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Fruit quality attributes of tomato affected by application of different levels of potassium humate and micronutrients (Zn, B and Fe)

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Abstract

Deficiency of micronutrients is a major hurdle to achieve the optimum quality of crop plants fruits in agriculture. These micronutrients are equally important as that of macronutrients. In addition, better availability of micronutrients to the crops played an imperative role in improvement of reproductive growth of plants. Low organic content of arid and semiarid regions is a major factor that significantly decrease the micronutrients phytoavailability and fruit quality. Tomato is one of important crops which is widely consumed as a salad and cooking of food. Similarly, use of humate as an organic soil conditioned is also getting attention of farming community due to its potential benefits. That's why keeping in mind the importance of organic matter and micronutrients, current experiment was conducted to examine the combine effect of potassium humate and micronutrients variable levels on fruit quality of tomato during summer and winter seasons. It is hypothesized that co-application of potassium and micronutrients application would be efficacious in improvement of tomato fruit quality. Results confirmed that 100% application rate of micronutrients (Zn, B and Fe) along with 15 kg ha^{-1} potassium humate was significantly best regarding an improvement in total soluble solids, lycopene, ascorbic acid and total acidity during summer and winter seasons. It is concluded that micronutrients should be used along with potassium humate to improve the quality of tomato fruits.

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Introduction

Imbalance nutrition is one of the major causes of poor quality of tomato fruit in the country. Continuous cropping with high yielding crop varieties, growing of same crop and fewer interest in INM (integrated nutrient management) has resulted in reduction of soil organic matter causing deficiency of micronutrients (Rakkiyappan and Thangavelu, 2000). These micronutrients are required in very small amounts but are equally important as macronutrients for plant growth (Davies, 1997). The micronutrients include zinc (Zn), copprer (Cu), boron (B), iron (Fe), manganese (Mn), molybdenum (Mo), cobalt (Co), nickel (Ni) and chloride (Cl). However, each of the nutrients has a slight range of deficiency and toxicity level (Imtiaz *et al.,* 2010).

Zinc is an important micronutrient needed by both humans as well as crops. Zn is an important component of different enzymes catalyzing many metabolic reactions in all crops. It plays a vital role in the growth and differentiation of cells and tissue that have a swift differentiation and turnover, as well as those in the gastrointestinal tract (Osendarp *et al.,* 2003). Zinc is an instrumental nutrient in maintaining the immune system and affects the number of aspects of cellular and humoral immunity (Shankar and Prasad, 1998). Zinc builds up crop yield and controls nitrogen management of plants (Souza *et al.,* 1998).

Furthermore, boron plays an important role directly and indirectly in improving the yield and quality of tomato in addition to suppress various diseases and physiological disorders (Magalhaes *et al.,* 1980). Boron deficient plants transpire less water, possibly due to higher concentration of sugars and other hydrophilic compounds in their cells. Its deficiency results in stunting of young plants due to shortening of internodes; leaves of young plants fail to emerge and death of growing points may occur. In several plant functions, boron is important directly and indirectly as it is involved in growth of cells in newly emerging shoots and roots, while in some plants it is crucial for flowering, pollination, fruit formation, seed development and sugar transport synthesized by different plant components (Marschner, 2002; Takano, 2006; Wallace, 2006; Dordas *et al.,* 2007; Takano *et al.,* 2007, 2008; Miwa *et al.,* 2008).

Iron plays a vital role in chlorophyll synthesis, carbohydrate production, cell respiration, chemical reduction of nitrate and sulphate and in nitrogen assimilation (Fortun *et al.,* 1989). Iron deficiency first appears in younger leaves in the form of yellowing of leaves due to chlorosis, showing that Fe is immobile in plants (Morris *et al.,* 1990). Iron chlorosis is mostly observed in calcareous soils covering 30% of the earth crust. Iron deficiency has a direct effect on mechanism of photosynthesis resulting in a drastic reduction in yield (Cummings and Xie, 1995). Some crops sensitive to iron deficiency are citrus, grapes, groundnut, sorghum, soybean, field bean, vegetables including tomato and ornamentals (Piccolo and Mbagwu, 1990). Alva and Oberza (1998) reported that application of iron humate increased growth, leaf iron content and fruit yield of orange and grapefruit.

