Fertigation in greenhouse production
the challenge to achieve environmental goals for soil grown crops in the Netherlands

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Content

- Greenhouse production in the Netherlands
- Characteristics of fertigation in greenhouses
- Fertigation in practice
- Environmental problems
- Improvements in fertigation practice
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- Greenhouse production in the Netherlands
- Characteristics of fertigation in greenhouses
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Statistics about the Netherlands

- Small country: 41 526 km²
  - land 4/5
  - water 1/5
- 16.1 million people
- Population density 475 people/km²
Intensive horticulture

Voogt; IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005
Greenhouse production in the Netherlands

**Characteristics of fertigation in greenhouses**

- Fertigation in practice
- Environmental problems
- Improvements in fertigation practice
Protected horticulture

- High yields
- High fertiliser inputs

Fertiliser use in protected horticulture

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>P</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>500</td>
<td>300</td>
<td>1000</td>
</tr>
<tr>
<td>2000</td>
<td>750</td>
<td>500</td>
<td>2000</td>
</tr>
</tbody>
</table>

Tomato

Ammerlaan et al., 2003
High fertiliser use

- High growth rates, high crop requirements
- High EC necessary for crop quality
- Unequal water distribution
- Surface water use
- Fertilisers costs insignificant

Low efficiency !!

![Graph showing N use efficiency in relation to total N applied](image)

Results of a monitoring project at > 40 nurseries

Voogt and Wubben, 1999
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Voogt; IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005

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Fertigation in greenhouses

- Late '40's - Introduction irrigation systems
- First steps in 1950’s,
- 1960’s, electric appliances
- 1970 Water soluble fertilisers, Introduction drip irrigation
- 1980 nutrient solutions, electronics
- 1990 liquid fertiliser, automation, improved sprinklers/drip nozzles

Voogt; IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005
Fertigation in current practice

- Fertigation programs
  - Nutrient solutions
  - Target values in soil
  - Crop stage adjustments
  - Soil type adjustments

Composition of the basic nutrient solution for fertigation for some greenhouse crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>NH4</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>NO3</th>
<th>SO4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>0.4</td>
<td>5</td>
<td>2</td>
<td>1.5</td>
<td>9.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Cucumber</td>
<td>0.9</td>
<td>3.5</td>
<td>2</td>
<td>1</td>
<td>8.4</td>
<td>1</td>
</tr>
<tr>
<td>Sweet Pep</td>
<td>0.4</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>8.4</td>
<td>1</td>
</tr>
<tr>
<td>Rose</td>
<td>0.9</td>
<td>3.5</td>
<td>2</td>
<td>1.1</td>
<td>8.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Example tomato crop

<table>
<thead>
<tr>
<th>Standard nutrient solution</th>
<th>NH4</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>NO3</th>
<th>SO4</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmol/l</td>
<td>0.4</td>
<td>5.0</td>
<td>2.0</td>
<td>1.5</td>
<td>9.4</td>
<td>1.5</td>
</tr>
<tr>
<td>mg/l</td>
<td>16</td>
<td>196</td>
<td>80</td>
<td>36</td>
<td>132</td>
<td>47</td>
</tr>
</tbody>
</table>

per 1 m³

Stock tank A
- Calciumnitrate: 43 kg
- Ammoniumnitrate: 6 kg
- Potassiumnitrate: 54 kg

Sum: 103 kg

Stock tank B
- Potassiumnitrate: 66 kg
- Magnesiumsulphate: 37 kg
- Potassiumsulphate: 0 kg

Sum: 103 kg

Adjustments water quality

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>mmol/l</td>
<td>mmol/l</td>
<td>mmol/l</td>
</tr>
<tr>
<td>NH4</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>K</td>
<td>5</td>
<td>7.5</td>
</tr>
<tr>
<td>Ca</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mg</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>NO3</td>
<td>9.4</td>
<td>12.4</td>
</tr>
<tr>
<td>SO4</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>Na</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>Cl</td>
<td>2.8</td>
<td>0</td>
</tr>
</tbody>
</table>

per 1 m³

Stock tank
- Ammoniumnitrate: 9 kg
- Potassiumnitrate: 176 kg
- Magnesiumnitrate: 28 kg
Soil analysis

