Advanced Materials Research *Online: 2012-12-13*
ISSN: 1662-8985, Vols. 610-613, pp 138-143
doi:10.4028/www.scientific.net/AMR.610-613.138

Fermentation Production of EM Active Calcium and Its Performance for the Prevention on Blossom-end Rot In Facility Tomato Cultivation

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Keywords: fermentation production, EM active calcium, prevention, tomato, blossom-end rot.

Abstract. The blossom-end rot (BER) induced by calcium deficiency will cause a great impact on tomato yield and quality. Aimed at the tomato physical barriers caused by calcium deficiency, the composite micro-organisms (EM) fermentation technology was applied to configure biological active calcium preparations of different calcium concentrations, with raw materials of calcium sulfate, lime and gypsum. The active calcium preparation with calcium concentration of 1 ‰ was sprayed on the fruits during the fruit development period in the field experiment. The results show that lime with highest solubility is the best raw material for the fermentation of EM active calcium preparations with the consideration of higher calcium concentration, reasonable pH and EC value, and the lowest cost. It also shows the incidence of blossom-end rot of the experimental group is 35.36 % lower than that of CK.

Introduction

In recent years, the planting, processing and exporting of tomatoes in China have been in a continuous increasing trend. China has the third largest producing region following the EU, the United States, and is the first largest exporter. Therefore China is the most important producer and exporter of tomato products in the world [1]. Tomato is a calcium addicted vegetable crop with high sensitivity to calcium nutrition [2,3]. In the tomato cultivation, the blossom-end rot is the most serious disease among the physiological diseases, which seriously affects the quality and the quantity of the tomatoes [4,5]. Nowadays, the blossom-end rot is increasingly severe, this disease usually cuts tomato production by 40% -50%, in some severe years, it even cuts the production by more than 60%. The blossom-end rot is difficult to control and it has become a major problem in tomato production [6]. The recent researches on the blossom-end rot show that the calcium deficiency is one of the direct causes of tomato blossom-end rot [7,8].

The shortcomings of today's agricultural production in the preparation of calcium are that the solubility of inorganic calcium is low and is easily be precipitated in the environment, and can hardly be absorbed by plants, making it difficult to meet the calcium needs of plants. Organic chelating or complexing calcium preparations can enhance the activity and the supply speed of the calcium, but it costs too much, and is difficult to promote the application in agricultural production [9,10]. In recent years, EM technology is used in the cultivated tomato plants for enhancing the ability of resistance to disease, reducing soil-borne diseases and increasing production [11,12].

EM (Effective Microorganisms) is made up of 10 species and more than 80 kinds of microorganisms, including yeast, lactic acid bacteria, actinomycetes, photosynthetic bacteria，which forms an effective microorganisms viable group [13]. In this paper, the EM technology for the fermentation test of EM active calcium was adopted, meanwhile, the effects of EM active calcium for the prevention on blossom-end rot in facility tomato cultivation was studied.

Materials and Methods

Fermentation production of EM Active Calcium

EM active calcium was fermented by Effective Microorganisms (EM), molasses, deionized water and calcium contained substances. Calcium contained substances included calcium sulfate (analytical reagent), lime (Construction materials), gypsum ($CaSO_4 \cdot 2H_2O$). 2.0% Ca^{2+} suspending liquids were prepared with three calcium contained substances and deionized water. The proportion of different materials in fermentation test of EM active calcium was presented in Table 1 Control treatment (CK) was fermented without EM. The materials for EM active calcium production were fermented by thermostatic shaking (QHZ-98A) under the condition of 37°C and 150 r/min.

The dissolution processes of precipitates in various treatments were observed. The pH, EC and Ca^{2+} concentration were determined during the experiment.

Table 1 Proportion of different materials in fermentation test of EM active calcium

Treatment	2% Ca^{2+} suspending liquid [ml]	EM [ml]	Molasses [ml]	Deionized water [ml]	The calcium content [‰]
1	30.0	15.0	15.0	240.0	2.0
2	27.0	15.0	12.0	246.0	1.8
3	24.0	12.0	12.0	252.0	1.6
4	21.0	12.0	9.0	258.0	1.4
5	18.0	9.0	9.0	264.0	1.2
6	15.0	9.0	6.0	270.0	1.0

Field experiments

The variety of tomato tested was the Century Red-crowned. The experiments were divided into the experimental group and blank control group (CK), and each group included 2 repetitions. During the fruit development period, 1 ‰ Ca^{2+} of EM active calcium was sprayed on the fruits every seven days [14,15], three times in total. CK was treated with water, instead of the EM active calcium.

