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Influence of fertilizer sources and stage-wise application rates on growth and quality of tomato (*Solanum lycopersicum* L. cv. Arka Vikas)

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Abstract
A field experiment was conducted to evaluate the effect of different fertilizer sources applied at stage-wise rates on the growth and quality of tomato (*Solanum lycopersicum* L. cv. Arka Vikas). The experiment was laid out in a randomized block design with seven treatments and three replications. Treatments comprised two fertilizer sources, namely water-soluble fertilizers (ammonium sulphate and soluble fertilizer 13-0-45 NPK) and straight fertilizers (urea and muriate of potash). Fertilizer doses were applied in three splits corresponding to crop growth stages of 0–45, 46–90, and 91–135 days after transplanting, while phosphorus was uniformly applied as a basal dose in the form of single superphosphate in all treatments. Fertigation was carried out at five-day intervals, and conventional soil application of urea, single superphosphate, and muriate of potash under drip irrigation served as the control. Results revealed that application of 100% recommended dose of straight fertilizers, applied in equal splits (33% each) at the three growth stages, significantly enhanced plant growth parameters such as leaf area, dry matter production, and earliness in fruit set and harvest. In addition, this treatment significantly improved fruit quality attributes, including lycopene and ascorbic acid content. The study highlights the importance of stage-wise fertilizer management in optimizing growth and improving fruit quality of tomato under drip fertigation systems.

Keywords: Tomato, *Solanum lycopersicum*, Arka Vikas, fertigation, quality, growth, drip irrigation, water soluble fertilizers, straight fertilizers

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important and widely cultivated vegetable crops in India and across the world, owing to its high economic value and nutritional significance. Tomato fruits are rich sources of essential minerals, vitamins—particularly vitamin C—and bioactive compounds such as carotenoids, which play a vital role in human health. The crop is consumed both fresh and in various processed forms, including sauces, pastes, and juices, making it an indispensable component of daily diets and the food processing industry (Chauratia *et al*., 2005) [8].

Efficient water management is crucial for achieving higher productivity and quality in tomato cultivation. Among various irrigation methods, drip irrigation has emerged as the most efficient system for supplying water directly to the root zone, thereby minimizing water losses and improving water-use efficiency. Several studies have demonstrated that drip irrigation not only conserves water but also enhances growth, yield, and quality of vegetable crops, including tomato (Tiwari *et al*., 1998; Hatami *et al*., 2012; Nadiya *et al*., 2013; Iqbal *et al*., 2014) [34, 17, 27, 19]. This system ensures uniform soil moisture distribution, reduces deep percolation losses, and improves nutrient availability in the effective root zone, making it a reliable and sustainable irrigation method (Singandhupe *et al*., 2007; Bhogi *et al*., 2011) [33, 7].

Fertigation, the application of water-soluble fertilizers through drip irrigation systems, has gained considerable attention as an efficient nutrient management strategy. This technique enables precise and timely application of nutrients in dissolved form, directly to the plant root zone during critical growth stages. Fertigation reduces labour requirements, minimizes soil compaction, and enhances nutrient-use efficiency, ultimately leading to improved crop performance (Singandhupe *et al*., 2003; Jat *et al*., 2011) [32, 20]. Furthermore, fertigation allows flexibility in adjusting fertilizer doses according to crop growth and nutrient demand, which is not feasible under conventional fertilizer application methods.

Excessive or imbalanced fertilizer application not only increases production costs but also induces adverse chemical changes in the soil, reduces nutrient uptake efficiency, and contributes to environmental issues such as groundwater pollution. Studies have shown that fertigation can reduce fertilizer requirements by 15–25% without compromising crop yield, while simultaneously improving nutrient availability and crop productivity (Hongal & Nooli, 2007) [18]. In tomato cultivation, fertigation offers a practical solution to overcome problems associated with nutrient leaching and inefficient fertilizer utilization common in traditional soil application practices.

Considering the importance of optimizing fertilizer sources and application schedules under drip fertigation, the present investigation was undertaken to evaluate the effect of different fertilizer sources applied at stage-wise rates at five-day intervals on the growth and quality attributes of tomato (*Solanum lycopersicum* L.).

Materials and Methods

Field studies were conducted at the research farm of the Vegetable Research Station, Agricultural Research Institute, Dr. YSRHU, Rajendranagar, Hyderabad, during the Rabi season of 2013–14. The experiment was laid out in a randomized block design (RBD) with three replications. The treatments consisted of two different sources of fertilizers: water-soluble fertilizers (ammonium sulphate and potassium nitrate) and straight fertilizers (urea and muriate of potash), applied at three different ratios: 50:25:25%, 25:50:25%, and 33:33:33%, corresponding to three growth stages—Stage I (0–45 DAT), Stage II (46–90 DAT), and Stage III (91–135 DAT).

