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Impact of integrated nutrient management on growth, yield and quality of tomato (*Lycopersicon esculentum* L.)

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Abstract

Tomato is considered as a member of the family *Solanaceae*. The botanical name of tomato is *Lycopersicon esculentum* Mill and is a diploid plant with 2n=2x=24 chromosomes. Tomato is the most popular home garden and the third most consumed crop in the world. It is very much beneficial for health because of its high nutrient status. The effect of Integrated Nutrient Management (INM) on the growth, yield and soil nutrient status to tomato, the study revealed that the integration of organic manures in combination with inorganic fertilizers was found significant in improving the overall plant growth, yield and soil macro nutrient status than the sole application of either of these nutrients. Now-a-days demands for tomato is increasing rapidly among the vegetable consumers in view of its better quality only one source of nutrients like chemical fertilizers, organic manures and bio-fertilizers cannot improve the production or maintain the production sustainability and soil health. Integrated plant nutrient management is the intelligent use of optimum combination of organic, inorganic and biological nutrient sources in a specific crop, cropping system and climatic situation so as to achieve and to sustain the optimum yield and to improve or to maintain the soil's physical, biological and chemical properties. Such a crop nutrition package has to be technically sound, economically attractive, practically feasible and environmentally safe. Therefore work done on the nutrient application to tomato is reviewed in this paper.

Keywords: NPK, vermicompost, FYM, soil nutrients, tomato

Introduction

Tomato (*Solanum lycopersicum* L.) belongs to family solanaceae, is an annual vegetable crop grown throughout the world and ranks second in importance after potato. The tomato is believed to have been originated in Central Africa and South America (Vavilow, 1951). Tomato having chromosome number 2n=24. It is herbaceous annual which is sexually propagated by seed. It is used as salad oil and in the manufacture of margarine. Tomato is one of the most widely, grown vegetable in India and has become popular within the last six decades. It is grown in small home gardens and market gardens for fresh consumption as well as processing purposes. It is consumed raw, cooked or processed as puree, ketchup, sauce etc. Although, a ripe tomato has 94 per cent water, being a good source of vitamin A and B and excellent source of vitamin C and has good nutritive value. It is very appetizing, removes constipation and has a pleasing taste. In India, tomato is cultivated in almost all parts of country. It is grown in an area of 1204 thousand hectare with a production and productivity of 19, 042 mt and 21.2 mt ha^{-1} respectively (NHB, 2014). In Karnataka it is grown in an area of 54,287 ha with a production 19, 06, 865 metric tonnes and productivity of 35.13 tonnes ha^{-1}. The major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andra Pradesh, Maharashtra, Madhya Pradesh and West BengalIt is grown in Nasik, Ahmednagar, Pune, Solapur, Satara, Sangali, Beed, Chandrapur, Latur, Parbhani & Nagpur districts of Maharashtra. Tomato ranks first among the processed vegetables. It is a very good source of income to small and marginal farmers. There are various types of flavouring compounds found in fruits, which enrich the taste. Tomatoes are used directly as raw vegetables in sandwiches, salad etc. And several processed products like paste, puree, soup, juices, ketchup, drinks, whole peeled tomatoes, sauces, and chutneys are prepared on large scale. The pulp and juice are digestible, a promoter of gastric secretion and blood purifier. It is reported to have antiseptic properties against intestinal infection. For tomato nutrition is one of the most important factors which govern the tomato production. The nutrients needed for tomato crop are supplied through organic, inorganic source and through micronutrients and biofertilizers integrated nutrient management (INM) is a holistic, approach that considers all the available farm resources that 3 can be used as plant nutrients.

The main principle of integrated nutrient management is to maximize the use of organic inputs while minimizing nutrient losses and to make supplementary use of chemical fertilizers. Good practices for integrated nutrient management often involve a combination of organic and inorganic sources of nutrients. Organic material maintains and improves soil productivity. Whereas chemical fertilizers are often needed if production is to increase. Integrated nutrient management contributes to better farm waste management, minimizing environmental\ pollution, improving soil productivity, and the production of safe food and feed. Application of different levels of nitrogen increases the plant growth significantly by increasing the plant height, number of branches, number of leaves ultimately resulted in increase in the yield of tomato fruits. Photosynthetic activity is also enhanced due to large leaf area (Baroah and Ahmed 1962) [7]. The application of organic, inorganic and biofertilizers would be the optimum integrated nutrient management practices for higher yield, nutrient uptake and fertility status of soil. By keeping this point in view, an attempt has been made to investigate the level of substitution of inorganic fertilizers with organic manures and biofertilizers for maximizing tomato production and good soil health in an integrated nutrient management system.

