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Research Article

Verification of Foliar Fertilizer (Magic K) to Improve Yield and Yield Related Traits of Tomato at Degem District, North Shewa Zone, Oromia, Ethiopia

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Abstract

Soil productivity and crop yield are essential for sustainable food security and economic development. Optimizing the use of foliar application of liquid fertilizers, such as Magic K, may play a significant role in enhancing food production and income generation under increasing population pressure. This study, titled "Verification of the Effectiveness of Magic K Liquid and Recommended Inorganic Solid NPS Mineral Fertilizer on Tomato Production under Irrigated Agriculture at Degem District, North Shewa Zone, Oromia, Ethiopia," was undertaken to evaluate the effectiveness of Magic K liquid fertilizer, both alone and in combination with the recommended rate of NPS mineral fertilizer, using irrigation schemes in Degem District of North Shewa Zone, Oromia Region, Ethiopia, during 2021. Four treatments—sole Magic K, sole recommended NPS, their combination, and a control (no fertilizer)—were arranged in a randomized complete block design (RCBD) with six farmers serving as replications. Agronomic data such as marketable, unmarketable, and total tomato fruit yield were collected and analyzed using Genstat software. Economic analysis was conducted using partial budget analysis. The Magic K treatment recorded the highest marginal rate of return (MRR = 72,011.11%), followed by the combined treatment of Magic K and NPS (MRR = 5,976.62%) with the highest net income (818,356.59 ETB/ha), and sole NPS application (MRR = 4,730.47%) with a net income of 734,791.59 ETB/ha. These findings suggest that the combined application of Magic K and NPS is both agronomically effective and economically viable for enhancing tomato production under irrigated agriculture in the study area.

Keywords

Marketable Yield, Unmarketable Yield, Partial Budget Analysis, Magic K

1. Introduction

Tomato (Solanum lycopersicum) is one of Ethiopia's most widely cultivated irrigated vegetable crops. It originated in Mexico, where early domestication and varietal selection occurred [1]. Globally, tomatoes are consumed fresh or processed, forming an essential component of various culinary dishes [2]. Nutritionally, tomatoes provide vital nutrients including vitamins C and E, β-carotene, lycopene, flavonoids, and minerals [3], and have traditional medicinal uses such as aiding digestion and purifying the blood [4].

Global tomato production reached 161.8 million tons in

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2012, with China, India, and the U.S. as top producers [5]. The Netherlands leads in productivity at 130 t/ha [6]. In contrast, Ethiopia's average yield was only 11.3 t/ha in 2012, despite research field results of up to 60 t/ha [7]. Such disparity highlights the need to improve smallholder productivity for both domestic processing and export markets [8].

Tomatoes are heavy nutrient feeders, requiring optimal nitrogen, phosphorus, and potassium levels [9]. Over-application of fertilizers, however, is common and inefficient [10]. Integrated approaches using foliar fertilizers like Magic K and blended NPS have been reported to improve both yield and nutrient efficiency in Ethiopian tomato cultivation [11].

This study was therefore initiated to verify the effect of Magic K compared with the recommended NPS fertilizer, assessing both agronomic and economic viability under small-scale irrigation in Degem District.

2. Materials and Methods

2.1. Study Area Description

The experiment was undertaken during the 2021 off-season at six on-farm sites within Degem District, located in the North Shewa Zone of Oromia Regional State, Ethiopia. The study area lies between 38°29′ to 38°44′ E longitude and 9°34′ to 10°03′ N latitude. The district experiences a mean annual rainfall ranging from 900 to 1400 mm, with mean annual minimum and maximum temperatures of approximately 15°C and 22°C, respectively. The dominant soil type of the experimental sites is Nitisols, characterized by a clayey texture [12].

The experiment was established under existing small-scale irrigation schemes. The tomato variety used, 'Kochoro', is high-yielding and tolerant to major diseases. Seedlings were raised on well-prepared raised nursery beds measuring 2 m by 1 m, with rows spaced 15cm apart. Seeds were sown shallowly and lightly covered with fine soil, followed by the application of a 2-3 cm thick layer of grass mulch. Daily irrigation was provided until germination, after which watering was done at three-day intervals. Transplanting was carried out when seedlings had reached the 3-5 true leaf stage or a height of 15-25 cm [13].

Prior to transplanting, the experimental fields were properly prepared using oxen plowing and manual labor. The full dose of the recommended NPS fertilizer was applied at transplanting, while the recommended nitrogen rate from urea (equivalent to 69 kg N ha^{-1}) was applied in two equal splits: half at transplanting and the other half 21 days later. Standard agronomic practices, including hand weeding and pest and disease control, were carried out as per the recommended tomato production guidelines.

