

Response of Physicochemical Properties and Enzyme Activities in Rhizosphere Soil to Yellow Leaf Curl Virus Disease of Cherry Tomato (*Lycopersicon esulentum* Mill.)

Xiao Deng^{1, 2, 3, *}, Chunyuan Wu^{1, 2, 3}, Yi Li^{1, 4, 5}, Huadong Tan^{1, 4, 5}, Jiancheng Su⁶

¹Environmental and Plant Protection Institute, Chinese Academy of Tropical Agricultural Sciences, Haikou, China

²Hainan Danzhou Tropical Agro-ecosystem National Observation and Research Station, Danzhou, China

³Key Laboratory of Low-carbon Green Agriculture in Tropical Region of China, Ministry of Agriculture and Rural Affairs, Haikou, China

⁴Hainan Key Laboratory of Tropical Eco-Circular Agriculture, Haikou, China

⁵National Agricultural Experimental Station for Agricultural Environment, National Long-term Experimental Station for Agriculture Green Development, Danzhou, China

⁶Hainan Star Farmer Ecological Technology Co., Ltd, Haikou, China

Email address:

dx0928@foxmail.com (Xiao Deng)

*Corresponding author

To cite this article:

Xiao Deng, Chunyuan Wu, Yi Li, Huadong Tan, Jiancheng Su. Response of Physicochemical Properties and Enzyme Activities in Rhizosphere Soil to Yellow Leaf Curl Virus Disease of Cherry Tomato (*Lycopersicon esulentum* Mill.). *International Journal of Applied Agricultural Sciences*. Vol. 9, No. 2, 2023, pp. 55-60. doi: 10.11648/j.ijaas.20230902.14

Received: March 20, 2023; Accepted: April 21, 2023; Published: April 24, 2023

Abstract: Tomato yellow leaf curl virus disease (TYLCVD) has become a devastating disease, which seriously threatens the healthy development of tomato industry in China. Creating a healthy soil environment may be the key to success in preventing TYLCVD. Field investigation and laboratory analysis were used to evaluate the response characteristics of macro elements, medium elements, micro elements and enzyme activities in the rhizosphere soil of cherry tomato to TYLCVD. The main objective of this study was to determine the suitable soil environment for the healthy survival of cherry tomato. Soil samples were collected from rhizosphere of healthy and diseased plants. The results showed that the occurrence of TYLCVD was related to the enzyme activities, pH value, macro elements N, P, K, medium elements Ca, Mg, S and micro elements Mn, Zn, Cu, Si in the rhizosphere soil of cherry tomato. Compared with healthy plants, the activities of urease, catalase and acid phosphatase were significantly decreased by 48.6%–77.4%, 23.7%–43.8% and 19.1%–31.0%, respectively, in rhizosphere soil of diseased cherry tomato plants ($P < 0.05$). The pH value, contents of alkaline hydrolysis N, available Mg, available S, available Mn, available Zn, available Cu and available Si in rhizosphere soil of diseased plants were significantly lower than those in healthy plants ($P < 0.05$). The pH value in rhizosphere soil of diseased plants was 0.18–0.25 units lower than that of healthy plants. And the contents of alkaline hydrolysis N, available Mg, available S, available Mn, available Zn, available Cu and available Si were reduced by 5.54%–20.0%, 29.7%–73.9%, 27.3%–48.8%, 6.95%–10.1%, 13.6%–15.2%, 10.6%–25.0% and 4.97%–8.30%, respectively. However, the contents of available P, available K and available Ca in rhizosphere soil of diseased plants were significantly higher than those in healthy plants ($P < 0.05$), were increased by 3.77%–41.2%, 6.75%–37.4% and 16.7%–50.5%, respectively. Our findings improve our understanding of the links between the occurrence of TYLCVD and the soil environment, which have implications for developing strategies for the prevention of tomato yellow leaf curl virus disease.