Effect of N, P, K, Ca and B on growth, yield and quality of Tomato

Nirtogen

Furthermore, the form of nitrogen supplied to the plants may influence the uptake of other macronutrients due to ion antagonism (Marschner 1995) [45]. In view of this background; many investigations have recently been concerned with the responses of tomato to the N form supplied to the plants via fertilization. Earlier studies concerned with the effects of nitrogen source on tomato and its interactions with other nutritional and environmental factors indicated that tomato is susceptible to the supply of ammonium as a sole or dominating nitrogen form (e.g. Kirkby and Knight 1977; Ganmore- Neumann and Kafkafi 1980; Pill and Lambeth 1980; Magalhães and Wilcox 1983; Errebhi and Wilcox 1990; Imas *et al.* 1997) [21]. Tan *et al.* (2000b) used 15N- labelled compounds in a hydroponic culture of tomato and found that the absorption, translocation, and assimilation of urea is poor at the seedling stage, but increases to almost similar levels with that of NO3-N at the reproductive growth stage. Based on Tomato nutrition, breeding and post-harvest technology. Passam *et al.* the above results, Tan *et al.* (2000b) suggest that urea may be used as an N-source in soilless grown tomato crops provided the plants are at the reproductive growth stage. More recent studies have confirmed this consideration. Thus, according to Claussen (2002) [14], the use of ammonium as sole or dominating N source in a solution culture of tomato resulted in impaired growth and yield restrictions. Siddiqi *et al.* (2002) and Akl *et al.* (2003) observed a restriction of both the vegetative growth and the fruit yield of tomato when NH_4-N/total-N in the nutrient solution was higher than 0.1. However, Claussen (2002) [14] and Dong *et al.* (2004) observed an increase in both total and fruit dry weight when the ammonium fraction was 0.25. According to Akl *et al.* (2003), the impaired growth of tomato when the ammonium fraction was in the range 0.15- 0.25 of the total-N supply was associated with low pH levels (<5) in the root zone. In contrast to Siddiqi *et al.* (2002) and Akl *et al.* (2003), Claussen (2002) [14] maintained the rhizosphere pH above 6 by adding $CaCO_3$ to the growth medium. Thus, it seems that the lowest level of NH_4-N/ total-N, that impairs the growth and yield of tomato, is mainly dictated by its impact on the rhizosphere pH, which is influenced not only by the nitrogen form but also by environmental factors (Chaignon *et al.* 2002) [10]. With respect to fruit quality, a NH_4 +-N-dominated nitrogen supply may markedly increase the incidence of fruits with blossom-end rot (BER), an effect which is ascribed to a depression of Ca uptake by the enhanced external NH4 + levels (Kirkby and Mengel 1967; Siddiqi *et al.* 2002; Akl *et al.* 2003; Heeb *et al.* 2005b) [29]. Siddiqi *et al.* (2002) and Heeb *et al.* (2005a) [28] state that the supply of 0.1 of total-N in the form of NH_4 + (10% of total N) is capable of enhancing the flavour of the fruits, presumably by elevating glutamine and glutamate levels. Saravaiya *et al.* (2010) reviewed that NPK content of tomato fruit as well as plant and uptake were higher with the application of 100 per cent recommended NPK rate than with 75 per cent recommended NPK rate. Sathyajeet Singh *et al.* (2014) reported that, in Tomato crop the yield (21.5 t ha^{-1}) contributing characters such as number of yield per plant (1.93 kg/plant), fresh and dry weight of fruit (177.07 g/fruit) were recorded higher in 50 per cent N from inorganic source + 50 per cent N from FYM, followed by 100 per cent from inorganic source, Qualitative characters such as TSS (4.97 ºB) and reducing sugar contents were found better in 100 per cent N from Poultry manure fallowed by 100 per cent from vermicompost (10 t ha^{-1}).