Most of scientist suggested to apply organic amendments to overcome the problem of micronutrients deficiency. Among different organic substances, humic acids are widely distributed in earth. These are found in soils as well as in manure, peat, compost, sewage, brown coal, carbonaceous shales and many other deposits. There is a great opportunity for producing commercial humic compounds and now many commercial products are available worldwide. Most of these products are obtained from lignite and peat (Chen *et al.,* 2004). Humic compounds containing 65-70% of organic matter in soil and are subjected to studies in a variety of areas in agriculture like fertility of soil, soil chemistry, physiology of plant and environmental sciences due to numerous functions performed by these compounds that may significantly promote the growth of plants (Knicker *et al.,* 1993; Friedel and Scheller, 2002).

These compounds play important role in soil conditioning, soil cation exchange capacity, carbon and nitrogen cycles, complexation of heavy metal ions and pesticides, reduction of ammonia volatilization from soil applied urea and plant growth and development (Ahmed *et al.,* 2006), also increase soil aggregation and water holding capacity (Wershaw and Aiken, 1985).

Hence, current study aimed the impact assessment of potassium humate in combination with different levels of micronutrients (Zn, B and Fe) on tomato crop fruit quality.

Material and methods

For quality parameters, stored fruits were homogenized well by grinding in simple food shaker. The homogenized juice was then centrifuged (9000 g, 15 minutes) to get clear fruit juice for following estimations.

Total soluble solids

From clear tomato fruit juice, total soluble solids (TSS) were determined by using a digital Refractrometer (ATAGO). Results were presented in °Brix after making temperature correction (AOAC, 1995).

Titrateable acidity

Titrateable acidity was measured by titrating 10 ml of fruit juice against 0.1 N NaOH with phenolphthlein as an indicator. The results were presented in percent of anhydrous citric acid (AOAC, 1995).

Lycopene content

Lycopene analysis was performed by using the method of Ranganna (1986). Measured sample (10 ml fruit juice) was repeatedly extracted with acetone to get the colourless residues. The extract so obtained was shifted to separating funnel having 10-15 ml petroleum ether. Thereafter, 5% sodium sulfate solution was added. The acetone phase was repeatedly extracted with petroleum ether, till it became colourless. The upper petroleum ether layer was pooled and volume was made to 50 ml with petroleum ether. The intensity of colour was measured at 503 nm in a spectrophotometer (UV-VIS Double Beam Spectrophotometer 2201). Petroleum ether was used as blank.

Ascorbic acid

Ascorbic acid determination was based on reduction of dye, 2, 6-dichlorophenol indophenol by ascorbic acid (AOAC, 1995). Tomato juice (0.5 ml) was mixed with 2.5 ml of extracting solution (3% metaphosphoric acid and 8% acetic acid). Filtration process was carried out through Wattman No. 4 filter paper. The filtrate was titrated against indophenol solution (25% 2, 6-dichlorophenol indophenol and 21% $NaHCO_3$ in water) till a light rose pink colour appeared and persisted for 5 seconds.

Statistical analysis

The data collected were subjected to two-way analysis of variance (ANOVA) using Statistix version 8.1 (Analytical Software, 2005). The least significant difference (LSD) test at 5% of probability was employed for testing the differences among the treatment means.

Results

Total soluble solids

Both main and interactive effects of different levels of potassium humate (KH) and application rate of micronutrients (Zn+B+Fe) differed significantly for total soluble solid of tomato fruits (Table 1).

It was observed that application of 75 and 100% Zn+B+Fe with15 kg ha^{-1} KH remained significantly best for total soluble solids of tomato fruits during autumn and spring season. Application of 75 and 100% Zn+B+Fe with 15 kg ha^{-1} remained significant as compared to control (no Zn+B+Fe and no KH) for total soluble solids of tomato fruit during autumn and spring season. Furthermore, 75 and 100% Zn+B+Fe with 15 kg ha^{-1} did not differ significantly from 50% Zn+B+Fe with15 kg ha^{-1} in autumn season but remained significantly better during spring season. Maximum increase of 14.2 and 14.6% in total soluble solids were observed where 75 and 100% Zn+B+Fe with 15 kg ha^{-1} was applied as compared to control during autumn and spring season respectively.

Table 1. Total soluble solids (Brix°) of tomato fruit as affected by various levels of potassium humate and micronutrients under field conditions during spring.