Determination methods and determination of indicators

The pH and EC values

After 24 hours of fermentation, the pH and EC values of each treatment were measured every day at the same time (10:00 am) by the pH meter (FE20) and the conductivity meter (FE30).

Ca^{2+} concentration

The calcium concentration of EM active calcium was measured by Atomic Absorption Spectrometry (AAS-700 atomic absorption spectrometer).

Single fruit weight, maturation rate and incidence of blossom-end rot

The single fruit weight of tomato under different treatments was calculated by the total fruit weight and fruit number.

The maturation rate:

$$R_m = N_m / N_t \tag{1}$$

The incidence of blossom-end rot:

$$R_i = N_i / N_t \quad (2)$$

Where, R_m was the maturation rate, N_m was the number of matured fruits, N_t was the number of total fruits; R_i was the incidence of Blossom-end rot, N_i was the fruit number with Blossom-end rot.

Results and Discussions

Variation of pH during the process of fermentation

The pH value during the process of fermentation showed a decrease tendency among different treatments (Table 2). The pH of Calcium Sulfate Group tended to be stable at 3.15-3.18 after the 6th day. The pH of Lime Group tended to be stable at 3.40-3.45 after the 6th day. The pH of Gypsum Group tended to be stable at 3.19-3.21 after the 5th day. The pH value of the Lime Group was more desirable among all treatments.

Table 2 Variation of pH during the process of fermentation

Material	Group	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
Calcium Sulfate	1-1	3.76	3.44	3.34	3.22	3.20	3.16	3.15
	1-2	3.75	3.43	3.33	3.23	3.19	3.16	3.15
	1-3	3.81	3.44	3.34	3.24	3.20	3.19	3.16
	1-4	3.78	3.47	3.33	3.24	3.19	3.18	3.17
	1-5	3.82	3.46	3.35	3.24	3.19	3.17	3.17
	1-6	3.81	3.47	3.34	3.24	3.19	3.18	3.18
Lime	2-1	4.39	3.75	3.59	3.50	3.44	3.41	3.40
	2-2	4.30	3.76	3.62	3.50	3.45	3.43	3.43
	2-3	4.38	3.76	3.61	3.49	3.43	3.42	3.42
	2-4	4.35	3.76	3.61	3.49	3.44	3.43	3.43
	2-5	4.49	3.75	3.60	3.49	3.44	3.42	3.42
	2-6	4.56	3.78	3.64	3.52	3.47	3.45	3.45
Gypsum	3-1	3.92	3.50	3.38	3.28	3.22	3.21	3.21
	3-2	3.89	3.50	3.37	3.27	3.22	3.20	3.20
	3-3	3.86	3.48	3.36	3.26	3.20	3.19	3.19
	3-4	3.85	3.48	3.35	3.27	3.21	3.20	3.20
	3-5	3.89	3.49	3.33	3.26	3.20	3.19	3.19
	3-6	3.83	3.46	3.58	3.25	3.35	3.19	3.19

Variation of EC during the process of fermentation

As was displayed in Table 3, the EC decreased with the reduction of Ca^{2+} concentration in different treatments. The EC of different treatments increased at first and decreased subsequently as a whole during the process of fermentation. The tested data showed that: EC of 2.0 ‰ Ca^{2+} Lime Group was 4.4% lower than the 2.0 ‰ Ca^{2+} Calcium Sulfate Group, and 8.2% lower than 2.0 ‰ Ca^{2+} Gypsum Group, respectively; EC of 1.6 ‰ Ca^{2+} Lime Group was 13.2% lower than the 1.6 ‰ Ca^{2+} Calcium Sulfate Group, and 7.9% lower than 1.6 ‰ Ca^{2+}Gypsum Group, respectively; EC of 1.0 ‰ Ca^{2+} Lime Group was 6.7% lower than the 1.0 ‰ Ca^{2+} Calcium Sulfate Group, and 2.3% higher than the 1.0 ‰ Ca^{2+} Gypsum Group, respectively.

