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Research Article
Foliar Application of Micronutrients and Low Molecular Weight Chitosan on Tomatoes Grown in Silt Loam Soil

[1]Tran Minh Quynh, [1]NguyenVan Binh and [2]Duong Kim Thoa

[1]Hanoi Irradiation Center, Vietnam Atomic Energy Institute, Minh Khai, Bac Tu Liem, Hanoi, Vietnam
[2]Fruits and Vegetables Research Institute, Trau Quy, Gia Lam, Hanoi, Vietnam

Abstract

Background and Objective: Microelements are essential nutrients for plant growth and development. Chitosan is well-known as an effective Plant Growth Promoter (PGP), which has been widely used in agriculture production. In this study, formulations of microelements and low molecular weight chitosan were prepared to provide micronutrients and PGP agents for tomato through foliar application. **Materials and Methods:** Four foliar fertilizers were prepared from microelement formulation and low molecular weight chitosan for tomato. The experiments were laid out in split plots with three replications. The yield attributes, yield and quality of tomato fruits were investigated to evaluate the effects of different foliar fertilizers on tomato plants. **Results:** The study indicated that foliar spraying of microelements and low molecular weight chitosan significantly improved the fruiting and production of tomato. The foliar fertilizer containing high chitosan content and low concentration of microelements (MF-3) produced the highest tomato yield. Total yield and marketable yield of tomato reached 27.25 kg per plot and 55.23 tons per ha, respectively. These values were about 16.8% higher than those of the control. Experimental results also revealed that total vitamin C content in the fruits harvested from the treated plants much higher than that of the control, though their total soluble solid and protein contents were slightly reduced by spraying with foliar fertilizers. **Conclusion:** Foliar fertilizers composed of microelement and chitosan can be applied to increase the yield and quality of tomato fruits.

Key words: Microelement, low molecular weight, chitosan, foliar application, growth and yield

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Corresponding Author: Tran Minh Quynh, Hanoi Irradiation Center, Vietnam Atomic Energy Institute, Hanoi, Vietnam
Tel: +84.24.37805323 Fax: +84.24.37655264

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a fruit and vegetable crop grown and consumed in most countries of the world. In Vietnam, tomatoes are widely cultivated as an important fruit vegetable in many areas due to their high nutrient value. According to the General Statistics Office of Vietnam, in 2017, the total area of tomatoes nationwide was estimate at 23.1 thousand hectares and the total yield reached 0.65 million tons, though the tomato planting area reduced by 3.3% compared to 2016. Tomato fruits are one of the main sources providing carbohydrate, protein, vitamin and minerals[1], so that production of tomato pays more attention from farmers and scientists. Tomato requires different ratios of macronutrients and essential micronutrients for various growth stages. The foliar application has been considered as the most effective way to provide microelements to the plants, especially for their flowing and fruiting.

Fertilizers are compounds containing the essential nutrients needed for plant growth. Their applications in intensive agricultural areas have maintained high yields of main crops and improved global food production for a long time. However, soil fertilization usually causes agricultural pollution because more fertilizers should be applied to soil than plants can absorb. On the other hand, foliar fertilization immediately provides major nutrients and minerals, as well as essential microelements to plant in certain growth stages. And the plant can absorb up to 95% of foliar fertilizer. Therefore, foliar fertilizers have become popular in modern agriculture production[2]. Foliar application of microelements not only replenishes needed micronutrients but also protects plants from diseases related to the deficiencies of microelements, so that improves their yield and quality. Some papers have been reported the effects of foliar microelement fertilizers on tomato as well as other vegetables to correct their micronutrient deficiencies and improve the crop production[3-5]. It also found that mineral amendments can suppress some soil-borne plant pathogens indirectly by stimulating indigenous populations of microorganisms that are beneficial to plant growth and antagonistic to pathogens[6].