Zn+B+Fe Consortia	Potassium humate levels (kg ha⁻¹) 0	5	10	15	Mean
Autumn season					
Control (0%)	2.7g	3.3e	4.1d	4.2d	3.5c
50%*	2.9fg	4.2d	4.3cd	4.6ab	4.0b
75%	3.0f	4.3cd	4.3cd	4.8a	4.1ab
100%	3.1ef	4.3cd	4.5bc	4.8a	4.2a
Mean	2.9d	4.0c	4.3b	4.6a	
Spring season					
Control (0%)	2.6 h	3.2 e	4.0 d	4.1 cd	3.5 c
50%*	2.8 g	4.1 cd	4.2 c	4.5 b	3.9 b
75%	2.9fg	4.2 c	4.2 c	4.7 a	4.0 a
100%	3.0 f	4.2 c	4.4 b	4.7 a	4.1 a
Mean	2.8 d	3.9 c	4.2 b	4.5 a	

Total acidity (% of citric acid)

Main effects of Zn+B+Fe and KH were significant but their interaction Zn+B+Fe × KH was non-significant for total acidity of tomato fruit (Table 2).

On an average, 50, 75 and 100% Zn+B+Fe remained non-significant to each other but differed significantly as compared to control for total acidity of tomato fruit. Increasing level of KH also enhanced the total acidity of fruit as compared to control (no KH). Maximum increase of 20 and 17% in total acidity of tomato fruit were observed where 100% Zn+B+Fe was applied as compared to control during autumn and spring season respectively. Similarly, 15 kg ha^{-1} KH gave maximum increase of 60 and 41% in total acidity of total acidity of tomato fruit as compared to control (no KH) during autumn and spring season respectively.

Table 2. Total acidity (percent of citric acid) of tomato fruit as affected by various levels of potassium humate and micronutrients under field conditions during spring and autumn season.

Zn+B+Fe Consortia	Potassium humate levels (kg ha⁻¹) 0	5	10	15	Mean
Autumn season					
Control (0%)	0.2	0.3	0.3	0.3	0.28b
50%*	0.2	0.4	0.4	0.4	0.35a
75%	0.3	0.4	0.4	0.4	0.37a
100%	0.3	0.4	0.4	0.5	0.40a
Mean	0.25b	0.37a	0.38a	0.40a	
Spring season					
Control (0%)	0.2	0.3	0.3	0.3	0.29b
50%*	0.2	0.4	0.4	0.4	0.36 a
75%	0.3	0.4	0.4	0.4	0.38 a
100%	0.3	0.4	0.4	0.5	0.41 a
Mean	0.29 b	0.36 a	0.38 a	0.41 a	

Ascorbic acid

Main effects of KH was significant but main effect of Zn+B+Fe and interaction Zn+B+Fe × KH were non-significant for total acidity of tomato fruit (Table 3). Increasing level of KH also enhanced the ascorbic acid content of fruit as compared to control (no KH) in autumn and spring season. It was observed that 10 and 15 kg ha^{-1} KH remained statistically alike to each other but differed significantly as compared to control in autumn and spring season. No significant change in ascorbic acid content of tomato fruit was noted where 5 and 10 kg ha^{-1} KH was applied in autumn and spring season. However, 5 kg ha^{-1} KH remained statistically alike with control for ascorbic acid content of tomato fruit in autumn and spring season. Application of 15 kg ha^{-1} KH gave maximum increase of 20 and 21% in ascorbic acid content of tomato fruit as compared to control (no KH).

Table 3. Ascorbic acid content (mg 100 g^{-1} fresh weight) of tomato fruit as affected by various levels of potassium humate and micronutrients under field conditions.

Micronutrients (%)	Potassium humate levels (kg ha^{-1})				Mean
	0	5	10	15	
		Autumn season			
Control (0%)	8.1	8.5	8.6	8.8	8.5
50%*	8.2	8.9	9.1	9.9	9.0
75%	8.3	8.9	9.5	10.0	9.2
100%	8.4	9.1	9.5	11.2	9.5
Mean	8.3c	8.9bc	9.2ab	10.0a	
		Spring season			
Control (0%)	8.2	8.7	8.8	9.0	8.7
50%*	8.4	9.1	9.3	10.1	9.2
75%	8.5	9.1	9.7	10.2	9.4
100%	8.6	9.3	9.7	11.4	9.7
Mean	8.4 c	9.0 bc	9.4 ab	10.2 a	

Lycopene content

Main effects of Zn+B+Fe and KH were significant but their interaction Zn+B+Fe × KH was non-significant for lycopene content of fruit (Table 4). On an average, 50, 75 and 100% Zn+B+Fe remained non-significant to each other but differed significantly as compared to control for lycopene content of tomato fruit. Increasing level of KH also enhanced lycopene content of fruit as compared to control (no KH). Maximum increase of 71% in lycopene content of tomato fruit were observed where 100% Zn+B+Fe was applied as compared to control during autumn and spring season. Similarly, 15 kg ha^{-1} KH gave maximum increase of 105% in total acidity of total acidity of tomato fruit as compared to control (no KH) during autumn and spring season.

