

Effect of Gibberellic Acid and Potassium Nitrate Spray on Vegetative Growth and Reproductive Characteristics of Tomato

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ABSTRACT

A study was carried out to investigate the effect of 2 levels of gibberellic acid (10^{-4} and 10^{-8}) and 2 levels of potassium nitrate (6 and 8 mM) spray on the growth, leaf-NPK content, yield and quality parameters of tomato. The application of gibberellic acid and potassium alone or in combination increased plant height, number of branches, number flowers per cluster, number fruits per cluster and faster fruit growth in addition to increasing fruit number, fruit firmness, weight and yield. The chlorophyll content, leaf-NPK content, blossom end rot and nitrate reductase activity were not affected by application of GA3 alone or in combination, but K application alone significantly decreased blossom end rot while increasing leaf-NPK content, chlorophyll content and nitrate reductase activity. With regard to fruit quality, the application of GA3 at 10^{-8} mM, 8 mM potassium nitrate and 10^{-8} mM GA3+ 8 mM potassium nitrate increased fruit lycopene content, total soluble solids, vitamin C and titratable acidity compared with the control treatment. From this study, it can be concluded that spraying with gibberellic acid and potassium alone or in combination increased vegetative growth and reproductive characteristics of tomato.

Key Words: Growth, Foliar Application, Yield and Quality Characteristics, Tomato

Abbreviations: GA3: Gibberellic acid; TSS: Total soluble solids; TA: Titratable acidity; K: Potassium

INTRODUCTION

Tomato is one of the most important vegetable crops grown all over Iran. Tomato has a significant role in human nutrition because of its rich source of lycopene, minerals and vitamins such as ascorbic acid and *b*-carotene which are anti-oxidants and promote good health (Wilcox *et al.*, 2003). It is, therefore, highly desirable to explore possible ways and means to enhance the productivity of this important crop employing cost effective and easy to use techniques.

GA3 is a natural growth hormone and is a part of a type of plant hormones called gibberellins. GA3 promotes cell division and a number of plant development mechanisms and encourages numerous desirable effects such as plant height, uniform flowering, reduced time to flowering and increased flower number and size (Srivastava and Srivastava, 2007). It has been well documented that the size and quality of the fruits can be affected application of plant growth hormones (Guardiola, 1992). Gibberellic acid (GA3) has been shown to increase fruit set and growth in clementine orange (Van Rensburg *et al.*, 1996). It is well documented in the literature that gibberellic acid is used widely in horticultural crops for improving fruit set (Taylor and Knight 1986).

Potassium is an essential macro-element required in large amounts for normal plant growth and development. While involved in many physiological processes, potassium's impact on water relations, photosynthesis, assimilate transport and enzyme activation can have direct consequences on crop productivity. When potassium uptake is lower than demand, foliar potassium is mobilized to the fruit, to the detriment of plant growth and fruit set and quality (Besford and Maw, 1975). Intensive research has been done to investigate the effects of K on fruit quality of vegetables grown in hydroponics, showing the significance of K in the nutrition of these crops (Kreij, 1999). Lin *et al.* (2004) found that increasing potassium levels significantly increased the concentration of total sugar, total soluble solids, glutamic acid, aspartic acid, alanine, and volatile acetate of muskmelon. In tomato, it has been reported that acid and reducing sugar contents, often correlated with K application, influence not only sweet and sour taste attributes, but also different flavor traits (Chapagain and

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Wiesman, 2004). On the other hand, Yagmur *et al.* (2004) reported that K fertilization rates did not affect the pH and color parameters. The aim of the present study was to test the effects of foliar spraying of GA3 and potassium nitrate either alone or in combination on the growth, yield, fruit quality characteristics and blossom end rot incidence of tomato fruit.

