Managing Water Consumption For Tomato Production Under Drip Irrigation In Greenhouse

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Outline

• Introduction
• Experimental design
• Results
• Conclusions
- Solar greenhouse is popular for vegetable production in China

- Simple structure without heating systems
- Inexpensive to build
- Cheap to maintain
- Area about 300-800 m², easily managed by a 3-5 person family

- Suitable for use in countries in temperate zones, especially in the developing countries
Drip irrigation, a modern irrigation technology, has been applied in greenhouse vegetable cultivation.

- When to irrigation?
- How much water to apply?
- How to make it simple and easy to accept?
Two major drip irrigation scheduling methods

Irrigation amount decided by:
- Evaporation pan
- Penman–Monteith equation

Irrigation according to calendar or fixed schedule
Two major drip irrigation scheduling methods

Irrigation time decided by:

- Direct measurement, such as by tensiometer
- Moisture accounting

Maintain soil moisture in the root zone within desired limits
☐ Tensiometer

- Soil matric potential- energy status
- Evaporation is not required
- Crop factor is avoided
- Cheap and easy to use
- Relatively slow response
- Needs careful maintenance
- The depth of the tensiometers and their position relative to the dripline need to be determined
Soil water condition in the root zone can be maintained when control the soil matric potential (SMP) at 20 cm depth immediately under emitters.

In the past 19 years, we have already carried out experiments for over 20 varieties or species of row crops, and the soil matric thresholds (SMP) were determined:

- **The SMP thresholds for waxy corn, oil sunflower, cotton, tomato, bean, bitter melon, squash, asparagus lettuce, radish, cabbage:** -35kPa
- **The SMP thresholds for potato, cucumber:** -25kPa
- **The SMP threshold for Celery:** -20kPa

References:


Experiments in the field

☑️ One SMP threshold in crop growth stages

To further improve water use efficiency and water productivity in greenhouse, experiment with different SMP thresholds in different crop growth stages
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The water shortage map of China

- In Hebei Province, north part of China
- One of the severe water shortage areas in China
- Sandy loam soil
- The soil bulk density was $1.3 \text{ g/cm}^3$ at 0-20 cm depth
## Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Three Stages / Date (245 Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The seedling stage</td>
</tr>
<tr>
<td>S1</td>
<td>-15 kPa</td>
</tr>
<tr>
<td>S2</td>
<td>-15 kPa</td>
</tr>
<tr>
<td>S3</td>
<td>-15 kPa</td>
</tr>
<tr>
<td>S4</td>
<td>-15 kPa</td>
</tr>
<tr>
<td>S5</td>
<td>-15 kPa</td>
</tr>
<tr>
<td>S6</td>
<td>-15 kPa</td>
</tr>
<tr>
<td>S7</td>
<td>-15 kPa</td>
</tr>
</tbody>
</table>

- **Seven treatments:** S1~S7
- **In seedling stage, uniformly SMP threshold of -15 kPa**
- **3-4 SMP levels in two stages**
  - In flowering and fruit setting period:
    - -15, -25, and -30 kPa
  - In fruiting period:
    - -15, -25, -30 and -45 kPa
Observation and equipment

- **SMP**: Six tensiometers installed at 20 cm, 70 cm and 90 cm depth at three places

- Water consumption (ET): the water balance method, $ET = I + P + \Delta S - D - R$
  - $I$ is irrigation amount (mm);
  - $P$ is precipitation, $P = 0$;
  - $R$ is surface runoff, $R = 0$;
  - $D$ is water flux below the 80 cm soil profile, and were calculated by positioning flux method (mm);
  - $\Delta S$ is the change of soil water storage in the 0-100 cm soil profile (mm)

- **Yield**
- **Abnormal fruit rate**
- **Soluble solids content**
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- Introduction
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- Conclusions
1) The temporal variation of SMPs at 20 cm depth for S3, S6 and S7

- The SMPs at 20 cm depth were basically kept within the threshold.
1) The temporal variation of SMPs at 70 cm depth for S3, S6 and S7
1) The temporal variation of SMPs at 90 cm depth for S3, S6 and S7

At the beginning, the SMPs at 70 cm and 90 cm depth were high, decreased gradually to around -30 kPa and -25 kPa, respectively.

For S3, S6 and S7, the soil water consumption reached a depth of 70-80 cm.
1) The temporal variation of SMPs at 20 cm depth for S1, S2, S4 and S5
1) The temporal variation of SMPs at 70 cm depth for S1, S2, S4 and S5.
1) The temporal variation of SMPs at 90 cm depth for S1, S2, S4 and S5