Phosphorus

Shinde (1998) [62] observed that, the ascorbic acid content, reducing sugar content and NPK concentration in fruit juice was significantly influenced due to the application of nutrients through organic sources. The highest reducing sugar percentage of 3.07 was obtained by application of vermicompost. Highest NPK concentration and ascorbic acid content was observed in chemical fertilizer application treatment. Uptake of nutrients was significantly affected by various organic and inorganic fertilizer treatments. The application of nutrients through vermicompost also had significant effect on the chemical properties like organic carbon content (0.61 %) N content (168.83 kg ha^{-1}), P content (21.33 kg ha^{-1}) and K content (271 kg ha^{-1}). Jones (1998) suggests a P concentration of 1% in the dry weight as the critical level between sufficiency and toxicity for tomato plants. Toxic levels of P in the leaves of tomato may also be imposed by Zn deficiency (Kaya and Higgs 2001). According to de Groot *et al.* (2001) [18], at mild P limitation the assimilate supply is not the limiting factor for reduced growth rates, but at severe P limitation the rate of photosynthesis is depressed, as indicated by the decrease in starch accumulation. Under conditions of severe P deficiency, the leaf N concentration is also suppressed, a due to a decrease in leaf cytokinin levels (de Groot *et al.* 2002) [19]. Results from recent research have indicated that foliar application of phosphorus in greenhouse tomato enhances the concentrations of chlorophyll, K, P, Mg and Fe in the leaves, accelerates fruit maturity and increases marketable yield and quality (Chapagain and Wiesman 2004) [11].

Potassium

It is well known, that an adequate supply of potassium enhances the titratable acidity of tomato fruit (Davies and Winsor 1967; Adams *et al.* 1978; Davies and Hobson 1981) [16], thereby considerably improving the sensory quality of tomato. Low levels of potassium supply in soilless cultivated tomato plants are associated with ripening disorders (Adams

2002) [1]. Indeed, according to Walker *et al.* (2000), the growth of tomato plants cultivated in a K-deficient nutrient solution (0.5 m M K+) was severely depressed in comparison with K-replete plants (4.5 m M K), while the supply of 1 or 5 mM NaCl virtually restored growth to the level of K-replete plants. As reported by Mulholland *et al.* (2001), high levels of air humidity may considerably restrict the K concentration in young expanding leaflets near the shoot apex compared with standard air humidity; under such conditions, leaf expansion, yield, and the proportion of Class 1 fruits may be drastically reduced. When tomato is grown under conditions of limited K supply, sodium may partially substitute for potassium. As reported by Hartz *et al.* (2005) [27], enhanced fertilization with potassium improves fruit colour, while at the same time reducing the incidence of yellow shoulder and other fruit colour disorders.

Calcium
Recent research has revealed that a low calcium level in the root zone is rarely a limiting factor for the vegetative growth of tomato (del Amor and Marcelis 2006) [20].
Nevertheless, the calcium nutrition of tomato demands special attention because this nutrient is intimately involved in the occurrence of the physiological disorder BER, which may considerably reduce fruit quality and market acceptability (Ho *et al.* 1993; Grattan and Grieve 1999) [24]. BER is caused by a local deficiency of Ca in the distal part of the fruit, which results in a disruption of tissue structure in that area (Adams 2002) [1]. Furthermore, an enhanced supply of calcium may reduce the incidence of shoulder check crack, another physiological disorder that leads to deterioration in fruit quality (Lichter *et al.* 2002). This defect appears as a surface roughness that develops primarily on the shoulder area of the fruit, which spoils the appearance and severely restricts the storability of the fruits (Huang and Snapp 2004a). According to Hao and Papadopoulos (2004) [26], the incidence of BER at an external Ca concentration of 3.75 increased linearly with increasing Mg levels in the root, while it was not affected by Mg concentration at 7.5 mM Ca. Various factors, including the cultivar, the external concentrations of Ca, NH_4-N, K, and Mg, salt or water stress, oxygen availability in the root zone, air relative humidity, and air temperature, may aggravate or ameliorate the occurrence of this physiological disorder (Saure 2001; Navarro *et al.* 2005). As a result of the involvement of so many factors in the occurrence of BER, no absolute, critical fruit Ca concentration associated with the appearance of this disorder has been identified (Ho and White 2005) [31]. Nevertheless, as suggested by Ho and White (2005) [31], the manipulation of the nutrient levels in the root zone or the growth environment are not adequately effective measures in reducing BER because they affect apoplastic Ca concentration in fruit tissue indirectly. Therefore, these authors suggest spraying Ca directly on to young fruits in order to prevent BER.