MATERIALS AND METHODS

In order to determine, the effect of different levels of GA3 and K used in spraying solution on the yield and quality of tomato during 2013-2014 growth seasons in Ilam (Elevation 1339 m, Latitude East 33.638, Longitude North 46.431), Iran. The soil of the experimental field was silty loam in texture with a pH of 7, containing total N (2.5%), total C (1%), a C/N ratio of 0.46, 75, 107 mg·kg⁻¹ of P, and K, respectively, and with an EC of 0.071 ds·cm⁻¹. Seeds of tomato cultivar Tivi F1 were sown in the month of March and were transplanted during the month of May. There were 3 ridges in 1 subplot and 10 plants in each ridge. Row-to-row distance and plant-to-plant distance was 75 cm and 30 cm, respectively. GA3 (10⁻⁴ and 10⁻⁸ mM) and potassium nitrate (6 and 8 mM), either alone or in combination, were applied as foliar spray 30 days after transplanting and when the fruits were berry-sized. A 10⁻² M stock solution of GA3 was prepared by dissolving 0.346 g GA3 (SIGMA, USA) in 10 ml of ethyl alcohol and the final volume was made up to 1000 ml with DDW. By diluting this stock solution with DDW, 10⁻⁴ and 10⁻⁸ M solutions of GA3 were prepared. A back-held spray pump was used for foliar application of the chemicals. After each treatment, the pump was washed thoroughly. A teaspoon of commercial washing powder was added as a wetting agent. Distilled water containing a comparable amount of wetting agent was sprayed on the plants in the controlled treatment. All foliar spraying was carried out early in the morning. The following characteristics were recorded, plant height, number of fruits per cluster, total yield, mean fruit weight, soluble solid content, total titrable acid, vitamine C, total nitrogen, phosphorous and potassium in leaves. Plant height was determined for 5 plants in the middle row in each treatment after the first picking. For this purpose, the plant height from the soil line to the top was determined with a measuring tape and averaged to represent corresponding treatments. The number of branches was counted for the middle ridge in each treatment at the first picking and the average number of branches per plant was calculated. Total nitrogen of the sample was determined by Kjeldahl method (Kacar 1972). For determination of P and K contents of leaf, plant samples were air-dried and were then ground. K was determined after dry digestion of dry and sub-samples in a HCL preparation, P was measured spectrophotometrically by reaction with ascorbic acid. Potassium was determined by flame photometry. Lycopene in fruits was estimated as described by Sadasivam and Manikam (1992). The number of flower clusters per plant, number of fruits per cluster, and number of fruits per plant were determined for 5 plants in the middle row of the plot. For this purpose, the number of flower clusters per plant, number of fruits per cluster, and number of fruits per plant were counted and divided by the total number of plants. Nitrate Reductase Activity (NRA) was determined by the method of Silveira *et al.* (1998). Leaf disc from the second youngest fully expanded leaves (200 mg fresh mass) were infiltrated twice for two minutes with 5 ml of reaction mixture containing 100 mmol/l Potassium Phosphate buffer (pH 7.5) ; 25 mmol/l KNO₃ ; and 1% isopropanol. The reaction mixture was incubated at 35°C for 30 minutes in the dark. NR activity was estimated from the amount of NO²⁻ formed during the incubation period and released from the leaf discs to the medium after boiling for 5 minutes. Aliquots were mixed with 2 ml of (1:1) 1% sulfanilamide in 2.4 mol /l HCl ; 0.02% N-1-naphthyl-ethylenediamine and the absorbance was taken at 540 nm. The total yield for each treatment was calculated by weighing the fruit picked in each plot and converting the weight to yield per hectare. The average fruit weight was estimated by weighing 10 fruits in each treatment, with the help of an electronic balance measuring in grams to the third decimal place, and then converting to average fruit weight. Sub-samples (10 g) were pressed through cheese cloth to extract the juice. Total soluble solids were determined on a portable refractometer 300003 (Sper Scientific Ltd., Scottsdale, Ariz.) standardized with distilled water. Total titrable acid and vitamine C was measured by NaOH (0.1 M) titration and indophenol's method according to Horvitz *et al.* (1970). Blossom end rot incidence (%) was estimated by counting the total number of fruits and fruits showing symptoms of blossom end rot in each plot. The blossom end rot incidence is expressed as a percentage

of total fruits. The fruit firmness was recorded with the help of a pressure meter (OSK 10576 CO., Japan). For this purpose, 5 fruits from each treatment were taken and penetration force was measured by gently inserting the probe into the equatorial region of the fruit. The readings for all 5 fruits were averaged to represent the corresponding treatments. During the trial three plants per experimental unit were sampled and fruit numbers and weight were determined. Photosynthetic pigments chlorophyll was determined using chlorophyll meter (SPAD-502, Minolta Co. Japan), which is presented by SPAD value. Average of 3 measurements from different spots of a single leaf was considered.