Keywords: Cherry Tomato, Yellow Leaf Curl Virus Disease, Rhizosphere Soil, Enzyme Activities, Macro Elements, Medium Elements, Trace Elements

1. Introduction

Cherry tomato (*Lycopersicon esulentum* Mill.) has been listed as one of the "four fruits" promoted by the Food and Agriculture Organization of the United Nations because of its rich nutritional value. However, the long-term single cultivation mode leads to the serious continuous cropping obstacles, which including imbalance of soil nutrient, high incidence of diseases and pests and the deterioration of soil physicochemical properties [1]. The production of cherry tomato has been affected by many diseases for a long time, especially tomato yellow leaf curl virus disease (TYLCVD), which has the characteristics of high incidence, great harm and high transmission efficiency [2]. At present, TYLCVD has become a devastating disease, which seriously threatens the healthy development of tomato industry in China. Therefore, creating the healthy soil conditions needed to grow cherry tomatoes may be the key to success in preventing TYLCVD. For human beings, the source of nutrients is closely related to the agricultural ecosystem, and high yield and good quality become the goal of agricultural production in the 21 century. Therefore, a reasonable amount of macro elements and a balance of micro elements should be applied during crop fertilization. Compared with macro elements N, P and K, the contents of medium elements Ca, Mg, S and micro elements B, Mn, Zn, Cu, Fe, Si, etc. are less in plants. But they have the same importance as macro elements and are irreplaceable. For example, Si can not only silicify the epidermal cells of crops, significantly increase the absorption of Light energy, but also can promote the growth of crop root, enhance root vitality and improve crop stress resistance. The response of soil enzyme activities to the fertilization management, the changes of land using and cropping system is more rapid than other soil indexes [3], so they can be used as an early warning and sensitive indicator to measure soil quality change in soil ecosystem [4]. In this study, the enzyme activities and physicochemical properties in rhizosphere soil of diseased cherry tomato plants with TYLCVD and healthy ones were compared. The major objective was to explore the physicochemical properties and biological characteristics in rhizosphere soil of cherry tomato that promote the TYLCVD occurrence, so as to provide reference and technical guidance for further clarifying the pathogenesis of tomato virus disease and the healthy soil environment suitable for plant survival.

2. Materials and Methods

2.1. Description of Study Area

On the basis of full investigation, three fields of long-term continuous cropping cherry tomato were selected to as study area in Guangpo Town, Lingshui County, Hainan Province, China. The cherry tomato variety, cultivation conditions and management methods of each field was basically same. The soil texture of three fields was all sandy loam. The study area has a typical tropical maritime monsoon climate with sufficient light and heat conditions and the annual precipitation is approximately 1,718 mm, and the annual average sunshine

duration is approximately 2,262 hours. The mean annual air temperature is 25.4°C, with a minimum temperature 20.6°C in January and a maximum temperature 28.6°C in June. The basic situation of study area was presented in Table 1.

Table 1. Basic overview for study plots.

Sample plots	Geographic location	Disease incidence
S1	110°07'07.8"E, 18°33'29.8"N	56.70%
S2	110°06'06.0"E, 18°33'38.7"N	46.70%
S3	110°02'21.4"E, 18°32'27.6"N	43.30%

2.2. Soil Sample Collection

Soil samples were taken from 0-20-cm tillage layer in mid-December 2021 during the fruiting period of cherry tomato. The whole plant was pulled out and the rhizosphere soil was collected by shaking root method according to Griffiths [5]. For each plot, 15 healthy and 15 diseased plants were selected to collect rhizosphere soil, and the healthy and diseased plants were equally divided into three parts, that is, three replicates per plot. The rhizosphere soil of 5 healthy and diseased plants were respectively well mixed into one composite sample per plot, sealed in sterile bags, and transported in an ice cube-filled box to the laboratory on the same day. The rhizosphere soils of healthy plants were named H1, H2 and H3, and those of diseased plants were named D1, D2 and D3, respectively. Each soil sample was air-dried after passed through a 2mm sieve, then, was divided into two parts. The first part was directly used for the determination of soil pH value, and the second part was used to determine the contents of macro elements, medium elements, micro elements and enzyme activities through sifting less than 0.15 mm.

