# Effects of nutrient solution irrigation quantity and powdery mildew infection on the growth and physiological parameters of greenhouse cucumbers

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**Abstract:** For important economic crops such as cucumbers, abiotic and biotic stress conditions have had an adverse effect. This study aimed to observe the effects of water stress and powdery mildew stress on cucumber plants. Biotic stress at two levels, B0 (no powdery mildew stress) and B1 (powdery mildew stress) with three fertigation requirement levels (T1: Full fertigation, T2: Moderate nutrient solution deficit, T3: Severe nutrient solution deficit). Therefore, set up six treatments of B0T1, B1T2, B0T3, B1T1, B1T2, and B1T3. Leaf gas-exchange parameter first decreases and then increases under B1T1, B1T2, and B1T2. The leaf gas exchange parameter was significantly decreased under B0T2 and B0T3. Compared to the control experiment (CK, B0T1: no disease infestation and full irrigation), the plant height of cucumber decreased by 7.55%, 10.62%, 15.28%, 23.27%, and 35.16%, respectively, under B0T2, B0T3, B1T1, B1T2 and B1T3; the stem diameter of cucumber decreased by 9.46%, 15.74%, 5.47%, 13.45%, and 23.72%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the leaf area of cucumber decreased by 13.76%, 29.96%, 13.43%, 38.21%, and 66.83%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3. The root-shoot ratio of cucumber was 3.92%, 3.13%, 3.63%, 3.84%, 4.41%, and 3.82%, respectively, under the B0T1, B0T2, B0T3, B1T1, B1T2, and B1T3. Therefore, this study can provide a basis for the research on greenhouse environmental control and cucumber cultivation management.

**Keywords:** greenhouse, cucumber, powdery mildew, nutrient solution, drought stress, growth traits, physiological traits
**DOI:** 10.25165/j.ijabe.20221502.6838

**Citation:** Mao H P, Wang Y F, Yang N, Liu Y, Zhang X D. Effects of nutrient solution irrigation quantity and powdery mildew infection on the growth and physiological parameters of greenhouse cucumbers. Int J Agric & Biol Eng, 2022; 15(2): 68–74.

## 1 Introduction

With the improvement of people's living standards, it is expected that the demand for vegetables will increase many folds in the future[1,2]. In order to solve this problem, facility agriculture has developed rapidly in recent years, which plays a vital role to improve vegetable production[3]. At present, China has the largest greenhouse area in the world[4]. Cucumber, as an important economic crop, is widely cultivated throughout the world. Cucumber has several nutritional values as functional food, possess high antioxidant properties as well as high mineral content[5]. The position in fruit and vegetables is second only to tomato[6]. China is a big producer of cucumbers. Its cultivated area accounts for about 60% of the cultivated area of cucumber in the world, ranking first in both scale and yield[7,8].

**Received date:** 2021-06-16 **Accepted date:** 2022-03-10

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Cucumber grows in a complex environment and is susceptible to stress from the external environment[9]. The stress of cucumber can be roughly divided into two types: abiotic stress (including nutrient deficiency, salt, drought, flooding, heavy metal pollution, and heat stress) and biotic stress (such as viruses, fungi, bacteria, nematodes, and insects)[1,10]. Abiotic and biotic stress will cause the loss of cucumber yield[11]. The increasing combination of continuous and simultaneous pressures with global warming and the resulting climate anomalies is also a cause for concern[12]. Therefore, understanding the response and adaptation mechanism of cucumber plants to different stress combinations is very important for improving production efficiency[3,13].

