



# The water balance in Ethiopian greenhouses

A case study for two rose farms

Erik van Os, Anne Elings & Wim Voogt







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Front cover:

Left: water storage in a basin at Olij Rose Farm

Right: a rose crop ready for harvest at J.J. Kothari

## **Wageningen UR Greenhouse Horticulture**

Adres : Droevendaalsesteeg 1, 6708 PB Wageningen, the Netherlands  
: P.O. Box 16, 6700 AA Wageningen, the Netherlands  
Tel. : +31 317 - 48 60 01  
Fax : +31 317 - 41 80 94  
E-mail : [greenhousehorticulture@wur.nl](mailto:greenhousehorticulture@wur.nl)  
Internet : [www.greenhousehorticulture.wur.nl](http://www.greenhousehorticulture.wur.nl)

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# 1 Summary

Water in Ethiopia is a scarce resource. Its use and pollution of the ground and surface water must be prevented. Greenhouse rose cultivation in Ethiopia is currently using ground or surface water that is not recirculated but drained off. Technologies are available to reduce the water consumption and increase the water use efficiency without affecting crop growth and production.

Estimates of water saving were generated that can be achieved if different technologies are used to save water. The situation at Olij Roses at Debre Zeit (a dry location at an altitude of 1950 masl), and J.J. Kothari at Sululta (a more wet location at an altitude of 2600 masl).

Water use can be reduced through implementation of the following technologies:

Technology	Olij Roses at Debre Zeit	J.J. Kothari at Sululta
Reduction of drain	20 %	25 %
Usage of rain water in water storage	20 %	35-40%
Re-circulation of drain water, possibly in combination with reversed osmosis to purify the water	20-40 %	
Combination of all technology	60-80%	60-65%

If these figures are accumulated, then total water savings of 60-80% are possible. In absolute numbers, this equals for each 100 ha of greenhouses to 1.5-2.0 million m<sup>3</sup> y<sup>-1</sup>. At other locations, with other parameters, savings may be different, however, it can be safely assumed that considerable water savings are possible in the Ethiopian protected rose industry if adequate technology is adopted.

## 1.1 Acknowledgements

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## 2 Introduction

Greenhouse horticulture in Ethiopia, although being a very young industry, shows high growth figures in terms of acreage, export, and employment. The Ethiopian government strongly supports this development, and private companies are seeking ways for investment and expansion. The rapidly increasing acreage of greenhouses in Ethiopia leads to similarly strong increases in water consumption. This may soon lead to water shortages, especially in regions where greenhouse farms form clusters (e.g., Holeta), water resources are scarce or not well-distributed over time. Environmental degradation as a consequence of over-exploitation of water resources is of concern to the Ethiopian government and society. One of the mechanisms to avoid this development is to design on the basis of local criteria greenhouse production systems with higher water use efficiency, have them introduced, tested and adopted.

Flower production in Ethiopia currently often takes places in the soil. This introduces the risk of nematodes and soil-borne bacteria. It also causes leaching of water and nutrients, and difficulties in optimizing the fertigation regime in view of the needs of the crop and limited availability of resources. Production and product quality are likely to be sub-optimal. In a competing international market, growers may directly benefit from a cultivation system that avoids those risks.

A cultivation system that deals with both the expected water shortages and at the same time improves cultivation methods, makes use of substrates instead of soil, recirculation, and a well-regulated fertigation regime.

This study estimates the water saving that can be achieved if different technologies are used to save water. The situation at Olij Roses at Debre Zeit (a dry location at an altitude of 1950 masl), and J.J. Kothari at Sululta (a more wet location at an altitude of 2600 masl).



## 3 Olij Roses

### 3.1 Assumptions

Water flows at Olij farm are computed on the basis of the following assumptions:

- Computations are in  $\text{m}^3$  per ha per year.
- The farm does not have assimilation lights, no heating, and no rain water basin.
- Climate data for 2007 and 2008 have been used; missing data have been interpolated. For absence of rainfall data, the rainfall data of the J.J. Kothari farm were used as an estimate. The J.J. Kothari site may receive more rainfall than the Olij site; if this is the case, then more reverse osmosis water is required, against higher costs.
- Day length is 12 hours, all year through.
- Condensation water is not retrieved.
- Crop transpiration is in all situations  $13500 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , which is based on the available climate data.
- There are various types of waste water: filter cleaning, leakage, and leaching to the outside. Filter cleaning takes  $200\text{-}300 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , and leakage is  $200\text{-}350 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ .

The model Waterstromen (WaterStreams) of Wim Voogt (see Annex III) has been used to compute the water flows.

### 3.2 Technological Levels

A number of different situations have been investigated. As a starting point, the open system with free drainage as recently existed, has been chosen. Technical improvements are added in further computations: reduced drainage, recirculation of water, reversed osmosis, and storage of rain water.

#### System 1

The starting point is an open system with 45% leaching to the outdoor environment. Irrigation water is obtained from a bore hole. This is the situation as existed up to mid 2008 at Olij, with rose cultivation in the ground.

#### System 2

As a first improvement, drain is reduced from 45% to 30%. This is realized by applying less water.

#### System 3

An important innovation is the introduction of a closed recirculation system with reversed osmosis, and therefore the introduction of substrate. Recirculation implies re-use of water, and therefore less leaching to the outdoor environment. Reversed osmosis is required for purification of the re-used water. For Olij, being a farm with breeding activities, this is of great importance. The basin is empty at the start of the computations.

The drain is assumed to be 50% (but is recirculated, not leached outdoor!). The capacity of the reversed osmosis system is  $600 \text{ m}^3 \text{ d}^{-1}$  ( $= 4.9 \text{ mm d}^{-1}$ ), which is the capacity of the recently installed equipment (Bosman B.V., The Netherlands). The treated water is stored in a basin with a capacity of  $7000 \text{ m}^3$ . Use of rainfall (in the basin) is not considered.

#### System 4

As system 3, but with 25% drain that is re-circulated.

**System 5**

As system 3, but with  $425 \text{ m}^3 \text{ d}^{-1}$  ( $= 3.5 \text{ mm d}^{-1}$ ), capacity of the reversed osmosis system. The basin of  $7000 \text{ m}^3$  is empty at the start of the computations. The lower reversed osmosis capacity may lead to the usage of other water resources (in this case bore hole water). As the Na content of the bore hole water is relatively high, and as the reversed osmosis system can not remove the salts of the additional water source (due to insufficient capacity), this implies more leaching to outdoor.

**System 6**

As system 5, but with 25% drain,  $450 \text{ m}^3 \text{ d}^{-1}$  capacity of the reversed osmosis system, and a small basin with a capacity of  $600 \text{ m}^3 \text{ ha}^{-1}$ . Other water than osmosis water and rain water is not needed. The use of rain water implies that less reversed osmosis water is needed (therefore 450 instead of  $600 \text{ m}^3 \text{ d}^{-1}$ ). Such a system is cheaper, as normal osmosis water is more expensive than rain water.

**System 7**

As system 6, but with  $400 \text{ m}^3 \text{ d}^{-1}$  capacity of the reversed osmosis system, and a larger basin with a capacity of  $3000 \text{ m}^3 \text{ ha}^{-1}$ . The use of a larger basin implies that a reversed osmosis system with a smaller capacity can be installed.

### 3.3 Results

The description of the water balance, including water savings, is given in Table 1.

For clarification: if it is said that 45% drains, this means that 45% of the water supply drains off the substrate. This water trickles into the subsoil in an open system and will be reused in a closed system. Additional there may be water needed for cleaning filters or for discharge out of the system. The amount of discharge out of the system is driven by the sodium level of  $4 \text{ mmol l}^{-1}$  around the roots. If this level is above  $4 \text{ mmol l}^{-1}$  there will be discharge to the environment.

**System 1**

An open system with 45% leaching to the outdoor environment requires  $24,750 \text{ m}^3 \text{ water ha}^{-1} \text{ y}^{-1}$ , which is all obtained from a bore hole. This is the situation as existed up to mid 2008 at Olij. The total amount of waste water is  $11,250 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , which includes  $11,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  drain water which trickles directly into the ground and  $250 \text{ m}^3 \text{ water ha}^{-1} \text{ y}^{-1}$  for cleaning filters.