2.2. Experimental Treatments and Design

The experiment was arranged in a Randomized Complete Block Design (RCBD) with six farmers' fields serving as replications. Each experimental plot measured 5 m × 5 m, and 20 seedlings were transplanted per plot at a spacing of 60 cm between plants and 100 cm between rows. Furrow irrigation was applied at three-day intervals throughout the growing period. Seedlings that failed to establish were replaced within one week of transplanting to ensure uniform plant population across treatments. A spacing of 1 meter between plots and 1.5 meters between blocks was maintained to facilitate the application of treatments and cultural practices. The tomato variety 'Kochoro' was used as a test crop to assess both agronomic and economic performance under different fertilizer regimes. The treatments consisted of four fertilizer combinations: Magic K alone, recommended NPS + Urea, their combination, and an unfertilized control. These treatments were arranged in the RCBD across the six farmer-managed sites under irrigated conditions.

The treatments included were

1) Control (zero, no Magic K and NPS fertilizers)
2) Full recommendation of inorganic NPS (at 69 kg ha-1N; 92 Kg ha-1P and 17 Kg ha-1 S)
3) Magic K (1.8 lit ha-1)
4) Magic K Phosphite 400 SL (1.8 lit ha-1) + fully recommended NPS (at 69 kg ha-1 N and 92 Kg ha-1P+17 kg/ha S)

The verification experiment was conducted with six replications, each established on a different farmer's field. In addition to agronomic performance, the economic feasibility of each treatment was assessed to determine the cost-effectiveness and potential profitability for smallholder farmers [14]. Data collected were fruit diameter, Plant height, Number of primary branches, Number of secondary branches, No Cluster per plant, number of fruits per cluster (or fruit number per plant), Total no of fruit Per plant, Number of marketable and unmarketable fruits per plant, Marketable fruit yield (t ha-1), Unmarketable fruit yield (t ha-1), Total fruit yield (TFY) (tha-1),

Data Analysis

Analysis of variance (ANOVA) was performed using Genstat 18th Edition statistical software to assess the effects of the fertilizer treatments on tomato yield and related parameters. Treatment means were compared using the Least Significant Difference (LSD) test at the 5% level of significance to determine statistically meaningful differences among treatments.

3. Results and Discussion

3.1. Pre-Planting Soil Properties of the Study Area

According to [15], the soil at the study site was classified

as clayey in texture. Furthermore, soil analysis revealed low organic matter content, nearly neutral pH, and low electrical conductivity (EC), indicating non-saline soil conditions (Table 1). Based on the sufficiency rating for electrical conductivity, optimal EC levels for tomato production typically range from 1.6 to 5.0 $dS \cdot m^{-1}$ [16]. Therefore, nutrient solution management strategies should be tailored to the specific nutrient requirements of tomato, the environmental conditions, and the intended production objectives, whether for commercial farming or home gardening. agic K effect on soil properties considered in the study.

Table 1. *Magic K effect on soil properties considered in the study.*

Treatment	PH (1:2.5)	EC (mS/cm)	OC (%)	TN (%)	Pav (PPm as P_2O_5)	Sav mg/Kg soil)	Texture (Hydrometer methods) (%)				Exchangeable (meq/100g soil)			
							Sand	Silt	Clay	class	Na	K	Ca	Mg
Control	8.00	0.05	1.13	0.05	94.11	27.48	20.94	35.63	43.43	clay	0.68	0.74	19.44	3.89
Sole recommended NPS fertilizers	7.05	0.04	0.88	0.05	119.41	29.51	22.54	33.68	43.78	clay	0.68	0.81	19.57	5.22
Sole recommended Magic K	7.36	0.05	1.10	0.05	111.58	25.54	23.58	33.23	43.19	clay	0.58	0.78	19.78	5.16
Combined recom Magic K & NPS	6.79	0.05	1.28	0.06	141.01	27.45	23.27	31.14	45.59	clay	0.66	0.94	20.71	5.18
Pre planting	7.09	0.45	1.10	0.05	111.61	85.96	31.79	23.82	44.39	clay	0.81	1.14	21.94	5.49

