Trends in Horticulture (2020) Volume 3 Issue 1
doi:10.24294/th.v3i1.1790

ORIGINAL RESEARCH ARTICLE

The impact of 1-MCP on growth and yield of cucumber in open field

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ABSTRACT

In order to explore the preliminary effect of 1-MCP application at seedling stage on the growth effect and yield of open field cucumber, this experiment conducted cultivation experiments on three application periods (leaf spraying at one leaf stage, 2 days before planting, spraying after the third harvest), two treatment times (one treatment, two treatment), and two management methods (removing the first and second female flowers, and conventional management). The results showed that in the open field cucumber cultivation experiment, the application of 1-MCP at seedling stage could promote the growth of cucumber, and the T4 treatment was the best, and the second treatment was better than the first treatment; T4 (0.35 mL 1-MCP + treatment 2 days before colonization + after the third harvest + routine management) treatment scheme had the best effect.

Keywords: Cucumber; 1-MCP; Growth; Yield

ARTICLE INFO

Received: 13 September 2020
Accepted: 23 October 2020
Available online: 8 November 2020

1. Introduction

As an ethylene inhibitor, 1-MCP can block the ethylene synthesis pathway and inhibit the physiological effect of ethylene on ripening. It has been widely used as a new fruit and vegetable preservative in post-harvest treatment. In addition, 1-MCP also has different effects on physiological activities of fruits and vegetables. 1-MCP has effects on ethylene, respiration, nutritional components, fruit hardness, color, diseases, etc. of fruits and vegetables[1]. The purpose of this study is to explore whether this effect of 1-MCP can run through the whole growth cycle of fruits and vegetables and what kind of impact it will have. 1-MCP is selected to be applied to the seedling stage of open field cucumber to study the impact of 1-MCP on the growth, development and yield of open field cucumber. The effect of 1-MCP on yield is urgently needed to prove the application effect of 1-MCP in vegetable cultivation, and then speculate on the mechanism of 1-MCP application in seedling stage, and expand the application of 1-MCP.

2. Materials and methods

2.1 Test materials

1-MCP: the tested product AF-701 (1-MCP with active ingredient of 1.3%) is from Dow Chemical Company, cucumber: ‘Shengyou’.

2.2 Test method

A total of 7 treatments (T1, T2, T3, T4, T5, CK1, CK2) are set for the open ground test. The treatment arrangement is shown in **Table 1**. Test design: completely randomized block design, the specification of

cultivation ridge is 9 m × 14 m, double row planting, row spacing of 140 cm, plant spacing of 40 cm, 45 plants in each treatment, repeated for 6 times. According to the determined planting time, each treatment is treated according to this time. According to the actual cultivation situation, each treatment is treated with 7 plug seedlings, and the dosage is calculated according to the effective concentration of product 1-MCP.

Table 1. Treatment detail of cucumber in open field

Handle serial number	Handle	Dose/ml	Application period	Management style
T1	1-MCP	0.35	One leaf stage foliar application	General management
T2	1-MCP	0.35	Spraying after the third harvest	General management
T3	1-MCP	0.35	2 days before planting	General management
T4	1-MCP	0.35	2 days before planting + after the third harvest	General management
T5	1-MCP	0.35	Foliar spraying 2 days before planting	Do not remove the first and second female flowers
CK1	Contrast	0		General management
CK2	Contrast	0		Do not remove the first and second female flowers

2.3 Determination items and methods

2.3.1 Statistical method of plant relative growth

The growth of the control treatment was taken as 100%, and the percentage of each treatment compared with the control was taken as the relative growth.

2.3.2 Statistical method of female flower flowering time

Statistics on the flowering time of the first, second and third female flowers were made, and the flowering time of 50% of the plants in each plot was taken as the flowering time.

2.3.3 Determination method of morphological index

To determine the morphological indexes, five healthy cucumber plants should be randomly selected from each plot. During the test cycle, the morphological indexes of these five plants should be accurately collected and measured at a time interval of 15 days. The morphological indexes of each plant should be measured at 0, 15, 30 and 45 days after planting.

2.3.4 Determination method of cucumber plant height

Measure the height from the first true leaf of the plant to the plant growth point with a tape measure, and calculate the relative growth rate of plant height with equation 1

$$V = (\ln L_2 - \ln L_1)/(T_2 - T_1) \quad (1)$$

In equation 1, V is the relative growth rate of plant height, T_1 and T_2 are the sampling time, and L_1 and L_2 are the plant height measured twice

2.3.5 Determination method of cucumber stem diameter

The diameter of stem base was measured with vernier caliper as the stem diameter of cucumber plant, and the net growth of stem diameter was calculated with equation 2

$$H = H_2 - H_1 \quad (2)$$

In equation 2, H is the net growth of cucumber stem diameter, and H_1 and H_2 are the stem diameters of cucumber plants measured twice respectively.