Some researchers have reported the effects of deficit irrigation on the growth and productivity of vegetables and farmland crops[14,15]. Cucumber plants undergo many adverse physical and chemical changes under drought conditions[16]. Water stress can affect leaf water potential, turgor pressure, cell volume, and stomatal opening[17]. Water stress can affect photosynthetic efficiency. Severe water stress can destroy the photosynthetic mechanism and pigment system of leaves. Water stress can decrease nucleic acid metabolism and protein synthesis of cucumbers, and then affect plant height, stem diameter, and leaf area[18-20]. Compared with drought stress, the effect mechanism of pathogen infection on oxidative metabolism of cucumbers plant was different[21,22]. The most common diseases are bacterial wilt, anthracnose, angular leaf spot, downy mildew, powdery mildew, gummy stem blight, and scab[23]. As a fungal disease, powdery mildew has the characteristics of wide distribution, fast spread, and great harm to cucumber plants [24]. Powdery mildew is a widespread disease of greenhouse and field-grown cucumber plants and it can lead to a significant yield loss[25,26]. Cucumber powdery mildew mainly harms the leaves, but also the petioles and stems, and generally does not harm the fruits. At the initial stage of the disease, white or pink near-circular lesions appear on the leaves or leaf backs. Under suitable conditions, the lesions gradually expand into contiguous lesions with no obvious edges, covered with a white powdery mildew layer, and the infected leaves are yellow, brittle, rolled up, losing photosynthesis, but not easy to fall off. Sometimes there will be scattered or piles of small black spots on the diseased spots; petioles or young leaves are onset, the symptoms are similar to those of leaves, but the amount of white powder is less. The disease develops gradually from the lower part of the plant upward. In the late stage, it may turn grayish brown or reddish brown. In severe cases, the whole leaf is covered with a layer of white powder (mycelium, conidia, and conidia), which will cause the plant to die[27-29]. To sum up, although relevant scholars have conducted a large number of studies on abiotic stress and biotic stress, respectively, there are few reports on the effects of abiotic and biological coupling stresses on crops, and the effects on crops are not clear.

Therefore, in order to explore the effects of coupled abiotic and biotic stresses on crops. The effects of nutrient solution irrigation and powdery mildew infestation on cucumber growth and physiological parameters in greenhouse were studied in this work. This research was conducted to determine the impact of powdery mildew infection and different nutrient solution irrigation levels on the leaf gas-exchange parameters, and to evaluate the combined effect on growth response, crop growth parameters, and material accumulation of greenhouse cucumber. The results of this study can provide guidance for growers, agronomists, and decision-makers to improve cucumber yield and quality.

## 2 Materials and methods

### 2.1 Plant materials and growth conditions

This study was conducted in a Venlo-type greenhouse, Jiangsu University, Zhenjiang, China. The greenhouse is east-west, with a length of 100 m and a width of 40 m, with a shoulder height of 2.4 m and a span of 2.4 m. The average air temperature of the greenhouse was 24.5°C (the range was from 14.57°C to 38.69°C). The relative humidity of the greenhouse was 82.6% RH (the range was from 21.06% to 97.2% RH). On August 24, 2020, cucumber seeds (*Cucumis sativus* L., Jinyou No. 1) were sown in plugs. Cucumber seedlings with three leaves were transplanted into plastic pots (10 L, perlite was used as the culture substrate) on August 31, 2020. The planting density was maintained at 5.54 plants/m$^2$. Cucumber plants were harvested at the flowering stage on September 27, 2020. Before inoculating cucumber powdery mildew spores, the same amount of sufficient fertilizer was used. The components of the standard nutrient solution are listed in Table 1 (All reagents come from Sinopharm Chemical Reagent Co., Ltd., Shanghai, China).

### 2.2 Experiment design

In order to investigate the effect of nutrient solution irrigation quantity and powdery mildew infection on leaf gas-exchange parameters, growth parameters, root systems parameters, and biomass of greenhouse cucumber. The experimental design is shown in Figure 1.

Biotic stress at two levels: B0 (no powdery mildew stress) and B1 (powdery mildew stress) with three fertigation requirement levels (T1: Full fertigation, T2: Moderate nutrient solution deficit, T3: Severe nutrient solution deficit) Therefore, six treatments of B0T1, B1T2, B0T3, B1T1, B1T2, and B1T3, were set. No disease infestation and full fertigation (B0T1) were set as a control group. The irrigation amount was 600 mL (field water capacity), 400 mL, 200 mL for T1, T2, and T3, respectively.

**Table 1 Component of standard nutrient solution**

| Standard nutrient solution group | Chemical reagent | Mass/g |
|---|---|---|
| Standard A | $Ca(NO_3)_2{\cdot}4H_2O$ | 826 |
| | $KNO_3$ | 607 |
| Standard B | $NH_4H_2PO_4$ | 115 |
| | $MgSO_4{\cdot}7H_2O$ | 483 |
| Standard C | EDTA-2Na | 27.8 |
| | $FeSO_4{\cdot}7H_2O$ | 37.2 |
| | $H_3BO_3$ | 2.86 |
| | $MnSO_4{\cdot}4H_2O$ | 2.13 |
| | $ZnSO_4{\cdot}4H_2O$ | 0.22 |
| | $CuSO_4{\cdot}5H_2O$ | 0.08 |
| | $(NH4)_6Mo_7O_{24}{\cdot}4H_2O$ | 0.02 |

Note: Each standard liquor was prepared in a 10 L aqueous solution. Use after diluting 100 times.

