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Effect of Fertigation Levels on Growth, Yield and Yield Components of Tomato (*Lycopersicon esculentum* Mill.) Under Kassala State Conditions, Sudan

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ABSTRACT:
The experiments were conducted at the farm of the Horticulture Department, Ministry of Production and Economic Resources, Kassala State which is located at latitude 15° 27´ N and longitude 36° 24´ E. The objective of the study was to explore the influence of fertigation levels on growth, yield and yield components of tomato crop under Kassala state condition, Sudan. Seedlings of tomatoes cultivar (*Advantage*) were raised in open nurseries for 7 to 8 weeks before transplanting. Cultural practices of transplanting, weeding, pest and insect control were carried out as recommended by ARC. Six levels of recommended dose of urea viz; 50%, 75%, 100%, 125%, 150% and 175% of urea recommended dose (URD) for manual methods was applied by fertigation during two consecutive winter seasons, 2019/2020 and 2020/2021. Treatments were arranged in a randomized complete block design with three replications in plots (2.8m×3m). The parameters measured included the plant height, plant stem girth, number of leaves per plant, number of days from transplanting to flowering, total yield (t/ha), marketable yield (t/ha), number of fruits per plant, fruit weight, diameter, fruit dry matter and total soluble solids of fruit. The results showed that the growth parameters of tomato increased with increasing levels of urea at both seasons and the highest values were recorded with 175% of urea recommended dose in both seasons. The result on yield and yield components showed that the effect of urea rates was very highly significant on both seasons and the highest yield and yield components were obtained under 175% URD while the lowest yield was obtained at 50% level. Moreover, the highest benefit cost ratio was recorded with 125% URD.
Keywords: Fertigation, urea recommended dose, tomato.

Introduction:

Tomato is the most popular home garden and the second most consumed vegetable after potato in the world. Tomato production has increased worldwide by 164% in 40 years while tomatoes world consumption has increased by 314% (Nicola *et al*., 2009). Tomato in Sudan is produced around large cities and towns along the Nile and on seasonally flooded plains. It is produced entirely for fresh domestic consumption. The bulk of marketed tomato is consumed in towns and cities, namely in Khartoum State (Yasir, 2008).

Kassala state is located in Eastern Sudan. The area around Kassala town has traditionally been used for fruits and vegetables production using underground water for irrigation. The total area under tomato production in Kassala was estimated by Ministry of Production and Economic Recourses, Kassala State, in 2019 as 1.3 thousand hectares, giving a total yield of 17.5 thousand tons.

Drip irrigation is defined as a method of irrigation where the water is directed to the root zone according to the plant water requirement (Suryawanshi, 1995). Drip irrigation has become more favorable due to its advantages which appear in the production, fertilizer application, the control of water application, as well as the deep percolation (Ayars, *et al*., 1999).

Fertigation is an agricultural technology that injects fertilizers into the water and then transporting them into the root zone (Hagin and Lowengart 1996). Fertilizer is one of the main factors limiting vegetable and crop production in arid and semiarid regions (Baldi *et al*., 2014). Tomato is reported to be a heavy feeder of nitrogen and fertigation increased yield of tomato by 20% to 30% compared with manual application (Hebbar *et al*., 2004). Moreover, Malakouti (2004) reported that fertigation saved 20% to 50% of the fertilizers, in addition it improved yield and quality of forage corn as compared with the common methods of fertilizer application. Meanwhile, Wang and Yingying (2016) reported that optimal management of fertilizer is required to obtain high yields and maximum profits in commercial tomato. Therefore, the objective of the study was to explore the influence

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of fertigation levels on growth, yield and yield components of tomato crop under Kassala state condition, Sudan

Materials and Methods:

The experiment was conducted at the farm of the Horticulture Department of the Ministry of Production and Economic Resources, Kassala, Kassala State, Sudan, during consecutive winter seasons, of 2019/2020 and 2020/2021. The farm is located at latitude 15° 27´ N and longitude 36° 24´ E. The average elevation of the area is 500 m above sea level. The climate of site is semi desert with annual rainfall ranging between 100 and 250 mm, which normally occurs between July and October. The temperature ranges between 20°C and 45°C in winter and summer, respectively. Winter season extends from November to February.

Seedlings of tomato, cultivar (*Advantage*) were raised in open field nurseries for 7 to 8 weeks before transplanting. All cultural practices such as fertilization, weeding, pest and insect control were carried out as recommended by ARC. The seedlings were transplanted in field at the first of December in both seasons. Harvesting was done manually every 3 days at complete maturity.