2.3. Analyses of Soil Physicochemical Properties and Enzyme Activities

Soil pH, organic matter (OM), alkali-hydrolyzed nitrogen (AN), available P (AP), and available K (AK) were measured using routine methods described by Lu [6]. Soil pH was measured using a pH electrode (Leici, Shanghai, China) at a soil: water ratio of 1: 2.5. The OM content was measured using a potassium dichromate volumetric method. The contents of AN, AP, and AK were analyzed using a diffusion method, the Olsen method, and ammonium acetate extraction flame photometry, respectively. Those of exchangeable calcium (Ca) and exchangeable magnesium (Mg) were analyzed by atomic absorption spectrophotometry. That of available sulfur (AS) was determined by phosphate-acetic acid-barium sulfate turbidimetric method. Those of available iron (Fe), available zinc (Zn) and available copper (Cu) were determined by DTPA extraction and atomic absorption spectrophotometry. That of available manganese (Mn) was determined by ammonium acetate extraction and atomic absorption spectrophotometry. That of available boron (B) was determined by boiling water extraction and curcumin colorimetry. That of available silicon (Si) was extracted from acetic acid buffer and determined by molybdenum blue colorimetric method. The activities of soil urease, catalase

and acid phosphatase were determined by kit (Suzhou Keming Biotechnology Co., Ltd.).

2.4. Statistical Analyses

Data from replicates are expressed as the mean \pm standard deviation (SD). Statistical analyses of the experimental data including averages, standard deviations and other significance were performed using SPSS v.17.0 software package (IBM Corp., Armonk, NY, United States). Statistical significance was kept at $P < 0.05$ for all analyses, and the error bars in each figure represented the standard deviation.

3. Results and Discussion

3.1. Response of Soil Physicochemical Properties to Tomato Yellow Leaf Curl Virus Disease

The pH value in rhizosphere soil of healthy plants was significantly higher than that of diseased plants ($p < 0.05$). The pH value in rhizosphere soil of healthy plants was 0.18-0.25 units higher than that of diseased plants (Figure 1). The medium nutrients of Ca, Mg and S, as essential nutrient elements of crops, play an extremely important role in the growth and development of crops, especially the macro elements of N, P and K were applied a lot, exacerbates the imbalance among nutrients. It can be seen from Table 2 and

Table 3 that the occurrence of TYLCVD in the three study plots was correlated with the contents of AN, AP, AK, Ca, Mg and S in the rhizosphere soil of the plants. The contents of AN, available Mg and AS in rhizosphere soil of diseased plants were significantly lower than those of healthy plants ($P < 0.05$), and reduced by 5.54% – 20.0%, 29.7% – 73.9% and 27.3% – 48.8%, respectively. However, the contents of AP, AK and available Ca in rhizosphere soil of diseased plants were significantly higher than those of healthy plants ($P < 0.05$), and increased by 3.77% – 41.2%, 6.75% – 37.4% and 16.7% – 50.5%, respectively.

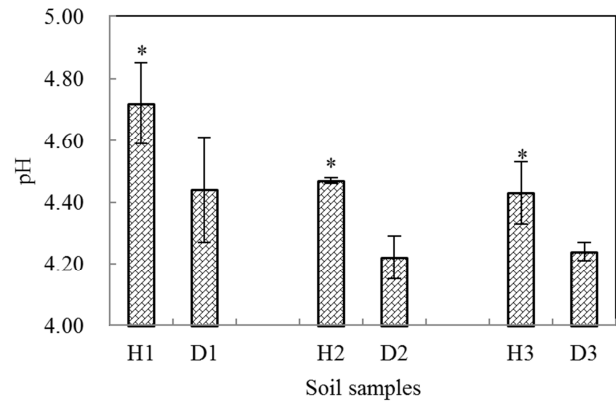


Figure 1. The pH in rhizosphere soils of healthy and diseased plants (* $P < 0.05$).

Table 2. The contents of macro elements in rhizosphere soils of healthy and diseased plants.

Sample plots	Samples	AN (mg·kg ⁻¹)	AP (mg·kg ⁻¹)	AK (mg·kg ⁻¹)
S1	H1	76.99±1.70 a	35.18±2.50 b	99.76±7.71 b
	D1	72.95±0.96 b	59.85±4.21 a	127.1±12.1 a
S2	H2	80.85±1.46 a	71.38±0.70 b	159.6±32.2 b
	D2	75.43±2.39 b	74.18±1.04 a	254.9±18.0 a
S3	H3	111.5±7.04 a	20.74±2.93 b	219.8±0.93 b
	D3	92.85±4.78 b	33.63±3.89 a	235.7±4.80 a

AN, Alkaline hydrolysis nitrogen; AP, Available phosphorus; AK, Available potassium. H, healthy rhizosphere soil; D, diseased rhizosphere soil. Values are the mean \pm standard error (n = 3). Values with different lowercase letters in each column are significantly different at $P < 0.05$.

