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ORIGINAL ARTICLE

Improved growth, productivity and quality of tomato (*Solanum lycopersicum* L.) plants through application of shikimic acid

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Transpiration rate;
Yield

Abstract A field experiment was conducted to investigate the effect of seed presoaking of shikimic acid (30, 60 and 120 ppm) on growth parameters, fruit productivity and quality, transpiration rate, photosynthetic pigments and some mineral nutrition contents of tomato plants. Shikimic acid at all concentrations significantly increased fresh and dry weights, fruit number, average fresh and dry fruit yield, vitamin C, lycopene, carotenoid contents, total acidity and fruit total soluble sugars of tomato plants when compared to control plants. Seed pretreatment with shikimic acid at various doses induces a significant increase in total leaf conductivity, transpiration rate and photosynthetic pigments (Chl. a, chl. b and carotenoids) of tomato plants. Furthermore, shikimic acid at various doses applied significantly increased the concentration of nitrogen, phosphorus and potassium in tomato leaves as compared to control non-treated tomato plants. Among all doses of shikimic acid treatment, it was found that 60 ppm treatment caused a marked increase in growth, fruit productivity and quality and most studied parameters of tomato plants when compared to other treatments. On the other hand, no significant differences were observed in total photosynthetic pigments, concentrations of nitrogen and potassium in leaves of tomato plants treated with 30 ppm of shikimic acid and control plants. According to these results, it could be suggested that shikimic acid used for seed soaking could be used for increasing growth, fruit productivity and quality of tomato plants growing under field conditions.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely consumed vegetable crops all over the world, and high-quality yield is an essential prerequisite for its economical success in the Saudi Arabia. Tomato has been recently gaining attention in relation to the prevention of some human diseases. This interest is due to the presence of carotenoids and particularly lycopene, which is an unsaturated alkylic compound,

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that appears to be an active compound in the prevention of cancer, cardiovascular risk and in slowing down cellular aging (Gerster, 1997; Di Cesare et al., 2012; Abdel-Monaim, 2012). Lycopene is found in fresh, red-ripe tomatoes as all-trans (79–91%) and cis- (9–21%) isomers (Shi et al., 1999; Boileau et al., 2002; Abdel-Fattah and Al-Amri, 2012).

Soils in the arid and semiarid regions like Saudi Arabia have little nutrient and mineral contents, which adversely affect plant growth and quality. One of the cost-effective strategies for counteracting deficiencies of soil minerals involves the application of chemical fertilizers. Increasing growth and quality of tomato plants through increasing the productivity per unit area as well as with expanding the cultivated area in newly reclaimed lands is the major important national target by application of cheap efficient strategies. Shikimic acid is the known precursor of aromatic amino acids, L-phenylalanine and L-tyrosine. These compounds are phenylpropane (C_6–C_3) derivatives as are the building units of lignin (Aldesuquy and Ibrahim, 2000). Phenylalanine is an excellent precursor in all plants but tyrosine in only really effective in the grasses (Stafford, 1974). The shikimic pathway, a collection of seven enzymatic reactions whose end product is chorismate, has been studied for many years in a variety of microorganisms and plants. In plants, chorismate is the precursor not only for the synthesis of aromatic amino acids (i.e. phenylalanine, tyrosine and tryptophan), but also for many secondary metabolites with diverse physiological roles (Weaver and Herrmann, 1997). Shikimic acid is used in several plants without side effects and also used in a large scale for growth enhancement and improving fruit quality of crop and vegetable plants for many years (Aldesuquy and Ibrahim, 2000; Elwan and El-Hamahmy, 2009).

In most plants, sucrose is the major product of photosynthesis and the major form of carbohydrate transported to non-photosynthetic organs (Favati et al., 2009). It can be involved in numerous metabolic pathways. Elwan and El-Hamahmy (2009) concluded that the quality of fruit pepper was positively correlated with the high amount of total soluble sugars. The shikimic acid pathway participates in the biosynthesis of plant phenolics (Logemann et al., 1995), where the most abundant classes of phenolic compounds in plants are derived from phenylalanine via elimination of an ammonia molecule to from cinnamic acid (Hahlbrock and Scheel, 1989). Phenolic compounds play an important role in the regulation of plant growth and metabolism and they are no longer considered to be a passive by-product. In some cases, phenolic treatment induces expression of the same genes and resistance against the same spectrum of pathogens as pathogen induced resistance (Lawton et al., 1996).

In the light of the above limited reviews, the present work aimed to evaluate the influence of seed presoaking with shikimic acid on growth parameters, fruit quality, transpiration rate, total leaf conductivity, photosynthetic pigments, mineral contents and productivity of tomato plants growing in field conditions.

2. Materials and methods

2.1. Plant and growth conditions

Seeds of tomato (*Solanum lycopersicum* Mill.) were surface sterilized in 7% sodium hypochlorite for 10 min, subsequently washed thoroughly with distilled water. The sterilized seeds were divided into four sets. Seeds of the 1st set were soaked in distilled water to serve as control, the other three sets (2nd, 3rd and 4th) were soaked in shikimic acid at 30, 60 and 120 ppm, respectively for about four hours, then washed with distilled water. All these treated seeds were left to germinate for 5 days on a moistened filter paper in dark at 25 °C. Uniform germinated seedlings were sown in a $8 \times 8 \times 9\ cm^3$ plastic plate containing moist-autoclaved vermiculite soil and left to grow in a greenhouse under controlled conditions. Three weeks later, plants were transplanted into plots ($25 \times 25\ cm^2$) in a randomized complete block design, three plots for each treatment and each plot had ten plants having inter row and inter plant spacing that were 70 and 40 cm, respectively, at the research experimental farm of the Facility of Science, King Saud University, Riyadh, Egypt in March 2012. The physical and chemical analyses of the soil used in this study are listed in Table 1. Soil characteristics were pH 7.58, electrical conductivity 1.51 ds cm^{-1}, total organic matter 0.74%, total nitrogen 70.0 mg kg^{-1}, total phosphorus 15.3 mg kg^{-1}, potassium 132 mg kg^{-1}, magnesium 114 mg kg^{-1} and calcium 560 mg kg^{-1}. All plants were watered as needed with tap water to maintain soil moisture near field capacity (75–80%) and fed once weekly with 35 g N m^{-2} as potassium nitrate and 35 g P m^{-2} as superphosphate as a nutritive solution. Harvesting (ten plants per each treatment) was carried out 12 weeks after transplant.

2.2. Measurements

2.2.1. Growth and fruit yield parameters

At harvest, shoot height and leaf number per plant were recorded. Fresh and dry (70 °C for 48 h) weights of shoots and roots were determined. Leaf area was measured using a leaf area meter (Li-Cor, Lincoln, NE, USA). Fruit number for each treatment was also recorded. Fruit thickness was measured by a caliper. Average weight of fruit's fresh and dry masses in each treatment was recorded.

2.2.2. Estimation of fruit quality

Total acidity in fruits for each treatment was determined in the supernatant obtained by extracting 10 g of fruit with distilled water according to the method of Wills and Ku (2002) using citric acid as a reference. Total soluble sugars in fruit extracts

Table 1 Physical and chemical analyses of soil used throughout this study.

Sand (%)	62
Silt (%)	15
Clay (%)	23
Soil texture	Sandy loamy
pH	7.58
E.C (ds m^{-1})	1.51
Organic matter (%)	0.74
N (mg kg^{-1})	70.0
P (mg kg^{-1})	15.3
K (mg kg^{-1})	132
Mg (mg kg^{-1})	114
Ca (mg kg^{-1})	560