Where: Na = sodium, Ca = calcium, Mg = magnesium, K = Potassium, CEC = exchangeable cations; (meq / 100 gm of soil = mequivalent per 100 g soil= cmol(+)/kg = centi mol (+) per kilogram), NPS = Nitrogen, Phosphorus and potassium blended fertilizers, Where, EC = Electrical Conductivity, mS/cm = milli siemen per centimeter, 1 $dS \cdot m^{-1}$ = 1 mmho/cm, 1 L = 0.2642 gal. Cu = copper, Zn = zinc, Fe= Iron, Mn = Manganise, S= Sulphur, OC = organic carbon, Pav + available P, total N = NT, PH(H_2O) (1:2.5) = PH in 1:2.5 soil to water ratio, OC = organic Carbon, Pav = p available, ppm = parts per million

Table 2. *Magic K effect on Tomato leave tissue at fruit harvest for nutrients and ash content on dry base (db).*

Treatment	PH (1:2.5)	EC (mS/cm)	OC (%)	TN (%)	Pav (PPm as P_2O_5)	Sav (mg/Kg soil)	Texture (Hydrometer methods)				Exchangeable (meq/100g soil)			
							Sand (%)	Silt (%)	Clay (%)	class	Na	K	Ca	Mg
Control	8.00	0.05	1.13	0.05	94.11	27.48	20.94	35.63	43.43	clay	0.68	0.74	19.44	3.89
Sole recommended NPS	7.05	0.04	0.88	0.05	119.41	29.51	22.54	33.68	43.78	clay	0.68	0.81	19.57	5.22
Sole recom Magic K	7.36	0.05	1.10	0.05	111.58	25.54	23.58	33.23	43.19	clay	0.58	0.78	19.78	5.16
Combined recom Magic K & NPS	6.79	0.05	1.28	0.06	141.01	27.45	23.27	31.14	45.59	clay	0.66	0.94	20.71	5.18
Pre planting	7.09	0.45	1.10	0.05	111.61	85.96	31.79	23.82	44.39	clay	0.81	1.14	21.94	5.49

3.2. Discussion

Soil Reaction (pH 1:2.5 Soil:Water)

The soil pH varied from 6.79 to 8.00 in a 1:2.5 soil to water ratio. These pH values ranged from neutral to moderately [17, 18] and strongly alkaline according to the rating criteria of [19]. Texturally, the soil is classified as clayey.

Organic Carbon (OC)

Organic carbon analysis results showed that all treatments resulted in low organic carbon content, falling within the low OC rating range (0.5-1.5%) as described by [20, 16, 18].

Total Nitrogen (N)

The total nitrogen content, determined by the Kjeldahl method, was also rated low (<0.1%) according to [20, 16, 18].

Available Phosphorus (Pav)

Available phosphorus, determined using the Olsen method, ranged from 94.11 ppm to 141.01 ppm (Table 1). These values fall in the high to very high ranges as per [21, 22].

Available Sulfur (Sav)

Available sulfur (S) levels in soil samples varied from 25.54 ppm to 85.96 ppm across treatments (Table 1), ranging from low to high. The critical and toxicity threshold for sulfur is 30 ppm according to [23].

Cation Exchange Capacity (CEC)

CEC values under all treatments were classified in the very high category (>40 cmol(+) kg^{-1}), based on the classification by [24].

Tissue Nutrient Content and Deficiency Observations

ANOVA results (Table 2) indicated that treatments significantly affected potassium (K) content in tomato leaf tissues at the fruit harvest stage. No statistically significant differences were observed for the other nutrient elements analyzed.

Visual nutrient deficiency symptoms in vegetable crops are often element-specific and useful for diagnosis. Plant tissue analysis validates visual assessments and detects hidden nutritional disorders uncommon in well-managed vegetable systems. General sufficiency, deficiency, and excess thresholds for essential nutrients are based on the guidelines provided by [27] and are summarized below:

Nitrogen (N): Mobile; deficiency appears in older leaves as chlorosis and red petioles. Optimal tissue levels: 2.0-5.0% dry weight.

Phosphorus (P): Deficiency shows in older leaves as stunting and purpling. Normal range: 0.25-0.6%.

Potassium (K): Deficiency begins in older leaves with marginal mottling progressing to necrosis; <1.5% leads to blotchy ripening.

Calcium (Ca): Immobile; deficiency affects new growth; blossom-end rot is a common symptom. Normal range: 0.6-5.0%.

Magnesium (Mg): Mobile; deficiency appears as interveinal chlorosis in older leaves. Sufficiency: 0.2-0.8%.

Sulfur (S): Similar to nitrogen deficiency but starts in upper leaves. Adequate range: 0.2-0.5%.