Statistical Analysis

The experiment was laid out in randomized complete block design with 4 replications, each consisting of 3 pots with each pot containing one plant. Data were analyzed by SPSS 16 software and comparing averages was done by Duncan's test and a probability value of %5.

RESULTS AND DISCUSSION

Chlorophyll and leaf NPK content

The potassium application resulted in a significant increase in chlorophyll of tomato leaves as compared to both the control and plants treated with GA₃ either alone or in combination. The chlorophyll increased to its maximum (48.14 SPAD) with 8 mM potassium nitrate application. N content was maximum in treatment 8 mM potassium nitrate (Table 1). The N content was not affected by application of GA₃ alone or in combination. The P content was not affected by application of GA₃ either alone or in combination. The maximum K (2%) and P (0.42 %) content was recorded with 8 mM potassium nitrate application, followed by 1.95(%) with 6 mM potassium nitrate and 1.8 (%) with 10⁻⁸ mM GA₃+8 mM potassium nitrate (Table 1). These results are in agreement with previous investigation indicated by Zhang *et al.* 2002; Lin and Danfeng 2003. They found that increasing in vegetative growth, net photosynthetic rate, NPK content and chlorophyll content were associated with increasing of K levels. Potassium affects respiration, photosynthesis, leaf NPK content, chlorophyll development, water content of leaves, carbon dioxide (CO₂) assimilation and carbon movement (Sangakkara *et al.*, 2000) Thus, it can be concluded that photosynthesis and, correspondingly, formation of carbohydrates such as glucose, saccharose, etc. increased due to chlorophyll content in response to potassium treatments for tomato compared with the untreated control.

Table 1. Influence of GA3 and potassium application on vegetative, reproductive growth and leaf NPK content of tomato plants.

Treatments	Chlorophyll (SPAD)	N (%)	P (%)	K (%)	Nitrate reductase activity $\mu\text{mole NO}_2^-$ (g. f.w.hr) ⁻¹	Flowers per cluster	Fruits per cluster	Plant height (cm)	Number of branches
Control	30.12c	1.98cd	0.21c	1.2c	3d	18.7c	5.1 b	70 c	5 c
10 ⁻⁴ mM GA3	34.7bc	2c	0.3ab	1.2c	3.8c	27.7b	5.4b	76.2 b	5.6 bc
10 ⁻⁸ mM GA3	39.8b	2.5b	0.31ab	1.71a	4.11c	33.7a	7.12a	90.14a	7.89 a
6 mM potassium nitrate	40.12b	2.7b	0.33ab	1.95a	6.5ab	26.17b	5.9b	76.8 bc	5.7 bc
8 mM potassium nitrate	48.14a	3a	0.42a	2a	6.9a	32.14 a	6.68ab	89.71a	7.68 a
10 ⁻⁴ mM GA3+6 mM potassium nitrate	34.15bc	2.24bc	0.31 ab	1.46b	5.14b	30.5 ab	6.72ab	85.6 ab	6.87 ab
10 ⁻⁴ mM GA3+8 mM potassium nitrate	36.5bc	2.29bc	0.31ab	1.5b	5.6b	30.14 ab	6.8ab	88.14 ab	7 ab
10 ⁻⁸ mM GA3+6 mM potassium nitrate	35.11bc	2.25bc	0.35ab	1.61b	5.55b	31.12 ab	7ab	93.12 a	7.14 ab
10 ⁻⁸ mM GA3+8 mM potassium nitrate	36.8bc	2.411bc	0.34ab	1.8a	5.68b	36.14 a	7.68a	98.14 a	8.13 a