2.3.6 Determination method of chlorophyll content in cucumber leaves

The chlorophyll content of cucumber leaves was determined by SPAD-502plus produced by Minolta company of Japan[1]. The average value of three leaves per plant was calculated after being measured respectively and expressed by SPAD value.

2.3.7 Determination of cucumber fruit quality

The organic acid content of fruit was determined by acid-base titration[2], the soluble protein was determined by Coomassie brilliant blue G-250[2], the vitamin C content was determined by 2,6-dichlorophenol indophenol method[2], and the nitrate

nitrogen content was determined by salicylic acid colorimetry[2].

2.3.8 Determination of cucumber yield

Economic yield: record the number, yield and single fruit weight of fruits in each plot at each harvest, and finally calculate the total yield[3,4].

2.4 Data analysis

Excel 2016 software and SPSS 19.0 software were used for data statistical analysis.

3. Results and analysis

3.1 Effects of different 1-MCP treatments on the growth of open field cucumber plants

It can be seen from **Figure 1** that at 14 days of colonization, T1, T2 and T3 showed significant differences with CK1 in plant growth, and the plant growth was lower than that of the control group. At the second female flower opening, T1 and CK1 showed significant differences, the plant growth was lower than that of the control group, T5 and CK2 showed significant differences, and the plant growth was higher than that of the control group. At the first harvest, T1 and CK1 showed significant differences, and the plant growth was still lower than that of the control group.

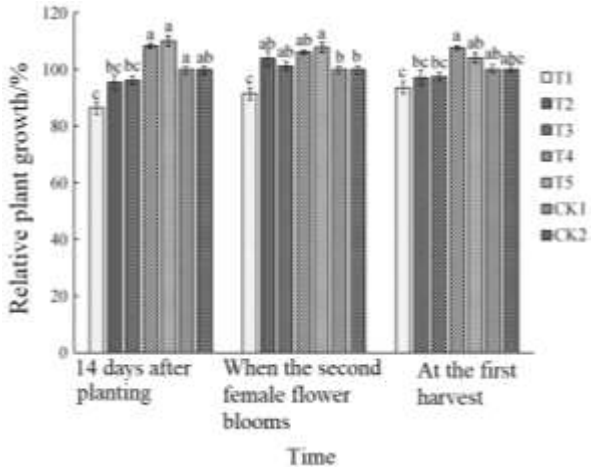

Figure 1. Effects of different 1-MCP treatments on the growth of cucumber in open field.

3.2 Effects of different 1-MCP treatments on flowering date of female flowers of open field cucumber

It can be seen from **Table 2** that the flowering date interval of the first three female flowers of each treatment is 0–2 days. T3 and T4 are one day earlier than CK1, and T5 is one day earlier than CK2.

Table 2. Effects of different 1-MCP treatments of date of female flowering of cucumber in open field

Handle	Female flower flowering date (month/day)		
	First	Second	Third
T1	5/5	5/9	5/13
	5/6	5/10	5/13
	5/5	5/10	5/14
T2	5/6	5/11	5/13
	5/5	5/11	5/13
	5/6	5/10	5/13
T3	5/4	5/10	5/13
	5/5	5/10	5/14
	5/4	5/9	5/13
T4	5/5	5/11	5/13
	5/4	5/10	5/13
	5/4	5/9	5/14
T5	5/5	5/11	5/14
	5/4	5/9	5/13
	5/5	5/11	5/14
CK1	5/5	5/11	5/14
	5/6	5/10	5/13
	5/6	5/10	5/14
CK2	5/6	5/10	5/13
	5/5	5/11	5/14
	5/6	5/11	5/14

3.3 Effects of different 1-MCP treatments on relative growth rate of plant height of open field cucumber

It can be seen from **Table 3** that there is no significant difference in the relative growth rate of plant height between each treatment group and the control group after 15 days of planting. After 30 days of planting, T4 and CK1 show significant difference, which is 23.72% higher than CK1. After 45 days of planting, T4 and CK1 show significant difference, which is 32.25% lower than CK1.

3.4 Effects of different 1-MCP Treatments on net growth of stem diameter of open field cucumber

It can be seen from **Table 4** that the effect of 1-MCP on the net increase of stem diameter of open field cucumber can be shown only 30 days after planting, but the effect weakens or even disappears after 45 days T3 and T4 showed significant difference 15 days after colonization, T2 and T4 showed significant difference 30 days after colonization, and there was no significant difference among the treatments 45 days after colonization.