**System 2**

As a first improvement, drain is reduced from 45% to 30%. This is realized by applying less water. An open system with 30% instead of 45% leaching to the outdoor environment requires  $19,200 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , which is all obtained from a bore hole. The total amount of waste water is  $5,850 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , which includes  $5,650 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  leaching and  $200 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  for cleaning filters. Water savings are 22% in comparison with System 1.

**System 3**

The introduction of a closed recirculation system with reversed osmosis has a great impact. Assuming 50% drain that is recirculated, total water use from the bore hole is  $14,500 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , which implies water savings of 42% in comparison with System 1.

#### System 4

If the drain that is recirculated in a closed system is reduced from 50% to 25%, then total water use from the bore hole is  $14,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , which implies water savings of 44% in comparison with System 1. The additional savings in comparison with System 3 (50% drain that is recirculated) are marginal. The reason is that the amount of water leached does not depend on the drain that is recirculated, but on the quantity of Na building up. This build-up is fairly independent of the drainpercentage.

#### System 5

If the capacity of the reversed osmosis is reduced too, in this case,  $425 \text{ m}^3 \text{ d}^{-1}$ , then additional bore hole water is needed to meet the demands of the crop. As the Na content of the bore hole water is relatively high, and as the reversed osmosis system can not remove the Na, this implies more leaching to outdoor. Total water use from the bore hole is  $14,500 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , of which  $7,500 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  is not purified, and  $7,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  is purified by the reversed osmosis. Water savings are 42% in comparison with System 1.

#### System 6

Whatever rain water is used, does not need to be pumped from a bore hole. With a small basin capacity of  $600 \text{ m}^3 \text{ ha}^{-1}$ ,  $5,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  rain water can be used, which is complemented with  $9,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  bore hole water. Water savings are 64% in comparison with System 1.

#### System 7

A larger rain water basin of  $3000 \text{ m}^3 \text{ ha}^{-1}$  implies that  $9,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  rain water can be used, which is complemented with  $5,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  bore hole water. Water savings are 80% in comparison with System 1.

In comparison: water use in a greenhouse in The Netherlands, with assimilation lights and heating, is approximately  $9,000 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ .

Table 1. The water balance of Olij Roses. Water use from the bore hole is shaded. RO = reversed osmosis.

system	water source ( $\text{m}^3 \text{ ha}^{-1}$ )			drain %	waste water ( $\text{m}^3 \text{ ha}^{-1}$ )	water savings (%)
	bore hole		rain			
	not purified	purified				
1 Open	24750			45	11250	
2 Open	19200			30	5850	22
3 Closed + RO $600 \text{ m}^3 \text{ d}^{-1}$		14500		50	1000	42
4 Closed + RO $600 \text{ m}^3 \text{ d}^{-1}$		14000		25	750	44
5 Closed + RO $425 \text{ m}^3 \text{ d}^{-1}$	7500	7000		50	1000	42
6 Closed + RO $450 \text{ m}^3 \text{ d}^{-1}$ (basin $600 \text{ m}^3 \text{ ha}^{-1}$ )		9000	5000	25	750	64
7 Closed + RO $400 \text{ m}^3 \text{ d}^{-1}$ (basin $3000 \text{ m}^3 \text{ ha}^{-1}$ )		5000	9000	25	750	80

### 3.4 Effect of climate

There are no major environmental differences between 2007 and 2008, as is summarized in Table 2 (see also Annex I).

Computations show that the small differences lead to 3% more water use in 2008 than in 2007. This does not have a significant impact on the water balance data.

*Table 2. Average daily values for a number of environmental characters in 2007 and 2008 in Debre Zeit.*

year	Temp min (°C)	Temp max (°C)	Temp av (°C)	Relative Air Humidity (in greenhouse) (%)	Radiation (J cm <sup>2</sup> )	Rainfall (mm)
2007	16.5	21.4	18.9	68	2148	726
2008	16.2	21.5	18.9	65	2211	

Because of the small differences between 2007 and 2008, nothing can be said about the effects of more extreme weather conditions, such as a higher greenhouse temperature due to higher radiation.