Boron
According to Alpaslan and Gunes (2001) [2], soil boron concentrations of 5 mg kg^{-1} or higher are expected to impose boron toxicity symptoms. Another recently investigated aspect related to boron nutrition in tomato is the interaction between boron and salinity or water stress. According to Ben-Gal and Shani (2002, 2003) [8, 9], under conditions of simultaneous boron deficiency and salt or water stress, the extent of growth suppression is determined by the factor imposing the most severe stress and not by an addition of the effects of both restrictive factors. Hence, a dominant-stress-factor model following the Liebig-Sprengel law of the minimum may be used to describe the responses of tomato to simultaneous exposure to boron and salinity or boron and water shortage. Furthermore, Ben-Gal and Shani (2002) [8] found that the yield response of tomato to boron nutrition correlates better with B concentration in the irrigation water and soil solution than with the levels of boron in the plant tissue. Boron deficiency in fresh-market tomatoes is a widespread problem that reduces yield and fruit quality (Davis *et al.* 2003) [17]. As reported by Smit and Combrink (2004), at too low B levels in the root zone, the leaves of tomato are brittle and appear pale-green, a considerable fraction of flowers abscises and the fruits lack firmness, a problem that is worsened during storage. Davis *et al.* (2003) [17] reported that the delivery of B either through the nutrient solution (1 mg L-1), or by foliar spraying (1.87 mg L-1) of boron chelated with mannitol, to tomato grown in river sand, was associated with increased plant growth and tissue K, Ca and B concentrations. In the above study, foliar spraying with boron significantly enhanced fruit B and K concentrations in comparison with no boron supply, which indicates firstly that B is translocated from the leaves to the fruit and secondly that B is also involved in K translocation within the plant. Enhanced uptake of Ca, Mg, Na, Zn and B with higher B levels in the root zone has been reported by Smit and Combrink (2004). According to Smit and Combrink (2004), the above symptoms appeared at a B concentration level of 0.02 mg L-1 in the nutrient solution supplied to a crop grown on quarz-sand, but a B concentration of 0.16 mg L-1 seemed to be optimal for tomato and levels of up to 64 mg L-1 did not cause any toxicity symptoms. In another study, it was shown that an enhanced boron supply (B foliar spray at 300 mg L-1) was associated with a less frequent incidence of the physiological disorder shoulder check crack (Huang and Snapp 2004a), the visible symptoms of which are described under ‘nutrition and fruit quality’.

Effect of inorganic fertilizers on growth, yield and quality of tomato
Shinde *et al.* (1992) [61] reported that the phosphorous content of vermicompost was more than farmyard manure. They also reported the contents of DTPA extractable micronutrients in vermicompost *viz.*, Fe (17.8ppm), Zn (19.2ppm), and Cu (7.6ppm).
Madhavi and Reddy (1994) found that poultry manure collected from different locations was a potential source of plant nutrients like nitrogen (0.84 to 1.21 %), phosphorous (0.91 to 1.07%) and potassium (1.35 to 2.35%). Application of poultry manure @ 10, 25, 40 and 50 t ha^{-1} increased tomato fruit weight by 58, 102, 37 and 31 per cent, respectively. Vasanthi *et al.* (1995) reported that vermicompost application along with inorganic fertilizers increased the organic carbon content and available nitrogen status of the soil by 87.7 and 42.9 per cent, respectively. Reports also revealed that vermicomposting significantly increased the organic carbon by 17.88 per cent, available nitrogen by 20.93 per cent, available phosphorous by 6.82 per cent and available potassium by 15.93 per cent (Bangar and Jatgar, 1995). Natarajan *et al.* (2004) reported the effect of organic and inorganic fertilizers on growth and yield of tomato. They observed application of 50 per cent RDF (100:50:50 NPK kg ha^{-1}) per cent FYM 12.5 t ha^{-1} resulted in highest vegetative growth and yield (586.51 q ha^{-1}). Kumar and Sharma (2004) recorded highest values for yield and soil available nutrients

with application of farmyard manure @ 25 t ha^{-1} + NPK 150:112.5:82.5 kg ha^{-1} in tomato.