Recommendation

<table>
<thead>
<tr>
<th>Target values soil</th>
<th>NH4</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>NO3</th>
<th>SO4</th>
<th>Na</th>
<th>Cl</th>
<th>EC mS/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1:2 volume extract) mmol/l</td>
<td>0</td>
<td>2.2</td>
<td>2.5</td>
<td>1.7</td>
<td>5</td>
<td>2.5</td>
<td>&lt; 4</td>
<td>&lt; 4</td>
<td>1.4</td>
</tr>
<tr>
<td>mg/l</td>
<td>0</td>
<td>86</td>
<td>100</td>
<td>41</td>
<td>70</td>
<td>78</td>
<td>92</td>
<td>142</td>
<td></td>
</tr>
</tbody>
</table>

Adjustments

<table>
<thead>
<tr>
<th>K supply ratio K/N soil analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>160% &lt; 0.20</td>
</tr>
<tr>
<td>130% 0.2 0.34</td>
</tr>
<tr>
<td>No adjustments 0.35 0.55</td>
</tr>
<tr>
<td>80% 0.56 0.65</td>
</tr>
<tr>
<td>60% &gt; 0.65</td>
</tr>
</tbody>
</table>

Recommendation Supply

Adjustments N supply

Adjustments total EC supply

Source: IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005
Details

- NH₄: extra with calcareous soils
- P: only base dressings
  - Exceptions extreme low P in soil
- Micro elements not standard; but
  - B in case of low B in irrigation water
  - Fe chelate: chlorosis susceptible crops

Voogt, IP International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005

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Environmental problems

Annual water and mineral use of some glasshouse crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Water (m³/ha)</th>
<th>N (kg/ha)</th>
<th>P (kg/ha)</th>
<th>K (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>12950</td>
<td>1150</td>
<td>205</td>
<td>1410</td>
</tr>
<tr>
<td>Cucumber</td>
<td>10400</td>
<td>980</td>
<td>240</td>
<td>1100</td>
</tr>
<tr>
<td>Rose</td>
<td>11500</td>
<td>990</td>
<td>110</td>
<td>910</td>
</tr>
</tbody>
</table>

Water and nitrogen efficiency rates for some crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Water (g/ha)</th>
<th>Nitrogen (g/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>0.80</td>
<td>0.55</td>
</tr>
<tr>
<td>Cucumber</td>
<td>0.79</td>
<td>0.54</td>
</tr>
<tr>
<td>Sweet pepper</td>
<td>0.88</td>
<td>0.61</td>
</tr>
<tr>
<td>Rose</td>
<td>0.78</td>
<td>0.60</td>
</tr>
<tr>
<td>Chrysanthemum</td>
<td>0.65</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Sonneveld et al., 1994, Van den Bos, 1999

Recent official data on N emission

Sonneveld, IP International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005
Description greenhouse system

Greenhouse system

<table>
<thead>
<tr>
<th>Groundwater</th>
<th>Seepage</th>
<th>Capillary rise</th>
<th>Irrigation</th>
<th>Evapotranspiration</th>
</tr>
</thead>
</table>

Voogt; IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005

Fertigation and measured nitrogen emission

No correlation !!!

Voogt and Wubben, 1999
Governmental policy, (Netherlands)
reduction environmental impact

- Obligatory for soil grown crops
  - Rainwater collection basin, 500 m³/ha
  - Re-use of drainage water if possible
- Targets for 2010
  - Reduction in consumption of, **N and P fertilisers**

Targets for N and P consumption 2000 – 2010

- Total input (manure, organic, chemical fertiliser)
- Specified per crop
- Linear reduction from 2000 - 2010

**Examples of target values**

<table>
<thead>
<tr>
<th>Crop</th>
<th>N kg/ha</th>
<th>P kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>1938</td>
<td>404</td>
</tr>
<tr>
<td>Lettuce</td>
<td>620</td>
<td>90</td>
</tr>
</tbody>
</table>

Source: IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005
How to achieve these goals?