Marine polysaccharides such as chitosan, alginate, carrageenan are non-toxic, biodegradable and biocompatible polymers, which can be used as a Plant Growth Promoter (PGP) in agriculture. It can easily be obtained in large quantities at a reasonable cost[7]. However, their large molecular size somewhat limited their applications in practice. Fortunately, they can be decomposed into smaller molecules, which can be easier penetrated through leaves tissues. Some methods include physical decomposition, chemical and enzymatic hydrolysis that have been applied to prepare low molecular weight chitosan for agriculture. Among these, irradiation treatment was proved as an effective way to degrade high Mw polysaccharides. It has been found that the PGP activities of some carbohydrates include chitosan much increased by radiation degradation[8]. It also reported that low Molecular weight (Mw) chitosan and oligochitosan exhibited improved PGP activities for plants[9,10]. Therefore, low Mw chitosan obtained by gamma radiation scission was used as a PGP agent in microelement fertilizer in the present study. The effects of four various foliar microelement fertilizers on the growth, yield and quality of tomato fruits were investigated for tomatoes grown in silt loam soil.

MATERIALS AND METHODS

Materials: High Mw chitosan (Mw~300 kDa, DD~75%) was purchased from Chitosan Vietnam Co. (Kien Giang, Vietnam) and low Mw chitosan (CTS2, Mw~10-30 kDa) has been prepared by gamma irradiation of initial chitosan. Mg-EDTA, Na Fe-EDTA, Mn-EDTA were purchased from Wako Pure Chemical Ind., Ltd. (Japan). Borax ($Na_2B_4O_7.10H_2O$), copper sulfate ($CuSO_4.5H_2O$), zinc sulfate ($ZnSO_4.2H_2O$), sodium molybdate ($Na_2MoO_4.2H_2O$) and other chemicals were of industrial-grade, bought from Xiling Scientific Co. Ltd. (China).

About 25 days old seedlings of tomato (VL3500) were kindly supplied by the Department of Vegetables and Spicy Crops, Fruit and Vegetable Research Institute.

Experimental design and treatment: Experiments were performed in a screen house belong to Hanoi Irradiation Center. Tomato seedlings were transplanted to silt loam soil in the split plots of 3.0 m^2 (2.5×1.2) with three replications for each treatment from 12 November 2018. The soil properties were analyzed and presented in Table 1. Planting density was 30.000 plants per ha. All plants were fertilized with decomposed manure, lime powder and NPK fertilizers according to the local standard (25 tons manure; 150 kg N; 100 kg P_2O_5; 150 kg K_2O per ha). Four foliar fertilizers composed of two micronutrient formulations and low Mw chitosan (MF-1-MF-4) were prepared as in Table 2. Each foliar solution was applied to the same treatment (MF) and control (DC) was sprayed with distilled water. Foliar applications were done manually for all treated plants at 10-15 (vegetative stage), 25-30 (pre-flowering) and 35-40 (fruiting)days after planting (DAP).

Table 1: Characteristics of experimental soil

Parameters	Unit	Value*
Moisture	%	21.5
Porosity	%	45.8
Density	g cm^{-3}	1.38
pH_{KCl}	-	6.8
Organic matter	%	1.72
Total nitrogen	%	0.14
Total phosphorus (P_2O_5)	%	0.13
Total potassium (K_2O)	%	1.58
Available phosphorus (P_2O_5)	mg/100 g	5.42
Available potassium (K_2O)	mg/100 g	8.14

*All measurements were carried out at the Soils and Fertilizers Research Institute in 2018

Table 2: Compositions of various foliar microelement fertilizers

Constituents	Concentration (g L^{-1})			
Foliar fertilizer	MF-1	MF-2	MF-3	MF-4
Magnesium (MgEDTA)	5	10	5	10
Boron ($Na_2B_4O_7.10H_2O$)	9	31.5	9	31.5
Iron (NaFeEDTA)	20	300	20	300
Manganese (Mn EDTA)	2.5	2.5	2.5	2.5
Copper ($CuSO_4.5H_2O$)	3.2	60	3.2	60
Zinc ($ZnSO_4.2H_2O$)	2.7	48	2.7	48
Molybdenum ($(NH_4)_6Mo_7O_{24}$)	1.6	9	1.6	9
Chitosan CTS2	15	15	22.5	22.5
pH	6.22	6.11	5.84	5.92

* MF: Foliar fertilizer composed of micronutrients and low molecular weight chitosan

Measurements: Incidences of pests and diseases were observed and their severities were recorded based on the AVRDC (World Vegetable Center) guidance. Harvesting of tomato fruits started from late February to early March 2019. The yield attributes, the yield of tomato fruits were calculated based on the average number of fruits per plant and average fruit weight. Total yield per plot, marketable yield was determined by harvesting the whole plot. At least 5 typical fruits were selected from each treatment for quality analysis. Tomato fruits were crushed gently using the laboratory mortar and pestle. pH and total soluble solids (TSS) of tomato juice were determined using a pH meter and refractometer. Protein and vitamin C contents were measured according to AOAC 2001.11[11] and AOAC 985.33[12] methods.