Table 3. Effects of 1-MCP on relative growth rate of plant height of cucumber in open field

Handle	Relative growth rate of plant height		
	15 d after planting	30 d after planting	45 d after planting
T1	0.0583 ± 0.0028 a	0.0301 ± 0.0021 bc	0.0292 ± 0.0025 a
T2	0.0614 ± 0.0035 a	0.0294 ± 0.0026 c	0.0271 ± 0.0016 a
T3	0.0628 ± 0.0041 a	0.0366 ± 0.0031 ab	0.0257 ± 0.0014 ab
T4	0.0618 ± 0.0034 a	0.0386 ± 0.0031 a	0.0208 ± 0.0012 b
T5	0.0563 ± 0.0029 a	0.0303 ± 0.0016 bc	0.0280 ± 0.0027 a
CK1	0.0598 ± 0.0028 a	0.0312 ± 0.0019 bc	0.0307 ± 0.0020 a
CK2	0.0593 ± 0.0025 a	0.0327 ± 0.0020 abc	0.0297 ± 0.0012 a

Different lowercase letters after the same column indicate that there are significant differences among the treatments ($P < 0.05$), the same as below.

Table 4. Effects of 1-MCP on net increment of stem diameter of cucumber plant in open field

Handle	Stem diameter increase/cm		
	15 d after planting	30 d after planting	45 d after planting
T1	0.9847 ± 0.1067 ab	0.6940 ± 0.1647 b	0.9507 ± 0.174 a
T2	0.9967 ± 0.1962 ab	1.1260 ± 0.0869 a	0.7333 ± 0.1225 a
T3	0.7347 ± 0.1096 b	1.0047 ± 0.1819 ab	0.6980 ± 0.2114 a
T4	1.3787 ± 0.1492 a	0.5953 ± 0.1248 b	0.7280 ± 0.1036 a
T5	0.9227 ± 0.2203 ab	0.8593 ± 0.0734 ab	0.7400 ± 0.2329 a
CK1	1.1967 ± 0.1321 ab	0.8073 ± 0.0803 ab	1.0327 ± 0.1486 a
CK2	1.1000 ± 0.0823 ab	0.6027 ± 0.1620 b	0.7327 ± 0.1009 a

3.5 Effects of different 1-MCP Treatments on chlorophyll content of open field cucumber

It can be seen from **Figure 2** that the chlorophyll content of T1 was significantly higher than that of T3 15 days after planting. At 30 and 45 days after planting, there was no significant difference among the treatments, but the chlorophyll content of T3 was always the lowest 30 days after planting, T2 was just treated, and its chlorophyll content reached the maximum among the treatments, increased by 8.17% compared with CK1. T4 has been treated twice, but its chlorophyll content has not shown a significant difference with CK1 and has been lower than CK1.

3.6 Effects of different 1-MCP Treatments on nutritional quality of open field cucumber

It can be seen from **Table 5** that the content of vitamin C in T1 and T2 is significantly different from that in CK1, which is reduced by 18.33% and 18.81% respectively compared with CK1 The nitrate content in T3 treatment group was significantly higher than that in T5 treatment group There was no significant difference in organic acid content and soluble protein content among the treatments.

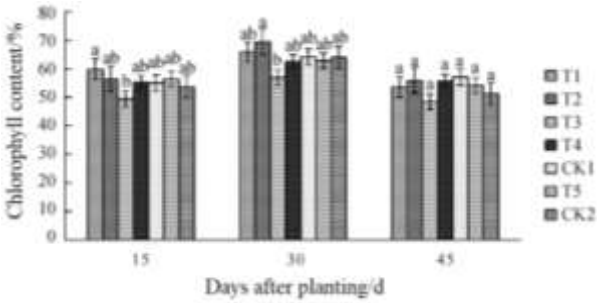

Figure 2. Effects of different treatments on cucumber Chlorophyll content in open field.

3.7 Effects of different 1-MCP Treatments on the yield of open field cucumber

It can be seen from **Table 6** that there is no significant difference among the treatments in terms of the number of fruits per hectare, fruit yield and single fruit weight. However, comparing the values of the treatments, it can be found that the number of fruits and yield of T4 are higher than those of other treatments, while only the number of fruits and yield of T3 are lower than CK1, the number of fruits and yield of T1, T2 and T4 are higher than CK1, and the value of T5 is also higher than CK2.