Tomato seeds were sown in a nursery, and 25-day-old seedlings were transplanted in the field at a spacing of 30 cm between plants and 1 m between rows. The crop was managed with need-based plant protection measures. Fertilizer application rates and forms were based on regional recommendations. The recommended dose of fertilizers for tomato was 120:60:60 NPK kg/ha.

Both water-soluble fertilizers (ammonium sulphate and potassium nitrate) and straight fertilizers (urea and muriate of potash) were applied at different stages of crop growth, while phosphorus (single superphosphate) was applied as a full basal dose (60 kg/ha). Fertilizers were first dissolved thoroughly in water in small tubs and then transferred to fertilizer tanks. The nutrient solution was uniformly supplied to all experimental plots along with irrigation at five-day intervals throughout the crop-growing period.

Observations were recorded for growth and yield parameters, including the number of primary branches, plant height at harvest, leaf area at 90 DAT, fruit set percentage, days to 50% flowering, and dry matter production at 45, 90, and 135 DAT. These data were analyzed to assess the effects of different fertilizer sources and application schedules on tomato growth and productivity.

Results and Discussion

Growth Parameters

Leaf Area

Significantly highest leaf area per plant at 90 DAT (913.73 cm^2) was recorded with the recommended dose of straight fertilizers applied at 33% each during the 0–45, 46–90, and 91–135 DAT stages. This may be attributed to the maintenance of turgid plant tissues under drip irrigation, allowing prolonged stomatal opening and greater leaf expansion. Regular nutrient availability at equal intervals, combined with unrestricted water supply, likely contributed to enhanced leaf surface development. These results are in agreement with findings of Zhing Bao Dong (2011) [35] and Prabhakar *et al*. (2013) [28] in watermelon. Additionally, increased plant height and branch number likely supported greater leaf area, as noted by Balasubramanian *et al*. (2011) [5].

Dry Matter Production

Dry matter accumulation in tomato was significantly influenced by stage-wise fertigation with different fertilizer sources. The highest dry matter production at 45, 90, and 135 DAT (69.37 g, 75.90 g, and 77.43 g, respectively) was observed with equal (33%) application of fertilizers at all three stages. Continuous nutrient availability at the root zone under drip irrigation facilitated efficient nutrient uptake, turgid leaf conditions, and prolonged stomatal opening, leading to enhanced photosynthesis. Greater light absorption and higher photosynthate accumulation resulted in increased dry matter, consistent with the observations of Kadam (1990) [22] and Kadam and Karthikeyan (2006) [21].

Number of Days for Fruit Set

The minimum number of days for first fruit set (53.6 days) was recorded with straight fertilizers applied at 33% in all three stages. Continuous and balanced availability of nitrogen and potassium through drip fertigation, particularly steady potassium supply from muriate of potash, likely accelerated fruit initiation. These findings align with those reported by Elam *et al*. (1995) [12] in tomato.

Number of Days for First Fruit Harvest

The earliest fruit harvest (62.7 days) was observed with the recommended dose of straight fertilizers applied at 33% during each of the three stages. Early fruit set directly contributed to reduced days for first harvest, corroborating the results reported by Elam *et al*. (1995) [12]

Growth tomato as influenced by different treatments

Recommended dose of fertilizers- 120: 60: 60 NPK Kg ha^{-1}

Straight fertilizers - Urea and Murate of potash

Water soluble fertilizers- Ammonium sulphate and soluble fertilizer (13-0-45)

Stage-I 0 to 45 days after transplanting

Stage- II 46 to 90 days after transplanting

Stage- III 91 to 135 days after transplanting

Phosphorus source applied in the form of Single super phosphate as basal dose in all the treatments.

Treatments	Leaf area (cm^2) at 90th day	Dry matter production at 45 DAT (g)	Dry matter production at 90 DAT (g)	Dry matter production at 135 DAT (g)	Days to first fruit set	Days to first fruit harvesting
T_1: 100% RDF water soluble fertilizers 50%, 25% and 25% during Stage I, II and III	708.77	50.47	54.60	53.70	55.6	67.0
T_2: 100% RDF water soluble fertilizers 25%, 50% and 25% during Stage I, II and III	763.03	54.40	60.26	60.16	55.0	63.3
T_3: 100% RDF water soluble fertilizers 33%, 33% and 33% during Stage I, II and III	884.03	66.10	73.40	71.70	54.0	63.0
T_4: 100% RDF straight fertilizers 50%, 25% and 25% during Stage I, II and III	746.53	51.63	55.83	55.53	55.3	65.0
T_5: 100% RDF straight fertilizers 25%, 50% and 25% during Stage I, II and III	838.93	61.47	66.73	64.83	54.6	63.0
T_6: 100% RDF straight fertilizers 33%, 33% and 33% during Stage I, II and III	913.73	69.37	75.90	77.43	53.6	62.7
T_7: Conventional method of fertilizer application and drip irrigation (Control)	653.03	49.30	49.80	53.09	56.0	67.7
SE (m) ±	51.827	4.01	4.22	2.94	0.56	0.59
CD at 5%	161.46	12.50	13.15	9.16	1.75	1.85