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

Nitrate reductase activity

The nitrate reductase activity increased significantly with foliar application of potassium nitrate alone. The nitrate reductase activity increased from 3 in the control to a maximum of 6.9 with 8 mM potassium nitrate application (Table 1). The nitrate reductase activity was not significantly affected by the foliar application GA₃ alone or in combination. Nitrates is one of the major sources of N, taken up by roots of higher plant, translocate to the shoot, store in vacuole and assimilate into reduced N products. Foliar application of K was found to increase nitrate content of ryegrass leaves under non-saline or saline condition (Tabatabaei and Fakhrzad, 2008) and NR activity and protein content in tomato and maize (Martinez and Cerda, 1989).

Number of flowers and fruits per cluster

The fruits per cluster were not affected by application of potassium nitrate alone, but GA₃ application resulted in a significant increase in the number of fruits per cluster. The maximum number of fruits per cluster (7.68) was recorded with 10⁻⁸ mM GA₃+8 mM potassium nitrate application. The difference among combinations of 10⁻⁸ mM GA₃+ 6 mM potassium nitrate, 10⁻⁴ mM GA₃+ 8 mM potassium nitrate and 10⁻⁴ mM GA₃+ 6 mM potassium nitrate was not significant (Table 1). The combination of GA₃+ potassium nitrate significantly increased the number of flowers per cluster from 18.7 in the control to 36.14 with 10⁻⁸ mM GA₃+ 8 mM potassium nitrate. The difference among 6 or 8 mM potassium nitrate applied alone and in combinations of 10⁻⁴ mM GA₃+6 mM potassium nitrate, 10⁻⁴ mM GA₃+8 mM potassium nitrate and 10⁻⁸ mM GA₃+6 mM potassium nitrate was not significant (Table 1). GA₃ is a natural growth hormone and promotes cell division and a number of plant development mechanisms and encourages numerous desirable effects such as plant height and uniform flowering. The results found are in agreement with the findings of Srivastava and Srivastava (2007) who observed that, GA₃ significantly reduce time to flowering and increased flower number and size. Davies and Zalman (2006) reported that, GA₃ significantly increased the total number of fruits, the fruit weight per plant by reducing pre-harvest fruit drop in orange. GA₃ promote vegetative growth and reproductive organ formation (Gemici *et al.*, 2000) with extended flowering, maturity period and less fruit size formation (Graham and Ballesteros 2006). Generally the essential element K has a great regulatory role within plant cells and organs such as, activating more than 50 enzymes, osmosis regulation and photosynthesis and loading and unloading of sugars in phloem (Mengel, 2007). Number of flowers and inflorescences increased when plants were treated with potassium nitrate, Khayat *et al.* (2010) reported similar results for 'Selva' strawberries, and also our findings were in accordance with previous works (Rahemi and Asghari, 2004). The element K has important regulatory roles inside and outside of plant cells, so it can be expected that plant access to an available K source should optimize plant growth and consequently this enables plants to flower more frequently.

Plant height and number of branches per plant

The number of branches per plant was significantly affected by the foliar application of K and GA₃ either alone or in combination. The number of branches per plant increased from 5 in the control to 7.89 and 7.68 with 10⁻⁸ mM GA₃ and 8 mM potassium nitrate, respectively, and to a maximum (8.13) with 10⁻⁸ mM GA₃+8 mM potassium nitrate (Table 1). The mean plant height increased significantly with foliar application of GA₃ and potassium nitrate either alone or in combination. The plant height increased from 70 cm in the control to a maximum of 98.14 cm with 10⁻⁸ mM GA₃+8 mM potassium nitrate application, followed by 93.12 cm, 89.71 cm and 90.14 cm with 10⁻⁸ mM GA₃+6 mM potassium nitrate, 8 mM potassium nitrate and 10⁻⁸ mM GA₃, respectively (Table 1). Plant height was predominantly increased by the application of GA₃ and K either alone or in combination. Plant height is a very important factor for good plant growth and ultimate yield. Along with plant height pod length, number of pods, number of leaves and other vegetative and reproductive attributes were also affected. Most of the vegetative and reproductive growth parameters especially plant height (Table 1) are similar to the findings of Ilias *et al.* (2007) and Abdel-Mouty and El-Greadly (2008). The present findings are in agreement with the results obtained by Adel and Thomas (1994) who reported increase in plant height of soybean at high than at low K application. Plants cannot complete a normal life cycle without sufficient K. Plants grown for food take up and use large quantities of K, P and K deficient plants often have slow growth, poor drought resistance, weak stems, and are more susceptible to lodging and plant disease (Xu, 2011). The possible reason was that K application improves the growth development of tomato and increased the number of branches per plant.