However, it should be noted that a system that makes use of bore hole water and reversed osmosis is less susceptible to fluctuations in water availability than systems that heavily rely on rain water. If the same amount of water falls within a shorter time period, then the basin may overflow and the water may be lost. On the other hand, if the rainfall distribution of the same amount of water is more even, then its utilization is better.

### 3.5 Discussion

System 1 is an open system that takes all water from the bore hole and uses its water just once.

There are three ways to save water:

1. Reduce the drain.
2. Close the system, re-circulate water, for instance in combination with reversed osmosis.
3. Use rain water.

A first step in water savings can be made by reducing the drain: a reduction from 45% to 30% saves 22% of water.

If the system is closed, then additional water savings are more than 40%. Some variation exists within a closed system in terms of water distribution. More drain that is recirculated implies more leakage and filter cleaning (so, more waste water). If the basin is filled with water, then water requirements in the dry months of e.g., March and October can be met from the water basin, without pumping additional bore hole water.

The use of rain water has an immediate impact on the use of bore hole water. Whatever rain water is preserved, does not need to be pumped from the bore hole. The size of the basin plays therefore an important role here. In the example calculations, and 20-38% less water is needed compared to a closed system without rainwater use, and 60-80% less water is needed compared to an open system.

Therefore, if all technologies are put together, then more than 60-80% bore hole water can be saved.

Drain reduction accounts for approximately 20%, closing the system for approximately another 20%, and the remaining 20-40% is accounted for by the use of rain water (depending on the size of the basin).

With an estimated water use of 24,750 m<sup>3</sup> ha<sup>-1</sup> y<sup>-1</sup> bore hole water in open systems, the savings are 15,750 to 19,750 m<sup>3</sup> ha<sup>-1</sup> y<sup>-1</sup>. For each 100 ha of greenhouses, this equals 1.6-2.0 million m<sup>3</sup> y<sup>-1</sup>.

## 4 J.J. Kothari

### 4.1 Summary

### 4.2 Assumptions

As not all details of the nursery were known some assumptions had to be made:

- Computations are in  $\text{m}^3$  per ha per year.
- Day length is 12 hours, all year through.
- Condensation water is not retrieved.
- The nursery uses ground water of a certain quality, the quality itself (contents of salts or metals or EC) is unknown. The sodium level in the additional water were assumed at 0.1, 0.5 or 1.0  $\text{mmol/l}$ .
- Climate data of the nursery are collected from the weather station of the climate computer of the year 2007, which include temperature relative humidity, radiation and rainfall. Missing data were estimated.
- Although the farm possesses heating pipes, these were assumed not to be used (of importance for calculations of transpiration of the crop).
- No artificial lighting, and as a starting point there is no rain water basin.
- Crop transpiration is in all situations  $12600 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , which is based on the available climate data.
- There are various types of waste water: filter cleaning, leakage, and leaching to the outside. Filter cleaning takes  $200\text{-}250 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ , and leakage is  $0\text{-}200 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ .

### 4.3 Technological Levels

A number of different situations have been investigated. As a starting point, the open system with free drainage as recently existed, has been chosen. The rose crop is cultivated on substrate, as is actually the case at J.J. Kothari. Different levels of sodium (Na) in the ground water are assumed. More Na implies more frequent flushing of the irrigation water in case of recirculation, and therefore a greater water consumption. Technical improvements are added in further computations: reduced drainage, recirculation of water, and storage of rain water.

#### System 1

Calculations were started for a rose nursery with plants cultivated on substrate. There is no circulation and the drain percentage is 45% (and therefore fully leached to the outdoor environment). The only water supply is bore hole water.

Three different concentrations of Na ( $0.1$ ,  $0.5$  and  $1.0 \text{ mmol l}^{-1}$ ) were assumed (systems 1a, 1b and 1c).

#### System 2

As a first improvement, drain is reduced from 45% to 25%, which is realized by applying less water.

The same three sodium concentrations were assumed (systems 2a, 2b and 2c).

#### System 3

Ground water can be (partly) replaced by rain water. Rain water has two advantages: it reduces the use of ground water, and it does not contain sodium, resulting in a lower frequency of flushing the system.