Table 3. The contents of medium elements in rhizosphere soils from healthy and diseased plants.

Sample plots	Samples	Ca (mg·kg ⁻¹)	Mg (mg·kg ⁻¹)	AS (mg·kg ⁻¹)
S1	H1	151.7±33.4 b	33.47±1.86 a	0.28±0.02 a
	D1	301.7±36.6 a	25.80±2.46 b	0.22±0.02 b
S2	H2	287.7±16.1 b	24.70±3.49 a	0.26±0.02 a
	D2	345.3±9.49 a	14.27±1.60 b	0.18±0.02 b
S3	H3	163.1±19.1 b	22.80±1.35 a	0.61±0.06 a
	D3	329.2±61.3 a	17.33±0.25 b	0.41±0.03 b

Ca, Exchangeable calcium; Mg, Exchangeable magnesium; AS, Available sulfur. H, healthy rhizosphere soil; D, diseased rhizosphere soil. Values are the mean \pm standard error (n = 3). Values with different lowercase letters in each column are significantly different at $P < 0.05$.

The available state of micro elements is the part that can be directly absorbed and utilized by plants, which has a direct effect on improving crop yield and quality. It can be seen from Figure 2 to Figure 5 that the occurrence of TYLCVD in the three plots was correlated with the contents of available Mn, available Zn, available Cu and available Si in the rhizosphere soil, which showed that healthy plants were significantly higher than diseased plants. And the contents of available Mn, available Zn, available Cu and available Si in

rhizosphere soil of healthy plants were 6.95%–10.1%, 13.6%–15.2%, 10.6%–25.0% and 4.97%–8.35%, respectively, higher than those of diseased plants. However, there were no obviously differences in the contents of available B and available Fe in rhizosphere soil between healthy plants and diseased plants (Table 4).

The above results suggested the need for regional soil testing and formulated fertilization techniques to avoid aggravating soil acidification and quality degradation due

to some nutrient excess or some nutrient deficiency in future fertilization practices, thus resulting in a decline in plant immunity and susceptible to diseases and insect pests.

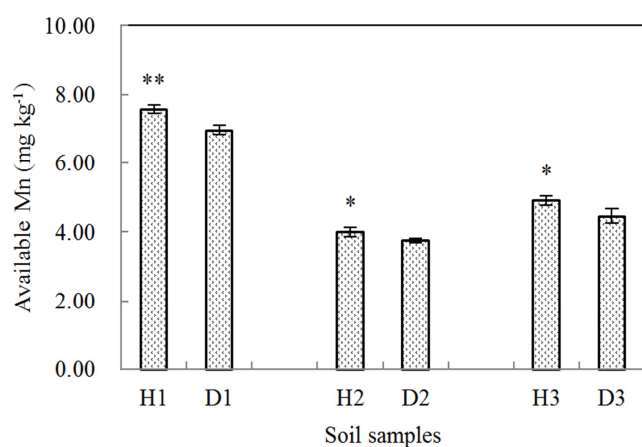


Figure 2. The contents of available Mn in rhizosphere soils of healthy and diseased plants (* $P < 0.05$; ** $P < 0.01$).

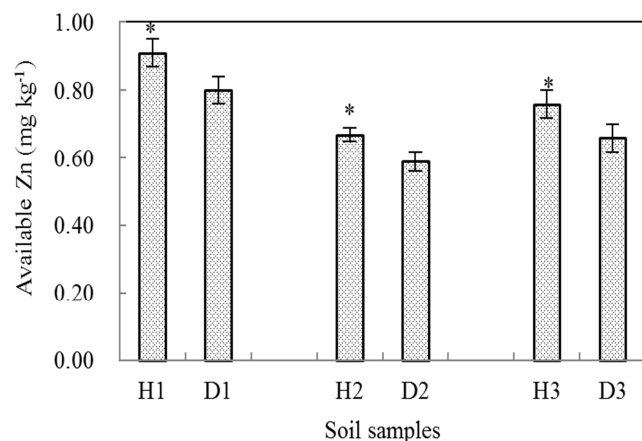


Figure 3. The contents of available Zn in rhizosphere soils of healthy and diseased plants (* $P < 0.05$).