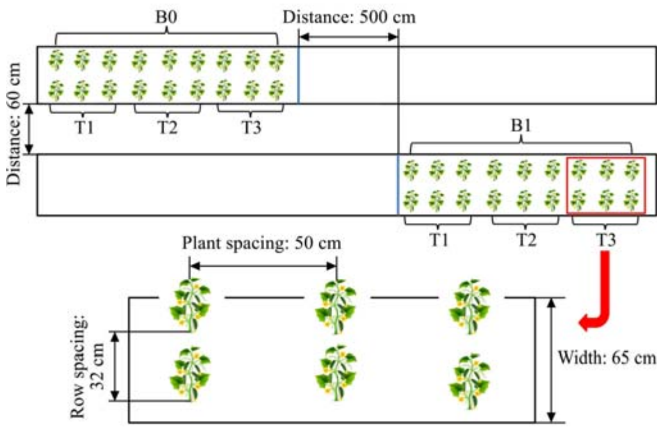



Figure 1 Schematic diagram design of the experimental

### 2.3 Pathogen inoculation

Cucumber powdery mildew sporangiospores were collected from cucumber leaves. Powdery mildew sporangiospores were maintained on potato dextrose agar(PDA; Sinopharm Chemical Reagent Co., Ltd., Shanghai, China) medium and maintained on cucumber plants by periodic transfer to the new plants when necessary[10]. When the fifth leaf of cucumber was grown (September 8, 2020), cucumber powdery mildew spores were prepared into a spore suspension of 1×106 spores/mL with sterile water. Cucumber leaves were inoculated in the evening with a disposable sterile syringe with a capacity of 2 mL (each leaf was inoculated with 2 mL spore suspension), and sterile water was set as control[25]. The inoculation method of cucumber powdery mildew is shown in Figure 2.

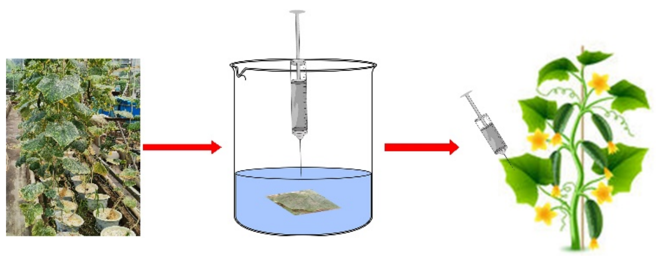


Figure 2 Inoculation method of cucumber powdery mildew

### 2.4 Leaf gas-exchange parameters

Leaf gas exchange parameters were measured on the 9th (Level 0), 14th (Level 3), and 19th (Level 7) days after seedlings were transplanted. Cucumber powdery mildew severity was graded according to GB/T17980.26-2000 (in Table 2). Cucumber leaf gas-exchange parameters were measured using a portables photosynthesis system (LI-6400, LI-COR Inc., Lincoln, NE, USA) on sunny days during 9:00-11:00 a.m. local time. All measurements were performed after at least 20 min of acclimation at 1000 $\mu$mol/m$^2$·s photosynthetic photon flux density (PPFD), 400 $\mu$mol/mol $CO_2$, and 500 $\mu$mol/s flow. The measurement light in the leaf chamber was used the red and blue LED light. The positions of selected leaves were kept similar in each plant.