✓ For S1, S2, S4 and S5, the soil moisture consumption was mainly in the upper 60 cm depth
2) Soil water deficit (∆S), drainage (D), and water use (ET)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>I/ mm</th>
<th>∆S/ mm</th>
<th>D/ mm</th>
<th>ET/ mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 -15~-15kPa</td>
<td>526.0</td>
<td>67.3</td>
<td>-15.9</td>
<td>442.9</td>
</tr>
<tr>
<td>S2 -15~-30kPa</td>
<td>484.4</td>
<td>63.6</td>
<td>-11.0</td>
<td>409.8</td>
</tr>
<tr>
<td>S3 -15~-45kPa</td>
<td>340.3</td>
<td>-37.3</td>
<td>23.0</td>
<td>400.5</td>
</tr>
<tr>
<td>S4 -25~-25kPa</td>
<td>192.7</td>
<td>-90.2</td>
<td>-22.1</td>
<td>260.8</td>
</tr>
<tr>
<td>S5 -30~-15kPa</td>
<td>251.9</td>
<td>-4.0</td>
<td>9.2</td>
<td>265.1</td>
</tr>
<tr>
<td>S6 -30~-30kPa</td>
<td>170.8</td>
<td>-39.0</td>
<td>40.5</td>
<td>250.3</td>
</tr>
<tr>
<td>S7 -30~-45kPa</td>
<td>140.6</td>
<td>-57.8</td>
<td>23.5</td>
<td>221.9</td>
</tr>
</tbody>
</table>

- The ∆S for S1 and S2 was positive, meant soil water gain; others was negative, implied soil water consumed
- The D for S1, S2 and S4 was negative, implied soil water percolated; others was positive, meant soil water replenished
- The high SMP threshold of -15 kPa caused the leach of water
- The SMP threshold of -45 to -30 kPa was beneficial for tomato to utilize more water stored in the soil
## 3）Yield and related quality indexes

<table>
<thead>
<tr>
<th>Treatment</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield/ (t·hm⁻²)</td>
<td>115.9b</td>
<td>115.1b</td>
<td>134.5a</td>
<td>118.5ab</td>
<td>103.8b</td>
<td>118.2b</td>
<td>129.5ab</td>
</tr>
<tr>
<td>Abnormal fruit rate/ %</td>
<td>25.7a</td>
<td>16.3ab</td>
<td>26.6a</td>
<td>26.5a</td>
<td>9.6bc</td>
<td>7.7c</td>
<td>7.4c</td>
</tr>
<tr>
<td>Soluble solids content / %</td>
<td>4.7cd</td>
<td>4.0de</td>
<td>4.1de</td>
<td>3.3e</td>
<td>5.2bc</td>
<td>5.8ab</td>
<td>6.4a</td>
</tr>
</tbody>
</table>

- The **S7** had the **high yield**, the **lowest abnormal fruit rate** and the **highest soluble solids content**
- The **S1, S3 and S4** had the **high abnormal fruit rate**, and a relatively **low soluble solids content**
4) Irrigation water use efficiency (IWUE) and water use efficiency (WUE)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation amount/ mm</td>
<td>526.0</td>
<td>484.4</td>
<td>340.3</td>
<td>192.7</td>
<td>251.7</td>
<td>170.1</td>
<td>140.6</td>
</tr>
<tr>
<td>Water use/ mm</td>
<td>442.9</td>
<td>409.8</td>
<td>400.5</td>
<td>260.8</td>
<td>265.1</td>
<td>250.3</td>
<td>221.9</td>
</tr>
<tr>
<td>IWUE / (t·hm⁻²·mm⁻¹)</td>
<td>0.22d</td>
<td>0.24d</td>
<td>0.40c</td>
<td>0.62b</td>
<td>0.41c</td>
<td>0.69b</td>
<td>0.92a</td>
</tr>
<tr>
<td>WUE / (t·hm⁻²·mm⁻¹)</td>
<td>0.26e</td>
<td>0.28e</td>
<td>0.34d</td>
<td>0.45bc</td>
<td>0.39cd</td>
<td>0.47b</td>
<td>0.58a</td>
</tr>
</tbody>
</table>

With the increase of SMP, the irrigation amount and water consumption increased obviously, while the IWUE and WUE decreased significantly.
5) Benefit analysis

<table>
<thead>
<tr>
<th></th>
<th>Yield t·hm⁻²</th>
<th>Irrigation amount (mm)</th>
<th>IWUE t·hm⁻²·mm⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drip irrigation + Irrigation by manager’s experience</td>
<td>75</td>
<td>450</td>
<td>0.17</td>
</tr>
<tr>
<td>Drip irrigation + Irrigation by SMP threshold of -30 kPa and -45 kPa (S7)</td>
<td>129.5</td>
<td>140.6</td>
<td>0.92</td>
</tr>
<tr>
<td>%</td>
<td>+72.7%</td>
<td>-68.8%</td>
<td>5.5 times</td>
</tr>
</tbody>
</table>

 ✓ The application of SMP threshold to schedule drip irrigation can achieve obvious effects on yield increasing, water and energy saving
Outline

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• Experimental design

• Results

• Conclusions
① One tensiometer is installed at 20cm depth immediately under emitters

② Irrigation amount for each irrigation event is around 6 mm

③ Observing the reading of tensiometer, water is applied when the SMP is near -30 kPa in flowering and fruit setting period, and -45 kPa in fruiting period

The study provide a valuable example in Water-Energy-Food Nexus
Thank you for your attention!