCLUSION

The above results showed that the moderate dose T_2 with or without organic (26.7 g N + 10.0 g P + 53.3 g K/m^2) significantly increased the quality of fruits during the two seasons; of tomato cultivated under evaporative cooling system, whereas, no significant increase in most parameters (except for acidity) were obtained at higher doses (40.1 g N + 20.0 g P + 80.0 g K/ m^2) with or without organic fertilizer compared to control at Khartoum state, Sudan.

VI. Acknowledgement

I would express my great thanks to Prof. Mirgani khogali Ahmed for his valuable help and assisting throughout this research, Dr. Salah El Turabi for his assistant in analysing data and Mrs. Zeinab Adam for her experimental work assistance at Shambat Agric Research Station, Sudan.

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