**Table 2 Grading of cucumber powdery mildew severity**

| Disease level | Symptoms described |
|---|---|
| Level 0 | Asymptomatic |
| Level 1 | Diseased spot area occupies less than 5% of the leaf area |
| Level 3 | Diseased area accounts for 6% to 10% of the leaf area |
| Level 5 | Diseased area accounts for 11% to 25% of the leaf area |
| Level 7 | Diseased area accounts for 26% to 50% of the leaf area |
| Level 9 | Diseased spot area accounts for more than 50% of the leaf area |

### 2.5 Growth parameters and biomass of cucumber plants

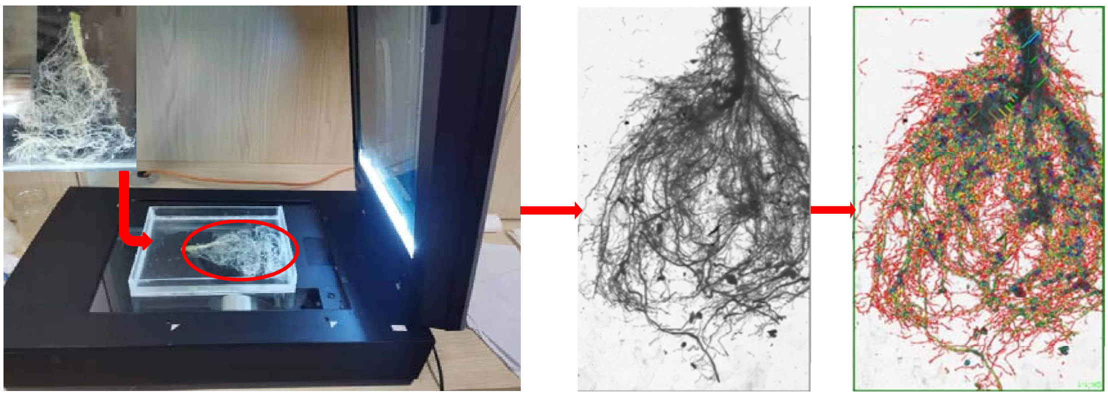
The measurement method of crop growth parameters and material accumulation is shown in Figure 3. Plant height (cm) from the perlite substrate surface to the plant top tip was measured by a metric ruler. Stem diameter (mm) was measured at a marked point of 10 cm height from the perlite substrate surface by Vernier caliper. Root was washed under a protective cleaning method[30]. Then, root system parameters were measured using the Perfection V700 photo scanner (made by EPSON Co., Nagano, Japan) and the WinRHIZO root analysis software (professional version). The fresh weights of the leaves, stems, and roots of each plant were measured at the end of the experiment. Then, they were put in an oven which was set at 105°C for 15 min, after which the temperature would be reset to 80°C, followed by keeping them drying until the weight was constant; a precision electronic scale (0.0001 g) was used to measure the dry weight of leaves, stems, and roots[1].

The root-shoot ratio for cucumber plants was calculated by Equation (1).

$$\text{Root}-\text{shoot ratio} = \frac{\text{DW(root)}}{\text{DW(leaves)}+\text{DW(stem)}} \quad (1)$$

where, DW (leaves) is the dry weight of leaves, g; DW (stem) is the dry weight of stems, g; DW (root) is the dry weight of roots, g.