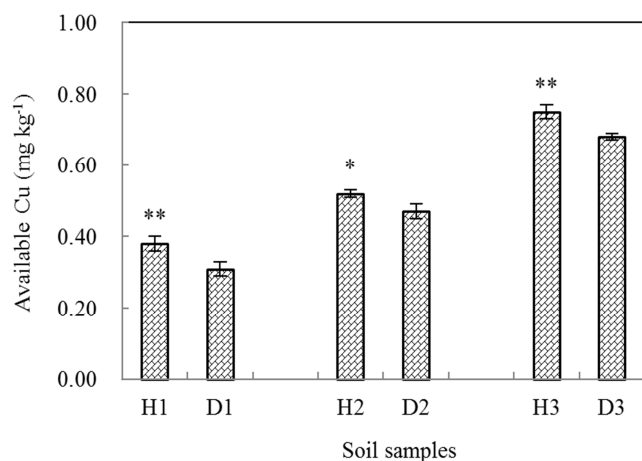


Figure 4. The contents of available Cu in rhizosphere soils of healthy and diseased plants (* $P < 0.05$; ** $P < 0.01$).

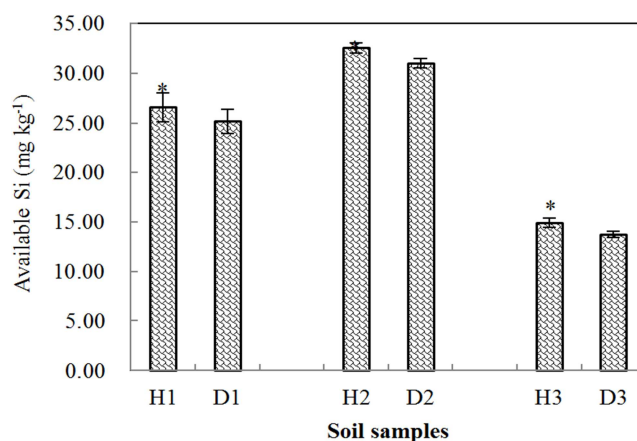


Figure 5. The contents of available Si in rhizosphere soils of healthy and diseased plants (* $P < 0.05$).

Table 4. The contents of available Fe and B in rhizosphere soils from healthy and diseased plants.

Sample plots	Samples	Fe (mg·kg ⁻¹)	B (mg·kg ⁻¹)
S1	H1	16.1±0.05 a	0.15±0.01 a
	D1	15.9±0.37 a	0.16±0.01 a
S2	H2	8.43±0.29 a	0.14±0.02 a
	D2	8.26±0.02 a	0.14±0.01 a
S3	H3	29.1±4.33 a	0.11±0.01 a
	D3	24.6±0.65 a	0.10±0.01 a

Fe, Available iron; B, Available boron. H, healthy rhizosphere soil; D, diseased rhizosphere soil. Values are the mean \pm standard error ($n = 3$). Values with different lowercase letters in each column are significantly different at $P < 0.05$.

3.2. Response of Soil Enzyme Activity to Tomato Yellow Leaf Curl Virus Disease

The enzymes play a very important role in nutrient cycling of soil ecosystem, known as "biocatalysts", which participate in almost all biochemical reactions in soil [7]. Many studies have shown that soil enzymes are involved in all the relevant biochemical reactions in soil, and the transformation of soil nutrient elements, formation of organic matter, degradation of crop residues, soil nutrient cycling and soil fertility maintenance are all inseparable from the action of soil enzymes [8-10]. Soil urease is involved in hydrolysis of urea, and its activity reflects the intensity of nitrogen metabolism and nitrogen conversion in soil and the supplying capacity of soil inorganic nitrogen [11]. As can be seen from Figure 6, compared with healthy plants, the urease activities in rhizosphere soil of diseased plants were significantly decreased in the three study plots ($p < 0.05$), and decreased by 77.4%, 51.6% and 48.6%, respectively. The decrease of urease activity may be caused by the secretion of certain substances that inhibit urease activity by the roots of infected plants, or it may be caused by the weak root activity of diseased plants, which affects microbial activities, resulting in the symptoms of malnutrition such as short stature and deformity of infected plants.