Yield, fruit weight and fruits per plant

The yield, fruit weight and fruits per plant of tomato increased significantly with foliar application of K and GA₃ either alone or in combination. The yield increased to its maximum (24.15 t ha⁻¹) with combination of GA₃ and potassium nitrate (10⁻⁸ mM GA₃+8 mM potassium nitrate) application. The number of fruits per plant and Fruit weight increased significantly from 76 and 60.3, respectively, to 100 and 130.14, respectively, with 10⁻⁸ mM GA₃+8 mM potassium nitrate application. The present findings are in agreement with the results obtained by El-Sese (2005) who reported treatment with GA₃ increased the yield of fruits. Similar findings have been reported in apple, pear and seedless grape; gibberellic acids (GA₃) have been shown to increase fruit set, growth, yield and fruit weight (Zabadal and Dittmer 2000). Stern and Gazit (2003) also described a similar trend in Yu Her Pau' litchi over two years in Taiwan. They also hypothesize that sprays of GA₃ during stage I of fruit growth would increase fruit and aril weight. Addition of GA₃, K plays an important role in tomato nutrition and fruit quality. This macroelement significantly affects the quantity and quality of tomato yield in greenhouses cultivation with a limited volume of the growing medium (Chohura *et al.*, 2009). K deficiency resulted in a decrease in net photosynthetic rate and dramatic decrease in crop yield (Ding *et al.* 2006). Golcz *et al.* (2012) have reported that the total yield, marketable yield, commercial fruit yield and total average yield per plant were increased by increasing application rates of potassium (K) fertilizers on pepper plant.