Discussion

Total soluble solids (TSS)

Total soluble solids (TSS) of tomato fruit was significantly enhanced by application of different doses of potassium humate. The effect of various levels of micronutrients was also statistically significant. The interactive effect of potassium humate and micronutrients levels was also found significant in improving the TSS of tomato fruit as compared to zero control. In field studies during spring and autumn season, the trend was consistent as observed in pot study. Total soluble solid was significantly improved by the application of different levels of potassium humate and different doses of micronutrients independent of each other while maximum TSS was observed by the combined application of potassium humate and micronutrients. Gennaro and Quaglia (2003) showed extensive data showing high TSS especially vitamin C in tomato and other vegetables grown as organic vegetables. Similarly, Yildirim (2007) found effect on TSS and ascorbic acid due to foliar application of humic acid treatment. This stimulating effect of Humic substances may be attributed to increased uptake of mineral nutrients (Dursun *et al.,* 2002) and the plant hormone-like activity of humic substances (Serenella *et al.,* 2002). Kazemi *et al.* (2013) also reported increased TSS in tomato due the combined application of Ca and humic acid and attributed this increase to the effect of Ca on nitrogen and potassium uptake and higher uptake of Ca due to the application of humic acid. The authors also argue that this increase in fruit quality parameters such as TSS may be due to micronutrients which directly or indirectly take part fruit yield and quality.

In a nut shell, TSS is an important attribute which influence the palatability and acceptability of produce. Saleh *et al.* (2006) and Yildirim (2007) also reported a significant increase in fruit quality in response to the application of humic acid in tomato.

Table 4. Lycopene content (mg kg^{-1} fresh weight) of tomato fruit as affected by various levels of potassium humate and micronutrients under field conditions.

Micronutrients (%)	Potassium humate levels (kg ha^{-1})				Mean
	0	5	10	15	
		Autumn season			
Control (0%)	41.7	47.5	47.5	51.5	47.0b
50%*	43.6	67.9	81.3	92.6	71.4a
75%	44.6	70.6	82.3	101.9	74.8a
100%	45.6	72.5	89.7	114.2	80.5a
Mean	43.9c	64.6b	75.2ab	90.0a	
		Spring season			
Control (0%)	42.5	48.5	48.5	52.5	48.0b
50%*	44.5	69.3	83.0	94.5	72.8a
75%	45.5	72.0	84.0	104.0	76.4a
100%	46.5	74.0	91.5	116.5	82.1a
Mean	44.8b	65.9b	76.8ab	91.9a	

Total acidity

Total acidity is an important fruit quality characteristic of tomato. Organic acids give the fruits sourness, and affect flavour by acting on the perception of sweetness. The main organic acids in tomato are citric and malic acid and citric acid is predominating. Acidity influences storability of processed tomato. The sum of sugars, organic acids and the amount of volatile compounds, as well as colour, shape and texture make the quality of tomatoes (Azodanlou *et al.,* 2003). Colombani *et al.* (2001) and Getinet *et al.* (2008) suggested that sugars are responsible for acidity. It means that plant with high sugars have more free organic acids has more acidity than the plants with low organic acids. While many some studies hypothesize that organic acids are produced within the fruit from stored carbohydrate material although a proportion may also be translocated from leaves and roots to fruit (Getinet *et al.,* 2008). Total acidity of tomato fruit was significantly influenced by the application of various levels of potassium humate and application of various doses of micronutrients either alone or in combination. However, in pot study, the combinative effect of micronutrients and potassium humate increased the total acidity in fruit as compared to the alone effect of either potassium humate or micronutrients and as compared to zero control as well where neither potassium nor micronutrients were applied. Under field studies during spring and autumn season, the same trend was observed as that in pot study but with little higher values of total acidity. The reasons for higher acidity in fruits harvested from the plants treated with potassium humate and micronutrients may be the higher translocation of carbohydrates from leaves to fruits as

K play main role in the translocation process. Habashy *et al.* (2008) found the highest total sugar and vitamin C which mainly contributes to acidity in tomato fruit as mentioned above in response to application of micronutrients along with humic acid and other chelating substances such as amino acids. The authors concluded that the addition of chelated micronutrients plays a vital role for maximum nutritional substances in tomato fruit. The same results were obtained by Kazemi *et al.* (2013) in tomato and Fathy *et al.* (2010) in Canino apricot that the application of humic substances enhanced TSS and acidity. Kim *et al.* (2007) also found increased acidity in tomato in the treatments where conventional fertilizers were supplemented with humic acid. However, our results are not in consistence with Haghighi *et al.* (2013) who observed no effect on acidity in tomato fruit by the application of humic acid in nutrient culture medium. Similarly, Shahmaleki *et al.* (2014) applied various humic acid levels as foliar application on tomato to assess the effect of treatment on fruit quality parameters. The authors observed improvement in fruit firmness and TSS but titratable acidity was found statistically non-significant as compared to control where no humic acid was applied.