a. Plant height b. Stem diameter c. Fresh weights d. Dry weights



e. Root system parameters

Figure 3 Measurement of crop growth parameters and material accumulation

### 2.6 Statistical analyses

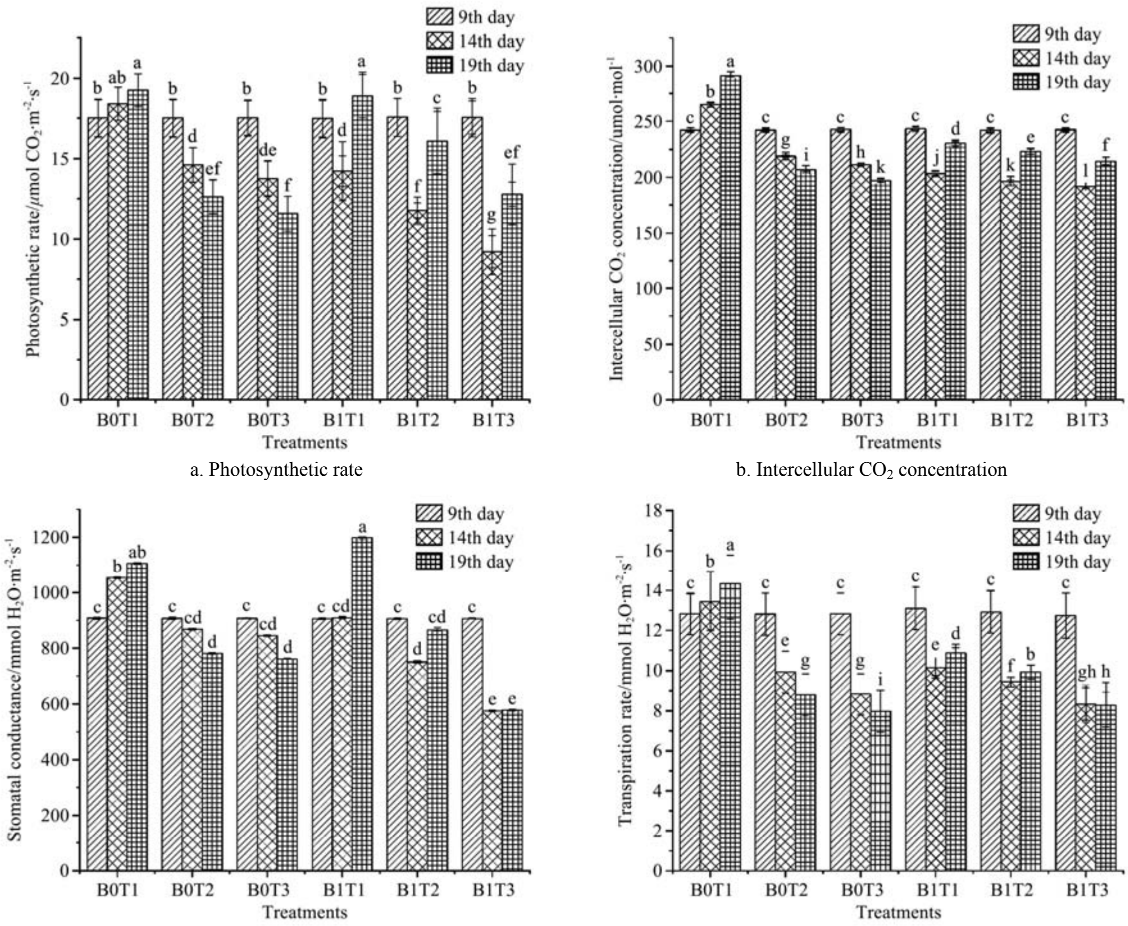
The data were analyzed using the statistical analysis software program SPSS 22. The statistical differences between groups were analyzed by using ANOVA. The least significant difference (LSD) test was used to determine a significance level of $p$<0.05.

## 3 Results and discussion

### 3.1 Leaf gas-exchange parameters

Gas-Exchange Parameters of cucumber leaves (9th, 14th, and 19th days after transplanting) are shown in Figure 4. There is no significant before different nutrient solution irrigation treatment and powdery mildew infection (9 d after transplanting). There are significant increases under the control experiment (CK). The leaf gas-exchange parameter first decreases and then increases under B1T1, B1T2, and B1T2. The leaf gas exchange parameter was significantly decreased under B0T2 and B0T3.

As can be seen from Figure 4, on the 14th day after transplanting, compared to CK, the averaged photosynthetic rate of cucumber leaves decreased by 20.55%, 25.18%, 22.68%, 36.05%, and 49.92%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the intercellular $CO_2$ concentration of cucumber leaves decreased by 17.33%, 20.26%, 23.28%, 25.83%, and 27.58%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the stomatal conductance of cucumber leaves decreased by 17.65%, 19.81%, 13.79%, 28.81%, and 45.53%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the transpiration rate of cucumber leaves decreased by 26.17%, 34.43%, 24.68%, 29.88%, and 37.99%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3. On the 19th day after transplanting, compared to CK, the averaged photosynthetic rate of cucumber leaves decreased by 34.44%, 39.89%, 1.92%, 16.42%, and 33.61%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the intercellular $CO_2$ concentration of cucumber leaves decreased by 28.95%, 32.34%, 20.93%, 23.31%, and 26.42%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the stomatal conductance of cucumber leaves decreased by 29.27%, 31.07%, 21.63%, and 47.67%, respectively, under B0T2, B0T3, B1T2, and B1T3, but the stomatal conductance of cucumber leaves increased by 8.37% under B1T1; the transpiration rate of cucumber leaves decreased by 38.52%, 44.38%, 24.15%, 30.77%, and 42.14%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3.



a. Photosynthetic rate

b. Intercellular $CO_2$ concentration

c. Stomatal conductance

d. Transpiration rate

Note: Error bars indicate standard deviations, with the same letter between treatments indicating no significant differences.