Fruit quality

The maximum fruit firmness of 3.81 kg cm⁻² was, however, recorded with 10⁻⁸ mM GA₃+8 mM potassium nitrate application. The GA₃ and potassium nitrate application also resulted in a significant increase in firmness of tomato fruit as compared to control. The differences among fruit firmness of fruits receiving 10⁻⁸ mM GA₃+6 mM potassium nitrate, 10⁻⁴ mM GA₃+8 mM potassium nitrate and 6 mM potassium nitrate were nonsignificant (Table 2). The TA and PH of tomato fruit was significantly affected by the application of GA₃ and K alone, but interaction GA₃+K were nonsignificant. The TA and PH increased from 2.7 and 1.8 (%) in the control to a maximum of 4.42 and 3 with 10⁻⁸ mM GA₃ application, followed by 4.41 and 3.11 with 8 mM potassium nitrate, respectively (Table 2). TSS, vitamin C and fruit lycopene content increased significantly with foliar application of GA₃ and K either alone or in combination. The TSS, vitamin C and fruit lycopene content increased from 4 °Brix, 14.8 (mg. 100 g fresh fruit⁻¹) and 1 (mg/100 g) (respectively) in the control to a maximum of 6.8 °Brix, 35.12 (mg. 100 g fresh fruit⁻¹) and 2.34 (mg/100 g) with 10⁻⁸ mM GA₃+8 mM potassium nitrate application, followed by 6.68°Brix, 34.17 (mg. 100 g fresh fruit⁻¹) and 2.2 (mg/100 g) with 8 mM potassium nitrate and 5.58°Brix, 33.14 (mg. 100 g fresh fruit⁻¹) and 2.17 (mg/100 g) with 10⁻⁸ mM GA₃, respectively (Table 2). The blossom end rot was not affected by application of GA₃ alone or in combination, but K application significant decreased blossom end rot. The incidence of blossom end rot was the highest (20.18%) in the control and decreased significantly to 3.12% with 8 mM potassium nitrate application. In plants, the potassium is related to the synthesis of proteins and carbohydrates, sugars and starch storage and this stimulated the growth and improved utilization of water and the resistance to pests and diseases (Faquin, 1994). Balibrea *et al.* (2006) have reported that an increase of TSS in tomato fruits may depend on a higher sugar import and accumulation. Sofia 2008 mentioned that the increase of TSS together with the increase of reducing sugars in the fruits of plants grown with the higher K levels in the nutrient solution confirm that K played an important role in the configuration of quality profile in tomato fruits. By increasing K from 200 to 350 ppm, acidity increased from 4.02 to 4.63% and juice pH increased from 3.87 to 4.14. K is known as electroneutrality maintenance element of organic acids in tomato fruit (Dorais *et al.*, 2001). It has been well documented that spraying GA₃ increased the fruit size and firmness in cherry fruits (Choi *et al.*, 2002). Our results were found to be in agreement with that of Huang and Huang (2005) who observed that, application of growth regulators like auxin and gibberellins can significantly increased the total soluble contents of the fruit in citrus species. Our results is supported by the finding of Clayton *et al.* (2006) and Khan *et al.* (2006) who reported that GA₃ sprays increased fruit soluble solids in sweet cherry and lycopene content of tomato fruit treated with GA₃.

Table 2. Effect of GA3 and potassium application on yield and quality of tomato.

Treatments	Yield (t ha ⁻¹)	Fruits per plant	Fruit weight (g)	Fruit firmness (kg cm ⁻²)	TA (%)	PH (%)	TSS (°Brix)	vitamin C (mg. 100 g fresh fruit ⁻¹)	Fruit lycopene content (mg/100 g)	Blossom end rot (%)
Control	12.11c	76c	60.3c	2.3c	2.7bc	1.8c	4d	14.8c	1c	20.18a
10 ⁻⁴ mM GA3	16.79bc	80.14b	78.14bc	3bc	3b	2.8ab	4.15c	19.6b	1.4b	18.14ab
10 ⁻⁸ mM GA3	22a	97a	110.71a	3.61a	4.42a	3a	5.85a	33.14a	1.68ab	18ab
6 mM potassium nitrate	17bc	82.5b	84.5bc	3.28b	3.14b	3 ab	4.2c	20.12b	1.32b	8.6cd
8 mM potassium nitrate	22.4a	97.14a	112.01a	3.85a	4.41a	3.11a	6.68a	34.17a	1.6ab	3.12d
10 ⁻⁴ mM GA3+6 mM potassium nitrate	18b	90.4ab	88.1b	3bc	3.8ab	2.1b	5bc	28.14ab	1.9a	15.14bc
10 ⁻⁴ mM GA3+8 mM potassium nitrate	18.14b	91.4ab	94.15ab	3.4b	4ab	2.5b	5.4bc	30ab	1.85a	10.5c
10 ⁻⁸ mM GA3+6 mM potassium nitrate	22.5a	95.4ab	100.8ab	3.42b	4.1ab	2.3b	5.42ab	30.4ab	1.89a	15.18bc
10 ⁻⁸ mM GA3+8 mM potassium nitrate	24.15a	100a	130.14a	3.81a	4.21ab	2.18b	6.8a	35.12a	2a	10c

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

CONCLUSIONS

This study clearly indicates that the effective concentration of GA3 and K to improve tomato fruit yield and quality tomato. In the case of K improvement of fruit yield and quality seems to be at higher concentration of 8 mM and GA3 at 10^{-8} indicated better result for yield and quality tomato. In general, it is important to continue the experiment in different growing seasons and conditions on different types of tomatoes to confirm the present result.

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