Ascorbic acid

Ascorbic acid also known as vitamin C is necessary for human health and tomato is a good source of vitamin C. Ascorbic acid is therefore considered fruit quality parameter. The observations recorded about ascorbic acid content of tomato fruit revealed that application of different levels of potassium humate, various doses of micronutrients and their interactive effect of different levels of potassium humate and micronutrients significantly improved as compared to zero control. Maximum ascorbic content in the tomato was observed from plants which were receiving potassium humate at the rate of 15 Kg ha^{-1} in combination with 100% recommended doses of micronutrients in pot study. Shahmaleki *et al.* (2014) also observed increased vitamin C content in tomato fruit in response to the application of humic acid as foliar application. Similarly, Premuzic *et al.* (1998) also observed significant increase in ascorbic acid content of the tomato fruit grown in hydroponics on organic substances such as vermicompost. In field studies during spring and autumn season, data on ascorbic acid content of tomato fruit significantly affected by application of different levels of potassium humate while various doses of micronutrients were unable to produce significant results in increasing ascorbic acid content of tomato fruit. The interactive effect of different levels of potassium humate and micronutrients also remained non-significant regarding increase in ascorbic acid content. Our results are in agreement with that of Polat *et al.* (2010) who observed increase in ascorbic acid content of tomato in the first year of study in response to application of organic substances but in the second years there were no significant difference in the ascorbic acid content of tomato fruit grown on organic fertilizer and conventional fertilizers.

The author concluded that this was due to difference in metrological conditions of the first and second year. Similarly, Dumas *et al.* (2003) reported highest vitamin C contents in the tomato grown on organic or ammonium fertilization in the first year of the study. Increased concentration of ascorbic acid may be due to the availability of moisture with increasing level of potassium humate as being humic substance it has ability to retain water for longer period of time and consequently the increased availability to plants.

Also with increased potassium humate levels there might be increased uptake of K and this higher concentration of K might play role in increased ascorbic acid accumulation in fruit. Similar observation has been recorded by von Uexkull (1979) that K increased the concentration of citric acid, malic acid, TSS, sugars and carotene in tomato fruit which enhanced the shelf life of fruit. Chatterjee *et al.* (2013) found that ascorbic acid (vitamin C) content of fruit was significantly improved by the levels of organics. Similar results were recorded by Patil *et al.* (2004) that combined application of vermicompost and inorganic rather than alone application of vermicompost or inorganic fertilizers.

Lycopene

Lycopene is a bright red pigment carotenoid and present in tomato and other fruits and vegetable as phyto-chemical and responsible for red color of tomato. Results revealed that lycopene content of tomato fruit was significantly improved by addition of various potassium humate levels and different doses of micronutrients. The interactive effect of potassium humate and micronutrients together yielded maximum lycopene content in pot study. However, in field study during spring season, the interactive effect was found statistically non-significant revealing the effect of other factors in the vast field macro-environment contrary to microenvironment in pots. The levels of potassium humate and various doses of micronutrients were however found significant in field study as well in improving lycopene content of fruit. Similar trend was observed in field study during autumn as that observed in field study during spring season. Kumari (2012) and Gupta *et al.* (2001) found increased lycopene content in response to the application of multi-micronutrients. This increase in lycopene content may be due to the higher uptake of K. Our results are in conformity with Sangtarashani *et al.* (2013) who studied the effect of Ca and K under salinity conditions on cherry tomato. Similarly, Salam *et al.* (2010) conducted investigation to judge the effect of boron and zinc application and different levels of NPK fertilizers on quality of tomato fruit and the authors observed that with zinc application lycopene content of tomato fruit was significantly enhanced. Hence one of the reasons for increased lycopene content may be the higher uptake of micronutrients such as boron and zinc.

Conclusion

On the basis of results, it is concluded that micronutrients and potassium humate are efficacious in improvement of fruit quality. Application of 100% Zn+B+Fe with 15 kg ha^{-1} potassium humate is most effective amendment for the improvement in total soluble solids, total acidity, ascorbic acid and lycopene content of tomato fruits. However, 75% Zn+B+Fe with 15 kg ha^{-1} potassium humate is more economical for improvement in the quality of tomato fruit attributes.

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