Iron (Fe): Deficiency in new leaves as interveinal chlorosis. Normal range: 30-150 ppm.

Manganese (Mn): Interveinal chlorosis in upper leaves; normal levels: 20-100 ppm; toxicity >500 ppm in acidic soils.

Zinc (Zn): Deficiency causes shortened internodes and chlorosis in young leaves. Ideal: 25-150 ppm.

Copper (Cu): Deficiency causes chlorosis and elongated leaves. Normal range: 4-20 ppm.

4. Yield and Yield Component Analysis

As presented in Table 3, the tomato yield and yield component parameters showed statistically significant differences among treatments at the 5% probability level. The highest marketable, unmarketable, 2 and total fruit yields were obtained from the treatment that combined 1.8 liters per hectare of Magic K Phosphite 400 SL with the recommended rates of 92 kg/ha phosphorus, 69 kg/ha nitrogen, and 17 kg/ha sulfur.

Both 6 the sole application of the recommended NPS fertilizer and its combination with Magic K resulted in higher yields compared to the control (no fertilizer). However, there was no statistically significant difference in marketable yield between the sole NPS application and its combination with Magic K. In contrast, the application of Magic K alone yielded significantly lower results compared to both the sole NPS and the combined treatments.

The highest unmarketable yield, 7.53 t/ha, was recorded from the combined Magic K and NPS treatment, which also achieved an 88.82% total yield increase over the control (33.1 t/ha). The same treatment provided an 83.99% increase in marketable yield. Though not statistically different, the combination treatment surpassed the sole NPS treatment by 14%, equating to 7.6 t/ha more yield. Conversely, Magic K applied alone did not produce a significant yield advantage over the control. Based on these findings, it is advisable for tomato growers to apply Magic K in combination with the recommended NPS rates to maximize yield.

Table 3. Verification of Magic K and NPS fertilizer on yield and yield parameters of Tomato.

Treatment	Plant height (cm)	No Prim. Branch PP	No Sec. Branch PP	No Cluster PP	No of mark fruit PP	Total no of fruit PP	No of Fruit per cluster	Fruit diame-ter (cm)	Mark. Fruit yield (ton/ha)	Un mark. Fruit yield (ton/ha)	Total Fruit yield (ton/ha)
Combination	44.34a	6.37a	5.62a	14.43a	32.91a	43.14a	2.96 a	15.9a	54.97a	7.53a	62.5a
NPS	40.57b	5.57b	4.68b	11.89b	24.03b	31.86b	2.64b	14.79b	49.39a	5.51b	54.9a
Magic K	36.94c	4.14c	3.54c	8.8c	15.49c	17.77c	1.99c	13.62c	36.37b	4.43b	40.8b
Control	32.8d	3.2d	2.51d	7.03d	10.66d	12.51d	1.77c	13.04d	29.88b	3.22c	33.1b
LSD $_{0.05}$	1.38	0.32	0.70	0.771	3.21	3.74	0.23	0.31	7.5	1.20	7.79
CV (%)	3.2	6	15.3	6.5	13.8	12.6	8.8	1.9	15.7	20.6	14.5

Where:- Combination = NPS+Magic K; NPS= recommended nitrogen phosphorus and sulphur; PP= per plant; No = number of; Mark. = marketable, unmark. = unmarketable; t/ha = tone per hectare; a, b, c, d, letter used to show statistical test difference,

Table 4. Treatment effect relative to Recommended NPS and control no fertilizer.

Treatment	Treat-ment	% Total Yield increase over NPS	Parity over NPS	% Yield increase over Control	Recommendation
Magic K phosphite 400 SL) (1.8 lit ha^{-1}) +NPS (69 N, 92 P2O5 kg ha^{-1}+17 kg/ha Sulphur)	Magic K + NPS	13.8	par	88.8	1st because of because high net return MRR above 100%
69 N, 92 P2O5 kg ha^{-1}+17 kg/ha S	NPS	0		65.9	2nd because of higher MRR &better net benefit
Magic K phosphite 400 SL(1.8 lit ha^{-1})	Magic K	-23.4	disparity	23.3	3rd because of highest MRR and less net benefit and lower yield
0 kg/ha	control	-39.7	disparity	No increase	Not recommended for better net benefit

5. Partial Budget Analysis

The economic feasibility of the fertilizer treatments was assessed using partial budget analysis as per the method outlined in [25]. Input cost data were collected during the experimental period. As presented in Table 5, the results of the verification trial on the foliar application of Magic K revealed that the highest net income, 818,356.59 ETB, with a marginal rate of return (MRR) of 5,976.62%, was obtained when tomato plants were treated with the combination of recommended NPS and Magic K. Although the highest MRR (72,011.11%) was recorded from the sole application of Magic K liquid fertilizer, it ranked third in terms of net income generated.