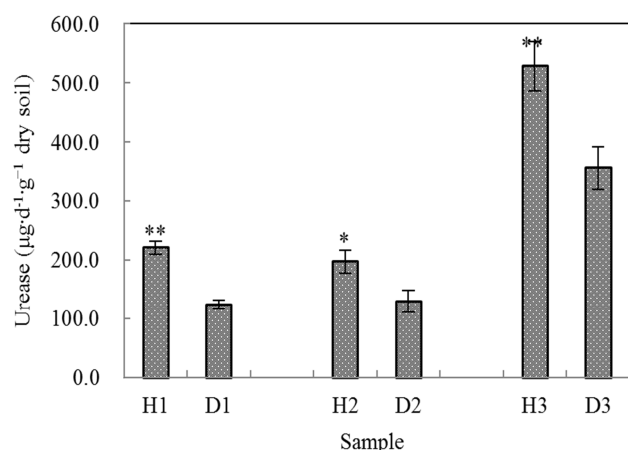


Figure 6. The urease activity in rhizosphere soils of healthy and diseased plants (* $P < 0.05$; ** $P < 0.01$).

Soil phosphatase can enzymatically decompose various organophosphorus compounds and provide effective phosphorus for plant growth. The activity of Soil phosphatase can characterize soil fertility, especially phosphorus status [12]. Figure 7 showed that the activities of acid phosphatase in rhizosphere soil of the diseased plants were decreased significantly in three study plots ($p < 0.05$). Compared with healthy plants, the activities of acid phosphatase were reduced by 19.1%, 31.0% and 20.3%, respectively.

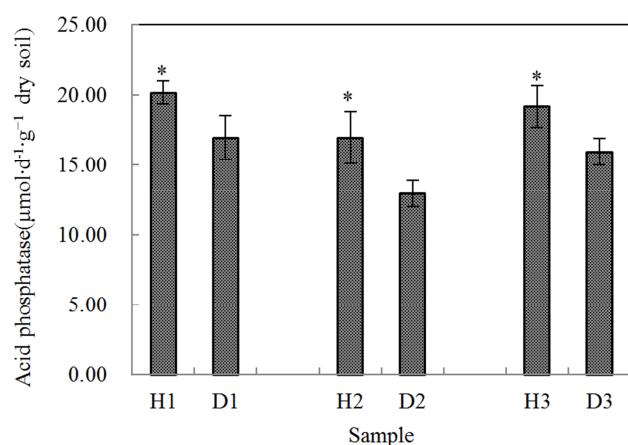


Figure 7. The activity of acid phosphatase in rhizosphere soils of healthy and diseased plants (* $P < 0.05$).

Soil catalase is a kind of redox reductase. It can quickly transform waste generated by soil metabolism into harmless or less toxic substances, and release oxygen at the same time, so as to reduce the toxicity of excessive accumulation of hydrogen peroxide to soil microorganisms and plant roots [13-15]. Figure 8 showed that the catalase activities in rhizosphere soil of diseased plants were significantly reduced in the three plots ($p < 0.05$), which was 43.8%, 39.1% and 23.7% lower than those of healthy plants, respectively. The reducing of soil enzyme activities signified the decrease of soil biological activity, which can weaken plant resistance.

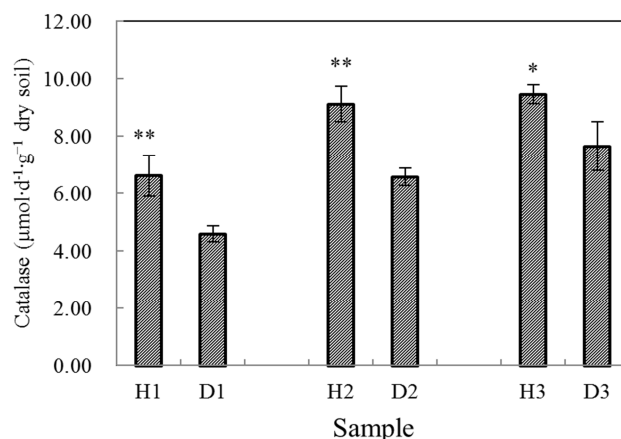


Figure 8. The activity of catalase in rhizosphere soils of healthy and diseased plants (* $P < 0.05$; ** $P < 0.01$).