Experiment was conducted to evaluate the effect of different rates of urea by testing 50%, 75%, 100%, 125%, 150% and 175% of recommended dose of urea for tomato by fertigation. Six treatments were arranged in a randomized complete block design with three replications in plots (2.8m×3m). The recommended dose of 50 kg/urea/feddan fertilizer for tomato was split in two doses, the first at 21 days after transplanting and the second at one month after the first dose.

The quantity of irrigation water was applied by drip irrigation every 3 days in the morning according to tomato crop water requirement in different growth stage.

The parameters measured included the plant height (cm), plant stem girth (cm), number of leaves per plant, number of days from transplanting to flowering, total yield (t/ha), marketable yield (t/ha), number of fruits per plant, fruit weight (g), diameter (cm), fruit dry matter and total soluble solids of fruit.

CropStat statistical package was used for data analysis and the least significant difference test was used for mean separation at the probability level of 0.05.

Results and Discussion:

Effect of urea fertigation levels on plant height and stem diameter of tomato

Plant height and plant stem diameter of tomato increased with increasing levels of urea and showed vey highly significant differences in both seasons (Table 1). The highest plant height and plant stem diameter were recorded with 175% URD in both seasons (Table 1). The role of nitrogen is manly during vegetative growth, which means an increase in biomass and thus leads to increased efficiency or ability to photosynthesis. These results are in conformity with the findings of Pawar *et al*. (2013) who found that the maximum plant height and plant spread were observed in 100% water soluble fertilizer by fertigation on tomato production. Moreover, Arunkumar *et al*. (2006) reported that growth parameters of sweet corn were influenced favorably with increasing levels of NPK application

Table (1): Effect of urea fertigation levels on plant height (cm) and plant stem diameter (cm) of tomato during two consecutive winter seasons, 2019/2020 and 2020/2021.

Levels of	Plant high (cm)		Plant stem diameter (cm)	
urea fertigation	19/20	20/21	19/20	20/21
50% of URD	38.3c	37.3d	0.8e	0.7e
75% of URD	40.7c	40.3cd	0.8e	0.8de
100% of URD	41.7c	43.3bcd	0.9ce	0.9cd
125% of URD	46.0bc	46.7abc	1.0bc	1.0bc
150% of URD	51.7ab	50.0ab	1.1ab	1.1ab
175% of URD	56.7a	52.7a	1.2a	1.2a
Sig. level	***	***	***	***
$SE^{\pm}$	2.5	2.3	0.34	0.03
CV%	9.4	9.0	6.2	4.6

***: *indicated significance at P≤0.001. Means within each column followed by the same letters are not significantly different according to LSD.*

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Effect of urea fertigation levels on number of leaves per plant and days from transplanting to flowering of tomato:

Fertigation levels showed significant effects on the number of leaves per plant in both seasons. The highest number of leaves per plant was under 175% and 150% URD compared to 50% URD. For days from transplanting to flowering there is a highly significant difference in both seasons (Table 2). The few days from transplanting to flowering were recorded on 50% URD comparing to 175% URD. Similar results were cited by Kavitha, *et al*. (2007) who reported that, the application of 100% water soluble fertilizer under shade improved the growth parameters namely early flowering, primary braches per plant and leaf area index at different stages of growth on tomatoes.

Table (2): Effect of urea fertigation levels on number of leaves per plant and days from transplanting to flowering of tomato during two consecutive winter seasons, 2019/2020 and 2020/2021.

Levels of urea fertigation	Number of leaves per plant		Days from transplanting to flowering	
	19/20	20/21	19/20	20/21
50% of URD	13e	12e	33c	34c
75% of URD	14d	13c	33c	35bc
100% of URD	16c	14c	34bc	35bc
125% of URD	18b	16b	34bc	36ab
150% of URD	20a	17b	35ab	36ab
175% of URD	20a	21a	36a	37a
Sig. level	***	***	**	*
$SE^{\pm}$	0.2	0.60	0.5	0.6
CV%	1.9	6.6	2.7	2.8

****: indicated significance at P≤0.001. Means within each column followed by the same letters are not significantly different according to LSD.*

Effect of urea fertigation levels on total yield and marketable yield:

Data analysis showed that the effect of urea levels was very highly significant on total yield and marketable yield in both seasons (Table 3). The highest yield was obtained under 175% of urea recommended dose, while the lowest yield was obtained for 50% of urea recommended dose. Marketable yield with175% RDU increased by 116% and 128% in the first and second seasons, respectively, as compared to the 100% of RDU (Table 3). The increase in yield with 175% of fertilizer recommended dose might be due to the more readily available form of fertilizer which resulted in higher availability of nutrients in the soil solution and consequently led to higher nutrients uptake. Also the higher yield due increase in fertilizer rates could be attributed to adequate nutrient supply, which in turn improved all growth and yield influencing characters as already quoted (Table 3). However, Khalifa, *et al*. (2018) reported that total yield of grapefruit with 125% of recommended dose of urea increased by 16% and 10% in the first and second year, respectively, as compared to the 100% of recommended dose of urea. Similar results were reported by Anitta, (2013) who found that drip fertigated maize at 150% recommended dose of fertilizer recorded significantly higher grain yield compared to 50%.

Table (3):Effect of urea fertigation levels on total yield (t/ha) and marketable yield (t/ha) of tomato during two consecutive winter seasons, 2019/2020 and 2020/2021.

Levels of urea fertigation	Total yield (t/ha)		Marketable yield (t/ha)	
	19/20	20/21	19/20	20/21
50% of URD	34.4c	30.0d	29.7b	28.1c
75% of URD	37.2c	31.4cd	30.3b	29.7c
100% of URD	55.6b	32.7c	44.9a	30.9c
125% of URD	58.9ab	36.4b	46.8a	35.0b
150% of URD	65.0ab	37.2b	49.4a	36.1b
175% of URD	70.0a	42.2a	52.2a	39.6a
Sig. level	***	***	***	***
$SE^{\pm}$	4.10	0.70	2.80	0.97
CV%	13.0	3.6	11.6	5.1

****: indicated significance at P≤0.001. Means within each column followed by the same letters are not significantly different according to LSD.*

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Effect of urea fertigation levels on number of fruits per plant and total soluble solids:

Fertigation levels revealed highly significant differences on number of fruits per plant and total soluble solids in both seasons. The 175% of urea recommended dose recorded the highest number of fruits per plant and the total soluble solids in both seasons (Table 4). This might be due to the availability of nitrogen in the soil which leads better utilization of urea. These results are in conformity with the findings of Khalifa, *et al*. (2018) who found that the highest number of fruits per tree of grape fruit were obtained under 125% of urea recommended dose. On the other hand, Wang, *et al*. (2019) reported that the highest soluble sugar content at 2.8% was achieved when application of N was 360kg/ha.

Table (4): Effect of urea fertigation levels on number of fruits per plant and total soluble solids of tomato during two consecutive winter seasons, 2019/2020 and 2020/2021.

Levels of	Number of fruits per plant		TSS	
urea fertigation	19/20	20/21	19/20	20/21
50% of URD	21f	19f	4.3e	5.0e
75% of URD	25e	24e	4.6de	5.1de
100% of URD	31d	29d	4.9d	5.4d
125% of URD	37c	35c	5.4c	6.0c
150% of URD	43b	40b	5.9bc	6.3bc
175% of URD	50a	47a	6.3a	6.7a
Sig. level	***	***	***	***
$SE^{\pm}$	0.81	0.96	0.10	0.91
CV%	4.1	4.8	3.6	2.8

****: indicated significance at P≤0.001. Means within each column followed by the same letters are not significantly different according to LSD.*

Effect of urea fertigation levels on fruits diameter and fruit weight :

The effect of urea fertigation levels showed very highly significant differences in fruit weight and diameter in both seasons. The highest fruit weight and diameter were obtained with 175% of URD. On the other hand, there were no significant differences between 175% of URD and 150% of URD in fruit weight and diameter in both seasons (Table 5). These results are in conformity with the findings of Khalifa, *et al*. (2018) who found that the highest fruit weight and diameter of grapefruit was obtained with125% of recommended dose of urea compared to the 50% of recommended dose of urea. Kavitha, *et al*. (2007) reported that fruit firmness of tomato were improved with the application of 100% water soluble fertilizer compared to lower application.

Table (5): Effect of urea fertigation levels on fruit diameter (cm) and fruit weight (g) of tomato during two consecutive winter seasons, 2019/2020 and 2020/2021.