Figure 4 Leaf photosynthetic parameters of cucumber plants

After powdery mildew infects cucumber plants, the pathogen can produce a spore structure from the leaves and pass through the stomata to tear the epidermis. The stomata are damaged and contracted, and the stomata conductance decreases[31]. In addition, under water stress, cucumber stomata close in response to drought in order to avoid dehydration[32]. Closure of stomata will hinder the transfer of $CO_2$ from outside to chloroplasts, affect the photosynthesis of cucumber, and then reduce the photosynthesis rate[33]. Under the water stress and powdery mildew stress, in order to reduce water loss, the transpiration rate of cucumber leaves decreased[34]. Due to the greenhouse environment being relatively stable, the $CO_2$ concentration in the air around the cucumber plant is almost constant. Under the water stress and powdery mildew stress, the stomatal conductance and photosynthetic rate of cucumber leaves decreased, resulting in decreases in intercellular $CO_2$ concentration[35]. As water stress intensifies, the photosynthetic rate, stomatal conductance, and intercellular $CO_2$ concentration of cucumber leaves decreased gradually. Compared with water stress treatment alone, water stress and powdery mildew stress have more serious effects on cucumber leaf photosynthetic rate, stomatal conductance, and intercellular $CO_2$ concentration. Compared with the 14th day, the photosynthetic rate, stomatal conductance, and intercellular $CO_2$ concentration of cucumber leaves increased on the 19th day. This may be the redistribution of resources by cucumbers in order to increase crop yields[36]. In addition, these will also be affected by temperature, $CO_2$ concentration, light, etc[37].

### 3.2 Cucumber plants growth parameters

The growth parameters of cucumber plants are shown in Table 3. The growth parameters of cucumber plants are significant differences ($p$<0.05). Compared to CK, the plant height of cucumber decreased by 7.55%, 10.62%, 15.28%, 23.27%, and 35.16%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the stem diameter of cucumber decreased by 9.46%, 15.74%, 5.47%, 13.45%, and 23.72%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the leaf area of cucumber decreased by 13.76%, 29.96%, 13.43%, 38.21%, and 66.83%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3.

From the above analysis, with the increase in water stress, the growth parameters of cucumber plants showed decreases. But, compared to water stress, growth parameters of cucumber plants decreased more significantly under water stress and powdery mildew stress. In addition, water stress has the greatest impact on cucumber leaf area and the weakest impact on cucumber plant height; and, powdery mildew stress and water stress have the greatest impact on cucumber leaf area and the weakest impact on cucumber stem diameter. On the whole, water stress, powdery mildew stress, and water stress have the greatest impact on the cucumber leaf area. Under the water stress, the gas-exchange parameters of cucumber leaves decreased (Figure 4). Cucumber mesophyll cells were destroyed after powdery mildew infected cucumber plants[31,32]. These factors will affect the growth of cucumber leaves.

**Table 3 Growth parameters of cucumber plants**

| Treatment | Plant height/cm | Stem diameter/mm | Leaf area/cm$^2$ |
|---|---|---|---|
| B0T1 | 113.90±6.55$^a$ | 8.77±0.39$^a$ | 3933.67±198.06$^a$ |
| B0T2 | 105.30±1.93$^b$ | 7.94±0.10$^{bc}$ | 3392.46±253.85$^b$ |
| B0T3 | 101.80±1.43$^b$ | 7.39±0.52$^c$ | 2755.29±272.14$^c$ |
| B1T1 | 96.50±1.70$^c$ | 8.29±0.20$^b$ | 3405.32±343.74$^b$ |
| B1T2 | 87.40±3.50$^d$ | 7.59±0.27$^c$ | 2430.69±348.4$^c$ |
| B1T3 | 73.80±2.65$^e$ | 6.69±0.18$^c$ | 1304.98±241.74$^d$ |

Note: Different lowercase letters of the same column of data indicate significant differences between treatments ($p$<0.05).