The different fertilizer combinations tested were agronomically superior and economically feasible, indicating that they could be accepted by farmers. The combination of NPS mineral fertilizer with Magic K produced the highest values for yield parameters, followed by the sole application of recommended NPS. Economically, the sole Magic K treatment also resulted in a high return, with an income of 720.11 ETB per kg of tomato yield, followed by the combination with NPS. While the combination of Magic K and NPS provided the best yield performance, the sole application of recommended NPS fertilizer was also considered economically viable and practical for farmers. All treatments demonstrated a positive economic return when compared to the control (no fertilizer), as shown in Table 5.

Similar results were reported in a related study conducted at Gudar, where the application of 150 kg/ha NPS on tomato resulted in a maximum net benefit of 252,091 ETB/ha with a marginal rate of return of 3,122% [26]. Based on the current study's findings, the application of 2 liters/ha of Max Harvest (diluted in 250 liters of water) as a foliar spray, in combina-

tion with 69 kg/ha nitrogen, 92 kg/ha phosphorus, and 17 kg/ha sulfur, is recommended for profitable production of marketable and total tomato yield in the Degem District of North Shewa Zone and areas with similar agroecological conditions. Therefore, for optimal yield, net benefit, and improvement in soil fertility and nutrient supply, it is recommended to apply 69 kg/ha nitrogen, 92 kg/ha phosphorus, and 17 kg/ha sulfur in combination with 1.8 liters/ha of foliar-applied Magic K Phosphite 400 SL in tomato production systems in Degem and comparable agroecology in Ethiopia.

Table 5. *Partial Economic Analysis.*

Treatment	Variable Input (kg ha^{-1} or L ha^{-1})			Unit price (ETB)			Total Variable cost (TVC)	Output/ Net Return (kg ha^{-1})	Unit price (ETB)	Gross Income (ETB ha^{-1})	Net Income (ETB ha^{-1})	MRR (%)
	NPS	Urea	Magic K	NPS	Urea	Magic K						
Control	0	0	0	0	0	0	0	29880	15	448200	448200.0	
Magic K + NPS	242	145	1.8	3882.5	2175.9	135.0	6193.4	54970	15	824550	818356.6	5976.62
NPS	242	145	0	3882.5	2175.9	0.0	6058.4	49390	15	740850	734791.6	4730.5
Magic K	0.00	0.00	1.80	0.0	0.00	135.0	135	36370	15	545550	545415.0	72011.1

Where: TVC = total variable cost, MRR= marginal rate of return; NPS - nitrogen, phosphorus and Sulphur blended fertilizer; Kg = kilogram; ha = hectare; Magic K = phosphite 400 SL (5%N-15% P2O5-20%K2O- 1%Mg-1%Ca)

6. Conclusion

Although many fertilizer combinations are agronomically superior, their acceptance by farmers may be hindered by economic feasibility. The highest unmarketable tomato yield of 7.53 tons/ha was observed with the combination of sole Magic K and sole recommended NPS. This treatment also resulted in the highest total fruit yield, with an 88.82% increase over the control (33.1 tons/ha, with no fertilizer). The sole application of recommended NPS mineral fertilizer also led to significantly higher yields of both marketable and total fruit compared to both the liquid Magic K treatment and the control. However, the combination of sole Magic K and NPS fertilizer resulted in an 83.99% yield advantage for marketable fruits and an 88.82% increase in total tomato fruit yield over the control. While not significantly different, the recommended NPS fertilizer treatment alone produced a 14% lower yield compared to the combination with Magic K (i.e., a reduction of 7.6 tons/ha). The sole application of Magic K showed no significant yield difference when compared to the control. Based on these findings, it is recommended that tomato growers use the sole recommended NPS fertilizer along with its combination with Magic K to achieve better yield responses and advantages.

The marginal rate of return (MRR) for Magic K alone (72,011.11%) was found to be the most economical, followed by the combination of the two sole treatments (5,976.62%MRR, with the highest net income of 818,356.59 ETB) and the recommended NPS fertilizer (4,730.47% MRR, with a net income of 734,791.59 ETB/ha). These combinations offer viable alternatives for producing marketable and total tomato fruit yields in irrigated agriculture, ensuring high yields, economic returns, improved soil quality, and essential nutrient supply in Degem District, North Shewa Zone, Oromia Region, Ethiopia.