Levels of	Fruit diameters (cm)		Fruit weight (g)	
urea fertigation	19/20	20/21	19/20	20/21
50% of URD	5.0e	5.0c	75d	76c
75% of URD	5.4d	5.4bc	82c	79c
100% of URD	6.1c	5.4bc	89b	86b
125% of URD	6.5b	6.0ab	95a	90ab
150% of URD	6.7ab	6.1ab	96a	93a
175% of URD	6.9a	6.2a	99a	96a
Sig. level	***	***	***	***
$SE^{\pm}$	0.99	0.21	1.43	1.9
CV%	2.8	6.3	2.8	3.9

****: indicated significance at P≤0.001. Means within each column followed by the same letters are not significantly different according to LSD.*

Effect of urea fertigation levels on fruit dry matter of tomato:

Dry matter of tomato fruits recorded very highly significant differences in both seasons (Table 6). The highest percentage of fruit dry matter was obtained with 175% of URD compared to other treatments. There was no significant difference between 175% of URD and 150% of URD in fruit dry matter in both seasons (Table 6). These results support those of Arunkumar, *et al*. (2006) who found that dry matter production of sweet corn increased with increasing levels of NPK at all growth stages of crop. Kavitha, *et al*. (2007) reported that ascorbic acid, lycopene and carotene of tomato were improved with the application of 100% water soluble fertilizer compared to lower application.

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Table (6):Effect of urea fertigation levels on fruit dry matters (%) of tomato during two consecutive winter seasons, 2019/2020 and 2020/2021.

No	Particulars	% of urea recommended dose					
		50	75	100	125	150	175
1	Variable cost (SDG/ha)						
	Irrigation system	90490	90490	90490	90490	90490	90490
	Land preparation	50400	50400	50400	50400	50400	50400
	Fertilizers	36000	54000	72000	90000	108000	126000
	Water man	80000	80000	80000	80000	80000	80000
	Weed control	28800	28800	28800	28800	28800	28800
	Power	29745	29745	29745	29745	29745	29745
2	Total cost (SDG/ha)	315555	333615	351675	369735	387795	405855

****: indicated significance at P≤0.001. Means within each column followed by the same letters are not significantly different according to LSD.*

Effect of urea fertigation levels on economic analysis of nitrogen of tomato:

Variable cost includes labour, power, operation and maintenance of drip irrigation and fertilizers cost of tomato is shown on Table 7. The treatments of 125%, 150% and 175% of URD recorded the same highest benefit cost ratio compared to other treatments (Table 8). The 125% of URD was suggested to use for tomato fertigation. These results are in conformity with the findings of Khalifa, *et al*. (2018) who found that the highest marginal rate of return of grapefruit was obtained with125% of recommended dose of urea compared to the 50% of recommended dose of urea.

Table (7.): The treatments of 125%, 150% and 175% of URD recorded the same highest benefit cost ratio compared to other treatments

Levels of	Fruits dry matter (%)	
urea fertigation	19/20	20/21
50% of URD	4.6e	4.5e
75% of URD	5.1d	4.9d
100% of URD	5.4cd	5.3c
125% of URD	5.7bc	5.6bc
150% of URD	5.9ab	5.9ab
175% of URD	6.1a	6.0a
Sig. level	***	***
$SE^{\pm}$	0.98	0.15
CV%	3.1	4.7

Table (8) :Benefit cost ratio of tomato under different rates of urea fertigation

Rates of urea fertigation	Average yield (kg/ha)	Gross return (SDG/ha)	Net return (SDG/ha)	Total cost (SDG/ha)	B/C ratio (%)
50% of URD	28900	2890000	2574445	315555	8.2
75% of URD	30000	3000000	2666385	333615	8.0
100% of URD	37900	3790000	3438325	351675	9.8
125% of URD	40900	4090000	3720265	369735	10.1
150% of URD	42750	4275000	3887205	387795	10.0
175% of URD	45900	4590000	4184145	405855	10.3

The price of one kg of tomato=100 SDG, the price of one kg of urea =300 SDG and one US=450SDG.

Conclusion:

The highest yield and yield components of tomato under Kassala conditions were obtained with 175% of urea recommended dose compared to 50% of urea recommended dose by fertigation.

125%, 150% and 175% of urea recommended dose recorded the highest benefit cost ratio compared to other treatments.

Recommendation:

Based on the above findings and economic analysis application of 125% of urea recommended dose by fertigation recorded the highest benefit cost ratio for tomato under Kassala conditions.

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