Table 3 Variation of EC [ms/cm] during the process of fermentation

Material	Group	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
Calcium Sulfate	1-1	9.31	9.74	9.58	9.55	9.49	9.62	9.58
	1-2	8.57	8.62	8.63	8.67	8.45	8.68	8.66
	1-3	8.75	8.91	8.82	8.71	8.78	8.75	8.99
	1-4	7.23	7.09	7.31	6.86	7.06	7.07	7.19
	1-5	7.92	7.98	7.88	7.87	8.02	7.66	7.99
	1-6	5.98	5.96	6.05	6.06	5.97	6.02	6.13
Lime	2-1	9.56	9.28	9.24	9.13	9.15	9.06	9.16
	2-2	7.94	8.12	8.28	8.59	8.18	8.08	8.38
	2-3	7.69	7.70	7.85	7.92	7.76	7.56	7.80
	2-4	7.09	7.32	7.26	7.27	7.35	7.14	7.22
	2-5	6.56	6.45	6.63	6.59	6.56	6.45	6.68
	2-6	5.45	5.56	5.67	5.63	5.51	5.57	5.72
Gypsum	3-1	9.90	9.98	10.22	9.74	9.65	9.66	9.98
	3-2	8.62	8.86	8.97	8.73	8.65	8.63	8.77
	3-3	8.52	8.57	8.98	8.71	8.20	8.33	8.47
	3-4	6.64	6.86	6.98	6.82	7.07	7.33	7.45
	3-5	7.14	7.17	7.54	7.50	7.35	7.28	7.40
	3-6	5.33	5.51	5.68	5.37	5.42	5.49	5.59

Dissolved precipitation during the process of fermentation

Most precipitation of Lime Group was dissolved at 3 days after fermented. The precipitation of 1.4‰ Ca^{2+} Gypsum Group was all dissolved after 6 days, and the same with the Lime Group. The precipitation of other treatments including control treatments changed little during the process of fermentation. The experimental results showed that lime was the suitable material for the production of EM active calcium on account of high solubility and low cost.

Ca^{2+} concentration of EM active calcium

From Table 4, the results could be obtained that the highest solubility of Ca^{2+} was found in the treatment of 1.0 ‰ Ca^{2+} concentration.

Table 4 The Ca^{2+} concentration of EM active calcium

Treatment	Configuration Ca^{2+} concentrations	Measuring Ca^{2+} concentrations	Solubility
Lime Group	1.0‰	0.71‰	71.0%
	1.2‰	0.79‰	65.8%
	1.8‰	0.95‰	52.8%
	2.0‰	1.03‰	51.5%
Gypsum Group	1.4‰	0.81‰	57.9%

Prevention of blossom-end rot and yield of tomato with EM active calcium application

It was shown in Table 5 that the single fruit weight of the experimental group was 28.59 % higher than that of the blank group. The maturation rate of the experimental group was 18.53 % higher than that of CK, and the incidence of blossom-end rot of the experimental group was 35.36 % lower than that of CK.

The results showed that spraying the EM active calcium on tomato fruits during the fruit development period could promote the tomato growth and prevent the blossom-end rot effectively.

Table 5 Single fruit weight, maturation rate and incidence of blossom-end rot in different treatment

Treatment	Single fruit weight [g]	Maturation rate [%]	Incidence of Blossom-end rot [%]
Experimental Group	186.43	48.96	8.33
CK	144.98	30.43	17.39

Conclusions

The experimental results showed that lime was the suitable material for the production of EM active calcium due to good solubility and low cost.

The pH during the process of fermentation showed a decrease tendency among different treatments. The pH of Lime Group tended to be stable at 3.40-3.45 after the 6^{th} day and the Lime Group was more desirable among all treatments.

The precipitation of the Lime Group and 1.4‰ Ca^{2+} Gypsum Group were all dissolved after 6^{th} days. The precipitation of other treatments including control treatments was not change during the process of fermentation.

The field experiment showed that spraying the active calcium on tomato fruits during the fruit development period could promote tomato growth and prevent the blossom-end rot. The incidence of blossom-end rot of the experimental group was 35.36 % lower than CK.

Acknowledgements

This work was financed by the National Natural Science Foundation of China(51179054), the National Technology Support Project (2012BAB03B03), the Priority Academic Program Development of Jiangsu Higher Education Institutions（PAPD） and the Special Fund for the Scientific Research of the Agricultural Welfare Project（200903001-05).

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