### 3.3 Root systems parameters

The cucumber root system parameters are shown in Table 4. Compared to CK, the total length of root decreased by 9.62%, 21.54%, 37.17%, 46.19%, and 51.29% , respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the surface area of root decreased by 9.04%, 26.39%, 46.35%, 46.69%, and 51.27%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the average diameter of root decreased by 19.07%, 28.28%, 40.63%, 46.97%, and 53.48%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the total volume of root decreased by 11.69%, 31.21%, 47.03%, 52.7%, and 54.57%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the total tips of root decreased by 16.55%, 28.1%, 48.63%, 56.72%, and 63.79%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3.

From the above analysis, with the increase in water stress, root systems parameters of cucumber plants showed decreases. Under the water stress and powdery mildew stress, there were significant differences ($p$<0.05). Compared to water stress, there are greater effects on root growth under water stress and powdery mildew stress. There was no significant difference ($p$>0.05) in the surface area and total volume of root under water stress and powdery mildew stress. The results showed that there were differences in total length, average diameter, and total tips of roots. Although the protective cleaning methods were used to clean and arrange the roots, there may be experimental errors when doing root cleaning.

**Table 4 Root systems parameters of cucumber plants**

| Treatment | Total length/cm | Surface area/cm$^2$ | Average diameter/mm | Total volume/cm$^3$ | Total tips |
|---|---|---|---|---|---|
| B0T1 | 2339.397±41.638$^a$ | 627.987±24.295$^a$ | 3.126±0.521$^a$ | 14.088±1.721$^a$ | 10038±931$^a$ |
| B0T2 | 2114.360±78.358$^b$ | 571.236±16.316$^b$ | 2.530±0.035$^b$ | 12.441±0.631$^a$ | 8377±328$^b$ |
| B0T3 | 1835.504±53.806$^c$ | 462.242±7.401$^c$ | 2.242±0.190$^{bc}$ | 9.691±0.598$^b$ | 7217±490$^c$ |
| B1T1 | 1469.741±8.411$^d$ | 336.91±10.903$^d$ | 1.856±0.072$^{bc}$ | 7.462±1.212$^c$ | 5157±558$^d$ |
| B1T2 | 1258.811±14.277$^e$ | 334.809±15.854$^d$ | 1.657±0.076$^c$ | 6.664±1.594$^c$ | 4344±208$^d$ |
| B1T3 | 1139.446±37.424$^e$ | 306.034±34.018$^d$ | 1.454±0.023$^c$ | 6.4±0.585$^c$ | 3635±340$^e$ |

Note: Different lowercase letters of the same column of data indicate significant differences between treatments ($p$<0.05).

### 3.4 Biomass of cucumber plants

The biomass of cucumber plants is listed in Table 5. Compared to CK, the fresh weight of cucumber leaves of different treatments decreased by 13.74%, 30.97%, 39.75%, 54.01%, and 58.79%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the dry weight of cucumber leaves decreased by 11.77%, 25.76%, 42.24%, 58.83%, and 59.37%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the fresh weight of cucumber stem decreased by 3.83%, 27.09%, 40.97%, 50.43%, and 57.18%, respectively, under B0T2, B0T3, B1T1, B1T2 and B1T3; the dry weight of cucumber stem decreased by 8.03%, 34.19%, 48.34%, 60.44%, and 58.76%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the fresh weight of cucumber root decreased by 13.87%, 40.34%, 35.17%, 59.15%, and 69.21%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3; the dry weight of cucumber root decreased by 28.62%, 34.04%, 45.42%, 54.35%, and 60.21%, respectively, under B0T2, B0T3, B1T1, B1T2, and B1T3.

**Table 5 Biomass of cucumber plants**

| Treatment | PFM/g·plant$^{-1}$ | | | PDM/g·plant$^{-1}$ | | |
|---|---|---|---|---|---|---|
| | Leaf | Stem | Root | Leaf | Stem | Root |
| B0T1 | 61.81±4.19$^a$ | 75.36±4.87$^a$ | 14.17±1.08$^a$ | 7.562±0.617$^a$ | 3.864±0.583$^a$ | 0.448±0.011$^a$ |
| B0T2 | 53.31±1.51$^b$ | 72.47±6.03$^a$ | 12.21±0.77$^b$ | 6.674±0.125$^b$ | 3.552±0.415$^a$ | 0.319±0.067$^b$ |
| B0T3 | 42.66±3.35$^c$ | 54.94±3.74$^b$ | 8.46±0.62$^c$ | 5.612±0.887$^c$ | 2.546±0.425$^b$ | 0.295±0.012$^{bc}$ |
| B1T1 | 37.23±5.41$^d$ | 44.48±7.22$^{bc}$ | 9.18±2.05$^c$ | 4.366±0.748$^d$ | 1.994±0.231$^{bc}$ | 0.245±0.023$^c$ |
| B1T2 | 28.42±0.88$^e$ | 37.35±2.86$^c$ | 5.78±0.54$^d$ | 3.112±0.374$^e$ | 1.527±0.205$^c$ | 0.204±0.017$^{cd}$ |
| B1T3 | 25.47±1.70$^e$ | 32.27±3.29$^c$ | 4.36±0.29$^d$ | 3.071±0.325$^e$ | 1.592±0.287$^c$ | 0.178±0.032$^d$ |