Statistical analysis: All data were statistically analyzed by Analysis of Variance (ANOVA), performed with EXCEL and IRRISTAT software. The means were compared using the least significant differences test (L.S.D) at 0.05.

RESULTS

Effects of various foliar microelement fertilizers on tomato growth: The effects of foliar application of microelements and low Mw chitosan on the growth and resistance of tomato plants to pests and diseases were observed with all treated and control tomatoes. As one can see from Table 3, incidences of major pests and diseases in tomato were at no symptom or light. Bacterial wilt, a popular disease in tomato could not be observed in both treated and control plants. Severities of other diseases include yellow leaf curl, late blight and fruit worm were at very low levels. Incidence and severity of diseases reduced by foliar application, even no late blight and yellow leaf appear in the plants sprayed with MF-4 fertilizer.

Table 3: Incidence and severity of pests and diseases on tomatoes sprayed with foliar microelement fertilizers

	Major pests and diseases			
Treatments	Yellow leaf curl (%)	Bacterial wilt (%)	Late blight (phytophthora) (score)	Fruit worm (%)
CON	5.55	0	1	4.62
MF-1	2.77	0	1	4.38
MF-2	2.77	0	1	4.33
MF-3	1.40	0	0	2.27
MF-4	0	0	0	2.51

*DC is control plant sprayed with fresh water and MFx are the treated plants sprayed with MFx foliar fertilizers, respectively

Table 4 shows yield attributes and yield of tomato fruits. There were small variations in the average number of fruits, but there were larger differences in fruit weight and

Table 4: Effects of foliar fertilizers composed of microelements and low Mw chitosan on yield attributes and fruit yield of tomato

Treatments	Number of fruits/plant	Average fruit weight (g)	Yield/plant (kg)	Total yield per plot (kg)	Marketable yield (tons/ha)
DC	23.13[b]	82.5[b]	1.91[c]	22.90[c]	47.56[c]
MF-1	24.56[a]	87.1[ab]	2.14[b]	25.67[b]	52.02[b]
MF-2	24.41[a]	88.9[ab]	2.17[b]	26.04[ab]	52.95[b]
MF-3	25.34[a]	89.6[a]	2.27[a]	27.25[a]	55.23[a]
MF-4	25.07[a]	89.3[a]	2.24[a]	26.86[a]	54.89[a]
CV%	2.42	2.87	4.90	5.80	
$LSD_{0.05}$	7.26	6.22	3.15	4.57	

*DC: Control plant sprayed with freshwater, MFx: The treated plants sprayed with MFx foliar fertilizers, respectively, CV: Coefficient of variation, $LSD_{0.05}$: Least significant difference at p = 0.05, The values followed by different letters in the same column are significantly different according to Duncan's Range Test at a = 0.05

Table 5: Effects of foliar fertilizers composed of microelements and low Mw chitosan on tomato fruit quality

Treatments	pH	TSS (°Brix)	Protein (mg g^{-1})	Vitamin C (mg/100 g)
DC	4.25	4.31	0.86	11.83
MF-1	4.39	4.06	0.75	13.71
MF-2	4.41	4.09	0.71	14.2
MF-3	4.48	4.01	0.68	14.7
MF-4	4.5	4.05	0.73	13.68

*DC: Control plant sprayed with freshwater, MFx: The treated plants sprayed with MFx foliar fertilizers, respectively

yield between treated and control plants. The highest total yields were 27,25 kg per plot and 55.23 tons per ha, respectively, which were higher than those of control. These values were obtained in the plants sprayed with MF-3 fertilizer.