4. Conclusion

The occurrence of TYLCVD was related to the enzyme activities, pH value, macro elements N, P, K, medium elements Ca, Mg, S and micro elements Mn, Zn, Cu, Si in the rhizosphere soil of cherry tomato. The pH value, contents of AN, available Mg, available S, available Mn, available Zn, available Cu and available Si in rhizosphere soil of diseased plants were significantly lower than those in healthy plants, while the contents of available P, available K and available Ca in rhizosphere soil of diseased plants were significantly higher than those in healthy plants. Indicating that applying of large amount of phosphorus and potassium fertilizer in soil can promote the occurrence of TYLCVD. At the same time, the medium elements of Mg, S and micro elements of Mn, Zn, Cu, and Si should be properly supplemented to improve the resistance of cherry tomato. Our findings improve our understanding of the links between the occurrence of TYLCVD and the soil environment, which have implications for developing strategies for the prevention of tomato yellow leaf curl virus disease.

Acknowledgements

This work was supported by the Hainan Province Science and Technology Special Fund of China [grant number ZDYF2021XDNY137]. We thank anonymous reviewers for their very helpful suggestions. We thank LetPub (www.letpub.com) for linguistic assistance and pre-submission expert review.

References

- [1] Q. Zhu, "Grafting culture technology of cherry tomato in Lingshui County of Hainan province". China Agricultural Technology Extension, 2017, 33 (7), pp. 32-33.
- [2] M. Ding, N. Yue, J. H. Dong, et al., "Genetic diversity of tomato yellow leaf curl China virus associated satellites DNA β infecting *Solanum lycopersicon*". J. Yunnan University, 2008, 30 (S), pp. 63-68.

- [3] A. A. Semikolennykh, "Catalase activity of soils in the northern part of the taiga zone (Arkhangel'sk oblast)". Eurasian soil Sci., 2001, 34 (1), pp. 77–83.
- [4] H. Zhang, H. Yu and W. Ding, "The influence of the long-term application of organic manure and mineral fertilizer on microbial community in calcareous fluvo-aquic soil", Acta Ecologica Sinica, 2011, 31 (12), pp. 3308-3314.
- [5] R. I. Griffiths, A. S. Whiteley, A. G. O'Donnell, et al., "Influence of depth and sampling time on bacterial community structure in an upland grassland soil," FEMS Microbiol Ecol, 2003, 43, pp. 35-43.
- [6] R. Lu, "Analytical Methods for Soil and Agricultural Chemistry". China Agricultural Science and Technology Press, Beijing. 1999.
- [7] Y. Lin, J. Hao, W. Ding, et al., "Effects of different tillage measures on soil microbial biomass", Acta Agriculturae Boreali-occidentalis Sinica, 2019, 28 (4), pp. 620-630.
- [8] P. Wu, Y. Wang, K. Yang, et al., "Effects of different nitrogen form and ratios on yield of maize and soil nutrient and enzymatic activity", Soil and Fertilizer Sci. in China, 2018, (05), pp. 24-32.
- [9] L. Zhou, Z. Zhou and C. Cao, "On the role of the totality of soil enzyme activities in the evaluation of the level of soil fertility", Acta Pedologica Sinica, 1983, (4), pp. 413-418.
- [10] L. Shiyin, N. Lixiao, P. Panyang, et al., "Effects of pesticides and their hydrolysates on catalase activity in soil", B. Environ. Contam. Tox., 2004, 72 (3), pp. 600-606.
- [11] Z. Nie, S. Qin, H. Liu, et al. " Effects of combined application of nitrogen and zinc on winter wheat yield and soil enzyme activities related to nitrogen transformation", J. Plant Nutrition and Fertilizers, 2020, 6 (3), pp. 431-441.
- [12] S. Kromer, D. M. Green, "Acid and alkaline phosphatase dynamics and their relationship to soil microclimate in a semiarid woodland", Soil Biology & Biochemistry, 2000, 32, pp. 179-188.
- [13] Z. Gao, D. Wang, L. Niu, et al., Catalase Activities in Salinized Rehabilitation Area of the Southern Hebei Plain, Chinese Journal of Soil Science, 2019, 50 (6), pp. 1434-1441.
- [14] X. Hu, Y. Jiang, Y. Shu, et al., "Effects of mining wastewater discharges on heavy metal pollution and soil enzyme activity of the paddy fields", Journal of Geochemical Exploration, 2014, 147, pp. 139-150.
- [15] Y. Yu, L. Li, L. Yu, et al., "Effect of exposure to decabromodiphenyl ether and tetrabromobisphenol A in combination with lead and cadmium on soil enzyme activity", International Biodeterioration & Biodegradation, 2017, 117, pp. 45-51.