Animal oriented manure has a salutary effect on soil fertility besides improving the soil conditions and plant growth. Poultry manure in this regard occupies the pride of place as it is rich in nutrients than the other manures (Amanullah *et al.*, 2007). Mudasir *et al.* (2009) reported that in tomato crop application of 3.5 t of Poultry Manure + 95 N + 75 P + 55 K kg ha^{-1} results in maximum plant height (130.06 cm), highest number of branches per plant (11.46), number of fruits per plant (62.31), fruit diameter (5.25 cm), fruit weight (59.75 g) and fruit yield (53.34 t ha-1), while minimum was observed in control (69.51cm, 5.69, 29.75, 3.16 cm,35.24 g and 24.92 t ha-1), respectively. The treatment comprising of 50 per cent nitrogen through FYM and 50 per cent nitrogen through cotton seed cake, vermiphos and along with RDF (300:150:150 kg ha^{-1}) has recorded higher quality parameter of tomato followed by the other treatments (Gosavi *et al.*, 2010). Patel *et al.* (2010) studied the integrated nutrient management in tomato cv. Pant T-3. They found the maximum values of fruit characters and yield contributing characters viz., Fresh weight and dry weight of fruit in the treatment of 100 % N from FYM + vermicompost + neem cake + Azotobacter followed by 50 % N from FYM + 50 % RDF. Prativa and Bhattarai (2011) studied maximum plant height and number of leaves per plant was observed with treatment 16.66 t ha^{-1} FYM + 8.33 t ha^{-1} vermicompost + NPK. Highest number of fruit clusters, maximum fruit weight and fruit yield (25.74mt ha^{-1}) were also recorded in treatment16.6 t ha^{-1} FYM + 8.33 m t ha^{-1} vermicompost + NPK (100:80:60 kg ha^{-1}) in tomato crop. Chinnaswami and Mariakulandai (2012) [12] studied that influence of organic and inorganic manures on the storage life of tomato and reported that combination of FYM and inorganic mixture (120:106:84 NPK kg ha^{-1}) significantly enhanced the keeping quality over control treatments. However, there is no significant difference was observed with respect to quality attributes in both organic and inorganic treated fruits.

Effect of biofertilizers on growth, yield, and quality on tomato:

The treatment comprising of 100 per cent recommended RDF along with vermicompost (2 t ha^{-1}) and bio-fertilizers (each 2 kg ha^{-1} of *Azotobacter* and PSB) inorganic manures on the storage life of tomato and reported that combination of FYM and inorganic mixture (120:106:84 NPK kg ha^{-1}) significantly enhanced the keeping quality over control treatments. However, there is no significant difference was observed with respect to quality attributes in both organic and inorganic treated fruits. Sharma (1995) studied effect of different bio-fertilizer on tomato seed production namely *Azotobacter*, *Azospirillum*, *Pseudomonas* and Vesicular Arbuscular Mycorrhiza (VAM). The study revealed that *Azotobacter* when applied to nursery, seedling and field soil resulted in maximum number of fruits per plant (19.23), fruit yield per plant (1109 g), 1000 seed weight (3.63 g), seed yield per plant (4.58 g) and per hectare (152.70 kg ha^{-1}) and highest cost benefit ratio (2.31). Renuka and Ravishankar (2001) [56] reported that plans inoculated with *Azospirillum* and Phospho bacteria recorded higher plant height (110.41 cm) and number of branches (3.66 $plant^{-1}$) compared to NPK alone (92.23 cm and 2.33 respectively) in tomato. Sudhakar and Purushotham (2008) [65] reported application of 75 per cent RDF (150:60:80 NPK kg ha^{-1}) and bio-fertilizer PSB (15 kg ha^{-1}) resulted in higher yield parameter like number of fruits per plant (25.75 g), yield per plant (751.8 kg) and yield (75.10 t ha^{-1}) of tomato. Anchal *et al.* (2008) [5] reported that vegetative parameter such as plant height (61cm), number of primary branches (14.7), dry matter accumulation (243.9 g per plant), yield (20.75 t ha^{-1}) and B:C ratio (3.0) were found to be superior with 50 per cent RDF + Bio-fertilizer + Vermicompost as compare to either alone or other combination treatment in tomato crop. Sudhakar and Purushotham (2008) [65] reported application of 75 per cent RDF (150:60:80 NPK kg ha^{-1}) and bio-fertilizer PSB (15 kg ha^{-1}) resulted in higher yield parameter like number of fruits per plant (25.75 g), yield per plant (751.8 kg) and yield (75.10 t ha^{-1}) of tomato. Mahato *et al.* (2009) reported that the higher growth parameters like shoot length (35.5cm), number of leaves per plant (5.6), root length (7.8 cm) was recorded in *Azatobactor* (2 kg ha^{-1}) along with 50 per cent RDF (150:50:50 kg ha^{-1}) during the raising of seedlings in nursery in tomato as compared to other treatments. Premshekhar and Rajashree (2009) reported that, growth and yield parameters like plant height (72.60 cm), number of fruits per plant (33.70) and fruit yield (43.85 t ha^{-1}) in tomato were found be maximum with application with *Azospirillum* (2 kg ha^{-1}) + 75 per cent Nitrogen + 100 per cent P and K as compared to other treatments. Chumyani *et al.* (2010) [13] reported that growth, yield and quality parameters of tomato *viz.*, plant height (69.37 cm), number of leaves per plant (50.87), fruit yield (48.68 t ha^{-1}) and TSS (5.07 ºBrix) were found to be maximum with application of 50 per cent NPK + 50 per cent FYM + bio-fertilizers as compared to other treatments. Neerja *et al.* (2010) [50] studied that the combined application of seedling dip with *Azotobactor* 2 kg ha^{-1} + 75 per cent N + full dose of PK + full dose of FYM (25 t ha^{-1}) treatment combination) significantly increased growth, yield and quality characters over RDF or organic manures alone there by a saving of 25 per cent chemical nitrogen application during the year of study also the maximum net returns to the tune of Rs.1, 48, 089/- and highest cost: benefit ratio of 1:2.51 was recorded in tomato. Yeptho *et al.* (2010) revealed that integrated application of 50 per cent NPK + 50 per cent poultry manure + bio-fertilizer recorded significantly higher plant height (164.33 cm), number of branches per plant (12.26), number of laves per plant (58.19), number of fruits per plant (33.27), fruit yield (77.54 t ha^{-1}) and TSS content (6.67 ºBrix) over the other treatments in tomato. Neerja *et al.* (2010) [50] studied that the combined application of seedling dip with *Azotobactor* 2 kg ha^{-1} + 75 per cent N + full dose of PK + full dose of FYM (25 t ha^{-1}) treatment combination) significantly increased growth, yield and quality characters over RDF or organic manures alone there by a saving of 25 per cent chemical nitrogen application during the year of study also the maximum net returns to the tune of Rs.1, 48, 089/- and highest cost: benefit ratio of 1:2.51 was recorded in tomato. Thakur and Rajneesh (2012) reported that, the organic amendments application of vermicompost (10 t ha^{-1}) recorded the highest fruit yield (21.93 kg $plot^{-1}$, 2.7×2.1 m^2 plot size) followed by *Azotobactor* (5 kg ha^{-1}) application in tomato. Ramakrishnan and Selvakumar (2012) studied the effect of combined inoculation of *Azatobactor* (2 kg ha^{-1}) and *Azospirillum* (2 kg ha^{-1}) which resulted in higher fruit yield (518.47 g/plant) followed by *Azatobactor* (2 kg ha^{-1}) alone treated plants (502.23 g/plant) in tomato.The study concludes that combined application of bio-fertilizers enhances the growth and yield of tomato crop.

Kumar *et al.* (2014) reported that application of PSB at 2 kg ha^{-1} results in maximum plant height (39.50 cm), higher number of branches per plant (6.93) and number of cluster per plant (9.83) as compared to *Azospirillum* 2kg ha^{-1} while, all growth parameters were found minimum under control in tomato.

Conclusion

The literature available reveals that application of organic, inorganic and bio fertilizer help in better vegetative growth, seedling stands, improved yield and quality of tomato. Thus, it can be concluded that organic, inorganic and bio fertilizer can be effectively used for improving growth, yield, and quality of tomato if applied at proper time and manner in suitable doses or concentrations.

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