Effects of foliar microelement fertilizers on tomato fruit quality: Table 5 shows some quality criteria of tomato fruits harvested from the control and treated plants. The results revealed that the pH of tomato juice was acidic and it slightly increased by foliar application of microelement fertilizers. There are significant differences in Total Soluble Solid (TSS), protein and vitamin C contents in the tomato fruits from treated and control plants. TSS and protein amounts in tomato fruits slightly reduced by spraying with foliar fertilizer, but their vitamin C content increased. However, there is no significant difference in quality among the treated fruits.

DISCUSSION

Supplementation of microelements and low Mw chitosan to tomato plants by foliar spraying limited the incidences of pests and diseases. Especially, the diseases related to a deficiency of microelements such as yellow leaf curl. The percentage of infected leaves was smaller in the plants sprayed with the fertilizers containing a higher amount of micronutrients (MF-3 and MF-4). In addition, low Mw chitosan in the foliar fertilizer can also stimulate immune responses of the plant against pests and disease, as reported by Yin *et al.*[10]. As the results, better production of tomato fruits can be observed with the plants sprayed with MF fertilizers. Foliar application of micronutrients and low Mw chitosan also improved the fruiting rate and produced more fruits. The average weight of the fruits harvested from treated plants was also significantly increased in comparison with that from the control. The highest average weight was 89.6 gram, which obtained in the fruits harvested from plants sprayed with the foliar fertilizer containing low microelement and high chitosan content (MF-3). It is clear that the foliar microelement fertilizers promoted the growth and development of tomato fruits. As a consequence, the total yield per plot and marketable yield of treated tomatoes significantly increased. These results are consistent with other studies that the yields of the crops significantly increased by foliar applications of micronutrients[13] and chitosan[14]. Foliar microelement fertilizers not only rapidly provided essential elements to plant, but also controlled the diseases related to their deficiencies, so increased the productivity[15,16]. Furthermore, these foliar formulations can protect tomato from the diseases caused by a deficiency of microelements, as well as stimulate immune responses of the plant against harmful pests. It also reported that yield of tomato increased by foliar spraying with chitosan due to its anti-disease and antimicrobial activity[17]. Chitosan in the fertilizer can act as an exogenous elicitor to promote the plant growth[18] or induce antibiotic phytoalexins to prevent other infections and improve the crop production[19]. Chitosan also changed the composition of free steroids producing adverse effects on disease pests and insects, so that increased the growth and yield of tomato[20]. Thus, foliar fertilizers composed of micronutrients and chitosan can be applied to improve the growth and yield of tomato, but further studies are required to investigate their effects on the quality of tomato.

Complexation of anthocyanin in tomato fruit and minerals such as Fe, Cu, Zn in fertilizers may increase the acidity level of tomatoes harvested from treated plants. The highest TSS amount was 4.31 °Brix in the control, reduced in all treatments.

Similar results were recorded with protein. The highest value of vitamin C was 14.7 mg/100 g, recorded with the fruits from the plants sprayed with MF-3 fertilizer. Foliar application of micronutrients and low Mw chitosan slightly reduced Total Soluble Solid (TSS) and protein content, but significantly improved total vitamin C content in the fruits harvested from the treated tomatoes.

CONCLUSION

Foliar fertilizers composed of microelements and low Mw chitosan much improved the growth and development of tomato produced more fruits with heavier weight. As the result, the fruit yields of the treated tomatoes were significantly increased. The highest marketable yields obtained in tomato plants sprayed with the foliar microelement fertilizer composed of low microelement formulation and high chitosan content (MF-3). This value was 55.23 tons per ha, about 16.82% higher than that of the control. The quality of tomato was significantly changed by foliar application of microelement and low Mw chitosan, though vitamin C content of the treated fruits remarkably increased.

SIGNIFICANCE STATEMENT

This study discovered the positive effects of foliar application of micronutrients and low molecular weight chitosan on the growth and yield of tomato fruits, which can be beneficial for the tomato production. Foliar fertilizers not only stimulated the resistance against pests and diseases of a tomato plant, promoted the growth and development of tomato fruits, but also improved their quality. These results will be useful to prepare new foliar fertilizers for tomato as well as other vegetables.

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