- Greenhouse production in the Netherlands
- Characteristics of fertigation in greenhouses
- Fertigation in practice
- Environmental problems
- **Improvements in fertigation practice**

Options

- Re-use of drainage water
- Tuning supply and demand
- Reduction N and P in soil
Re-use of drainage water

- High efficiency water and fertilisers
- Quantity problem
- Quality problem

Re-use drainage water: quantity

**Example**

<table>
<thead>
<tr>
<th>radish crop</th>
<th>Total irrigation</th>
<th>838 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total drainage</td>
<td>699 mm</td>
</tr>
</tbody>
</table>

Synchronisation problem

Korsten et al., 1995
Re-use drainage water: other problems

- Salinity:
  - Na and Cl
  - Ca and SO4 / Ca and HCO3

- Phytopathogens

- Deep ground water / no drainage

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Tuning supply and demand

Solution

The fertilization model for soil grown greenhouse crops
**Aim**

- Avoidance vertical flow of water
- Supply to crop demand
  - Water supply adjusted to water uptake
  - Nutrient supply attuned to crop growth

**Fertigation model**

- Fertilisation uptake model
- Irrigation transpiration model

**Basic principles:**

- Evapotranspiration = crop requirement
- Soil water holding capacity >> irrigation per time
- Nutrient supply is connected to water supply
- Perfect water quality, no salinity problems
- Uniformity in distribution of irrigation
- Uniformity in crop growth
Water supply

Based on transpiration model

- crop specific factors
- global radiation
- air temperature
- heating temperature
- plant size
- soil type

Fertiliser supply

Based on nutrient uptake model

- Simple model
  - concentration based (EC nutrient solution)
  - Initially based on total crop uptake
    - 1 Estimation of total yield
    - 2 N, K uptake estimated from linear regression
    - 3 Uptake allocated to weekly periods
    - 4 Nutrient solution calculation
    - 5 Supply concentration calculation, in relation with actual transpiration
  - Cropping stage adjustments
Fertigation model

**INPUT**
- radiation
- heating temperature
- air temperature
- plantsize

**OUTPUT**
- Irrigation quantity
- frequency

**Setpoints:**
- irrigation time
- frequency
- correction factor
- concentration

**Nutrient supply unit**
- pump

**Soil moisture content**
- FD sensor / Tensiometers

**Setpoints:**
- irrigation time
- frequency
- correction factor
- concentration

---

**Nitrogen**

<table>
<thead>
<tr>
<th>N-supply</th>
<th>N-uptake</th>
<th>N-surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>120</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td>160</td>
<td>180</td>
<td>200</td>
</tr>
</tbody>
</table>

**Water balance**

<table>
<thead>
<tr>
<th>Water supply</th>
<th>Evapotranspir.</th>
<th>Water balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>40</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

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Voogt; IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005
Results water balance

Results Nitrogen balance
Fertigation model

- WUE increase from 0.65 - 0.95
- NUE increase from 0.56 - 0.85

Problem

Inequality of water supply and irrigation

Van den Burg et al., 1992
Heemskerk et al., 1994
Additional improvements

- Reduction in N and P “buffer” in soil profile

Reduction of N

<table>
<thead>
<tr>
<th>Target level N soil</th>
<th>N supply kg/ha</th>
<th>Yield %</th>
<th>N uptake kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>0</td>
<td>50</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>100</td>
<td>150</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>150</td>
<td>200</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>200</td>
<td>250</td>
<td>400</td>
<td>500</td>
</tr>
</tbody>
</table>

Van den Bos., 2002
Reduction of P

![Bar chart showing P trial lettuce, 14 crops]

\[ \text{P target value in soil} \]

\[ \text{P supply kg/ha} \]

\[ \text{Yield g/head} \]

\[ \text{P uptake kg/ha} \]

Van den Bos, 2004

Voogt; IPI International Symposium on Fertigation: Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005

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Conclusion

- Current fertigation strategy not sustainable
- Complex hydrology; re-use drainage water not general applicable
- Supply tuned to crop requirement best solution \textit{i.e. Fertigation model}
- Further improvements by reduction N and P in soil
- Bottle-necks:
  - High standards for water quality
  - Unequal distribution of water

Van den Bos, 2004

Voogt; IPI International Symposium on Fertigation: Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005
And...

- Growers attitude: Economics far more important than fertiliser costs and/or environmental concern

Challenge:
- License to produce / to deliver (market demand, certification, consumers)

Thank you