Quality Parameters

Lycopene and Ascorbic Acid Content

Significant differences were observed among the treatments for most quality parameters, except for lycopene and ascorbic acid content. The highest lycopene (7.42 mg/100 g) and ascorbic acid (3.27 mg/100 g) contents were recorded with the recommended dose of straight fertilizers applied at 33% each during the 0–45, 46–90, and 91–135 DAT stages. These values were statistically on par with water-soluble fertilizers applied at the same rates and stages.

Potassium plays a key role in lycopene biosynthesis, likely through its influence on the electron transport chain involved in phytoene desaturation. Fanasca *et al*. (2006) [16] reported that potassium activates enzymes regulating carbohydrate metabolism, such as pyruvate kinase and phosphofructokinase, and affects precursors of isopentenyl diphosphate (pyruvate and glyceraldehyde-3-phosphate). According to Rodriquez-Amaya (2001) [31], potassium may influence enzymes like phytoene synthase or phytoene desaturase, which catalyze the first committed step in carotenoid biosynthesis. Studies by Bae *et al*. (1999) [3] link electron transport directly to phytoene desaturation and lycopene formation. Additionally, potassium is involved in ATP synthesis, proton uptake, and electron flow in thylakoid membranes of plastids, the site of carotenoid biosynthesis (Lebedeva *et al*., 2002; Quitrakul and Izawa, 1973) [25, 29]. Environmental factors such as sunlight and temperature also influence lycopene development, as high temperatures can degrade lycopene, while shaded fruits often develop better color (Denisen, 1948; McCollum, 1956; Robertson *et al*., 1995) [10, 26, 30].

Vitamin C content was significantly higher when straight fertilizers (urea and muriate of potash) were fertigated at equal rates throughout the crop period. These findings are consistent with Kiviani *et al*. (2004) [23] in tomato. Aruna *et al*. (2007) [1] also reported increased ascorbic acid content with 100% recommended doses of ammonium sulphate, super phosphate, and potassium chloride.

Quality of tomato as influenced by different treatments

Treatments	Lycopene content (mg/ 100 g)	Ascorbic acid content (mg/ 100 g)
T_1: 100% RDF water soluble fertilizers 50%, 25% and 25% during Stage I, II and III	7.30	2.67
T_2: 100% RDF water soluble fertilizers 25%, 50% and 25% during Stage I, II and III	7.36	2.89
T_3: 100% RDF water soluble fertilizers 33%, 33% and 33% during Stage I, II and III	7.37	3.17
T_4: 100% RDF straight fertilizers 50%, 25% and 25% during Stage I, II and III	7.34	2.75
T_5: 100% RDF straight fertilizers 25%, 50% and 25% during Stage I, II and III	7.37	3.17
T_6: 100% RDF straight fertilizers 33%, 33% and 33% during Stage I, II and III	7.42	3.27
T_7: Conventional method of fertilizer application and drip irrigation (Control)	7.28	2.62
SE (m) ±	0.02	0.08
CD at 5%	0.06	0.25

Recommended dose of fertilizers- 120: 60: 60 NPK Kg ha^{-1}

Straight fertilizers - Urea and Murate of potash

Water soluble fertilizers- Ammonium sulphate and soluble fertilizer (13-0-45)

Stage-I 0 to 45 days after transplanting

Stage- II 46 to 90 days after transplanting

Stage- III 91 to 135 days after transplanting

Phosphorus was applied as a basal dose in the form of single super phosphate in all treatments. The observed increase in ascorbic acid content may be attributed to enhanced enzymatic activity involved in amino acid synthesis under high temperatures, as reported in greenhouse-grown tomato fruits (Lamalfa and Iconardi, 1994) [24]. Higher vegetative growth could also have provided greater energy and assimilates to the fruits, contributing to increased vitamin C accumulation. These results are supported by Baroah and Ahmed (1962) [6], who observed that nitrogen had little effect on vitamin C content, whereas potassium significantly enhanced it. Similarly, El-Nemr *et al*. (2012) [14] reported that increased potassium availability resulted in higher vitamin C content in tomato fruits.

Conclusion
Drip fertigation with equal rates of straight fertilizers applied at three stages of crop growth (0–45, 46–90, and 91–135 DAT) significantly enhanced both plant growth and fruit quality compared to other treatments. The superior performance of this treatment can be attributed to the consistent and balanced availability of nutrients throughout the crop growth period, which optimized vegetative development, fruit set, and accumulation of quality parameters such as lycopene and ascorbic acid.

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