Note: PFM: Fresh plant biomass; PDM: Dry plant biomass. Different lowercase letters of the same column of data indicate significant differences between treatments ($p$<0.05).

The gas-exchange parameters of cucumber leaves decreased when cucumber plants were infected by powdery mildew and under water stress (Figure 4). The decrease in leaf photosynthetic rate will affect the synthesis of sucrose in the cytoplasmic matrix. The sucrose content in the plant mesophyll cells will decrease, and the sucrose transported to other organs through the phloem will also decrease. And then affect the accumulation of cucumber plant biomass. The more severe the external environmental stress on cucumber plants, the greater the impact on the accumulation of biomass. Under normal water conditions, mesophyll cells can absorb non-free abscisic acid. When drought occurs, abscisic acid will change to free form, but free form abscisic acid cannot pass through the cell membrane of mesophyll cells. The concentration increases in the cytoplasm, stimulating the closing of the stomatal guard cells. The increase in the content of abscisic acid in the cell will also increase the concentration of calcium ions in the cytoplasm and decrease the absorption of potassium ions, causing the depolarization of the cell membrane, which leads to the closure of stomata. In the process of stomata closure, because the carbon dioxide concentration is relatively low, it will affect photosynthesis, but at the same time for the synthesis of some proteins, the activity of nitrate reductase and the formation of protochlorophyll will be reduced. After powdery mildew infects petioles and tender stems, a white powdery mold layer grows on the surface of the leaves, which affects photosynthesis, interferes with normal metabolism, causes premature aging, and loses yield. Water stress and powdery mildew stress reduce the rate of assimilation formation and affect the root shoot ratio of plants.

The root shoot ratio of the cucumber plant was 3.92%, 3.13%, 3.63%, 3.84%, 4.41%, and 3.82%, respectively, under the B0T1, B0T2, B0T3, B1T1, B1T2, and B1T3. It was the highest under the B1T2. Under the water stress and powdery mildew stress, the respiration rate of cucumber plant leaves increases, and the photosynthetic activity decreases, resulting in a decrease in total biomass[38]. Under the water stress and powdery mildew stress, the impact on the above-ground part is greater than the impact on the root system, increasing the root-shoot ratio[39].

## 4 Conclusions

Six treatments of B0T1, B1T2, B0T3, B1T1, B1T2, and B1T3, were set. Compared to water stress treatment alone, water stress and powdery mildew stress had greater effects on the photosynthetic rate, stomatal conductance, and intercellular $CO_2$ concentration of cucumber leaves. With the increase in water stress, growth parameters of cucumber plants showed decreased. But, compared to water stress, growth parameters of cucumber plants decreased more significantly under water stress and powdery mildew stress. In addition, water stress has the greatest impact on cucumber leaf area and the weakest impact on cucumber plant height; powdery mildew stress and water stress have the greatest impact on cucumber leaf area and the weakest impact on cucumber stem diameter. With the increase in water stress, root systems parameters of cucumber plants showed decreases. Compared to water stress, there are greater effects on root growth under water stress and powdery mildew stress. The root-shoot ratio of cucumber treatments was 3.92%, 3.13%, 3.63%, 3.84%, 4.41%, and 3.82%, respectively, under the B0T1, B0T2, B0T3, B1T1, B1T2, and B1T3.

## Acknowledgements

This work was partially financially supported by the National Natural Science Foundation of China (Grant No. 32071905; No. 32171895; No. 61771224) and the Priority Academic Program Development of Jiangsu Higher Education Institutions (Grant No. PAPD-2018-87).

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