Therefore, we recommend the foliar application of Magic K at a rate of 1.8 liters/ha diluted in 250 liters of water, in combination with the recommended NPS, to enhance tomato production and productivity in Degem District and similar agroecologies in Ethiopia.

Abbreviations

N	Nitrogen
P	Phosphorus Fertilizer
NPS	Nitrogen Phosphorus, and Potassium Compounded/Mixed Fertilizers

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] J. J. Rick, "The role of natural hybridization in plant evolution," Genetics, vol. 76, no. 1, pp. 25-38, 1974.

[2] D. R. Panthee and F. R. Louws, "Genomics of fungal disease resistance in tomato," Curr. Genomics, vol. 15, no. 1, pp. 30-39, 2014.

[3] G. E. Lester and J. L. Jifon, "Tomato Lycopene: Recent Advances in Breeding and Biotechnology," Sci. Hortic., vol. 127, pp. 130-138, 2010.

[4] A. R. Rao and L. G. Rao, "Carotenoids and human health," Pharmacol. Res., vol. 55, pp. 207-216, 2007.

[5] FAOSTAT, "Tomato production statistics 2012," FAO, Rome, 2013.

[6] J. W. Jones et al., "Yield potential of tomato under controlled environments," Hortic. Rev., vol. 42, pp. 43-89, 2014.

[7] CSA, "Agricultural Sample Survey 2011/2012," Central Statistical Agency, Addis Ababa, Ethiopia, 2012.

[8] S. Lemma, "Tomato research experiences and production prospects," EIAR, Research Report No. 43, 2002.

[9] M. Hanson et al., "Fertilizer recommendations for vegetable crops," UF IFAS Ext., pp. 1-40, 2015.

[10] A. Agegnehu and A. Amede, "Integrated soil fertility and nutrient management," Pedosphere, vol. 27, no. 4, pp. 662-680, 2017.

[11] M. Tadesse et al., "Effects of blended and liquid fertilizers on tomato," J. Plant Nutr., vol. 44, no. 12, pp. 1752-1764, 2021.

[12] Ethiopian Institute of Agricultural Research (EIAR), "Tomato Production Manual," Horticulture Research Division, Addis Ababa, Ethiopia, 2015.

[13] M. Tadesse, A. Asfaw, and T. Tilahun, "Agro-climatic characterization and agricultural potential of North Shewa Zone, Oromia, Ethiopia," African Journal of Agricultural Research, vol. 13, no. 11, pp. 567-576, 2018. https://doi.org/10.5897/AJAR2017.13088

[14] CIMMYT, From Agronomic Data to Farmer Recommendations: An Economics Training Manual, Completely revised edition, Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), 1988.

[15] Soil Survey Staff, Soil Survey Manual, USDA, 2003.

[16] F. A. Hassan and M. A. El-Far, "Response of tomato to EC of irrigation water," J. Appl. Sci. Res., vol. 9, no. 2, pp. 1028-1034, 2013.

[17] W. L. Lindsay and W. A. Norvell, "DTPA soil test development," Soil Sci. Soc. Am. J., vol. 42, pp. 421-428, 1978.

[18] J. M. Bremner and C. S. Mulvaney, "Nitrogen-total," in Methods of Soil Analysis Part 2, ASA and SSSA, 1982.

[19] A. Horneck et al., "Soil pH and organic matter," Oregon State Univ., EC 628, 2011.

[20] I. J. Bennett et al., "Total carbon and organic matter," in Methods of Soil Analysis, 2nd ed., 1996.

[21] W. L. Lindsay and W. A. Norvell, "Phosphorus availability in alkaline soils," Soil Sci. Soc. Am. J., vol. 42, 1978.

[22] A. M. Olsen et al., "Available phosphorus estimation," USDA Circular, no. 939, 1954.

[23] J. L. Havlin et al., Soil Fertility and Fertilizers, 7th ed., Pearson, 2005.

[24] M. E. Sumner and W. P. Miller, "Cation exchange capacity," in Methods of Soil Analysis Part 3, 1996.

[25] D. A. H. Paul and T. J. Kovar, Plant Analysis Handbook II, Micro-Macro Publishing, 2003.

[26] A. Ashe, "Effect of NPS on tomato yield at Guder," Afr. J. Plant Sci., in press, https://doi.org/10.5897/AJPS