Table 5. Effects of different treatments on the qualities of the cucumber in open field

Handle	Vitamin C content/(mg/100g FW)	Nitrate content/(μg/g FW)	Organic acid Content/%	Solubility protein/(mg/100g FW)
T1	10.6854 c	271.4545 ab	0.1541 a	11.3610 a
T2	10.6231 c	292.0606 ab	0.1485 a	11.5339 a
T3	13.0841 ab	304.6879 a	0.1686 a	11.2270 a
T4	13.3956 a	250.8485 ab	0.1552 a	11.2054 a
T5	12.6791 b	219.3333 b	0.1485 a	11.3307 a
CK1	13.0841 ab	226.0000 ab	0.1586 a	11.2443 a
CK2	12.9595 ab	255.6970 ab	0.1507 a	11.1232 a

Table 6. Effects of different treatments on cucumber yield in open field

Handle	Quantity/(PCS/hm^2)	Output/(kg/hm^2)	Single fruit weight/g
T1	52,204.5 a	10,712.5 a	0.205 a
T2	53,284.7 a	10,766.3 a	0.202 a
T3	51,388.9 a	10,378.7 a	0.206 a
T4	54,100.5 a	10,847.9 a	0.201 a
T5	50,948.0 a	10,257.6 a	0.201 a
CK1	51,833.0 a	10,565.3 a	0.200 a
CK2	49,823.6 a	10,022.5 a	0.201 a

4. Discussion

In this experiment, the treated cucumber seedlings were cultivated in the open field to observe and record the apparent indexes during the whole growth and development period of cucumber, in order to find out whether 1-MCP can affect the growth and development of open field cucumber and increase the yield of open field cucumber. In terms of plant growth, the T4 treatment scheme is the best, probably because the T4 treatment period is related to the treatment times, and the results of the second treatment also show that the plant growth is better than that of the first treatment. To a certain extent, the flowering date of cucumber is closely related to the yield of cucumber. Cucumber blooms early and has a large early yield, resulting in high profits. 1-MCP treatment can advance the flowering date of cucumber by 1 to 2 days, which has a certain practical significance in the production process[5]. 1-MCP has a position similar to ethylene structure and can bind to ethylene receptor, but it is not easy to peel off from ethylene receptor, thus hindering the reaction of fruit and vegetable tissues to ethylene and delaying the process of ripening and aging[1].In the aspect of relative growth rate of cucumber plant height, 1-MCP treatment could increase the relative growth rate of cucumber plant height in the early growth stage. T4 treatment was the best. The effect of 1-MCP on the relative growth rate of cucumber plant height could not last long. The effect of secondary spraying of 1-MCP was greater than that of primary spraying on the relative growth rate of cucumber plant height in the open field. The effect of the second treatment was better than that of the first treatment. The earlier the treatment, the lower the chlorophyll content. In terms of nutritional quality, the management mode has an impact on fruit quality, which may be related to the volatility of 1-MCP, and the amount of 1-MCP that can be effectively used after treatment is not much. In terms of the effects of different 1-MCP treatments on cucumber yield, 1-MCP treatment can increase cucumber yield, T4 treatment is higher than other treatments, and the yield increase effect is the best 1-MCP can effectively inhibit the emergence of respiratory peak, which may inhibit the binding of ethylene and its receptor in fruits and vegetables, thus isolating the result of respiratory response induced by it[6]. 1-MCP has certain effects on the nutritional components of fruits. Studies on apples[7–9], bananas[10], chestnuts[11] and zucchini[12] show that 1-MCP can delay the reduction of titratable acids and soluble solids, inhibit the transformation and decomposition of starch, and significantly improve the storage quality of fruits.

This study mainly focuses on the observation and analysis of phenotypic indicators. In the next step, we should comprehensively and systematically study the best use concentration and treatment method of 1-MCP for all kinds of fruits and vegetables in each growth period in combination with production practice, and then explore its action mechanism at the physiological, biochemical and even molecular levels in combination with theoretical research, so as to provide a basis for the application of 1-MCP in the horticultural industry[5].

5. Conclusion

The effects of 1-MCP on the growth and yield of open field cucumber were studied. The conclusions are as follows: in the open field cultivation experiment, the T4 treatment scheme is the best, and the second treatment is better than the first treatment. The effect of secondary spraying AF-701 on the relative growth rate of plant height of open field cucumber was greater than that of primary spraying. The effect of secondary treatment on the nutritional quality of open field cucumber was less than that of

primary treatment. The second treatment had the best yield increasing effect, that is, T4 (0.35 mL AF-701 + treatment 2 days before planting + the third post-harvest treatment + routine management) had the best yield increasing effect.

Acknowledgement

This work is supported by National Modern Agricultural Industry System Special Fund Project (CARS-25-C-06)

Conflict of interest

The author declares no conflict of interest.

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