The size of the rain water basin was assumed to be  $500 \text{ m}^3 \text{ ha}^{-1}$ .

The same three sodium concentrations were assumed (systems 3a, 3b and 3c).

#### System 4

As system 3c (high sodium), but with a rain water basin of 1500 m<sup>3</sup> ha<sup>-1</sup>.

## 4.4 Results

Table 3. The water balance of J.J. Kothari. Water use from the bore hole is shaded.

System	Na (mmol l <sup>-1</sup> )	water source (m <sup>3</sup> ha <sup>-1</sup> )			drain %	waste water (m <sup>3</sup> ha <sup>-1</sup> )	water savings (%)
		bore hole		rain			
		not purified	purified				
1a open	0.1	23250	0	23250	45	10650	
1b open	0.5	23250	0	23250	45	10650	0
1c open	1.0	24400	0	24400	45	11800	-5
2a open	0.1	17200	0	17200	25	4600	26
2b open	0.5	17200	0	17200	25	4600	26
2c open	1.0	18250	0	18250	25	6900	22
3a Closed (basin 500 m <sup>3</sup> ha <sup>-1</sup> )	0.1	8600	0	4500 13100	25	400	63
3b Closed (basin 500 m <sup>3</sup> ha <sup>-1</sup> )	0.5	8600	0	4500 13100	25	400	63
3c Closed (basin 500 m <sup>3</sup> ha <sup>-1</sup> )	1.0	9200	0	4500 13700	25	1000	60
4 Closed (basin 1500 m <sup>3</sup> ha <sup>-1</sup> )	1.0	8200	0	5500 13700	25	950	65

#### System 1

System 1a can be considered to resemble the present situation. The total water usage was estimated at 23250 m<sup>3</sup> ha<sup>-1</sup>. A higher sodium concentration in the ground water influences the accumulation of this element in the (open) system. The Na concentration in system 1a is around 0.5-0.6, in system 1b constant at around 2.6 mmol l<sup>-1</sup>. In system 1c (Na concentration in the ground water at 1.0 mmol l<sup>-1</sup>) additional leaching is required to maintain the Na concentration between 3 and 4 mmol l<sup>-1</sup> (4 mmol l<sup>-1</sup> is the value above which a decrease in growth may be expected). Each week about 25 m<sup>3</sup> water ha<sup>-1</sup> should be additionally leached to decrease the sodium level in the substrate.

#### System 2

Water is saved in system 2 with about 25% by decreasing the drain percentage, while the sodium concentration in the substrate is not rising. The lower drain percentage of 25%, combined with a sodium concentration in the supply water of 0.1 or 0.5 mmol l<sup>-1</sup> does not harm the crop. However, at a sodium level of 1.0 mmol l<sup>-1</sup> a similar amount of water has to be leached as compared to the situation with a drain percentage of 45% (system 1c).

#### Systems 3 and 4

Ground water can be (partly) replaced by rain water. Rain water has two advantages: it reduces the use of ground water, and it does not contain sodium, resulting in a lower frequency of flushing the system.

The size of the rain water basin was assumed to be 500 m<sup>3</sup> ha<sup>-1</sup>.



The same three sodium concentrations were assumed (systems 3a, 3b and 3c).

Collection of rain water and re-circulation of drainwater will save more than 60% of water, even if the drain collection tank is only  $500 \text{ m}^3 \text{ ha}^{-1}$  (situation 3). If the storage capacity is larger,  $1500 \text{ m}^3 \text{ ha}^{-1}$  (situation 4), the total water amount does not change ( $13700 \text{ m}^3 \text{ ha}^{-1}$ ), but there is a shift of water source from less bore hole water to more rain water). This results in a further saving of bore hole water of 65%. A collection tank of  $500 \text{ m}^3 \text{ ha}^{-1}$  may cover a water need of 33% of the total water requirements, while a basin of  $1500 \text{ m}^3 \text{ ha}^{-1}$  may cover a need of 40% of the total water requirements.

## 4.5 Discussion

The concentration of nutrients influences the frequency with which the system needs to be flushed to avoid accumulation and detrimental effects on crop growth. The introduction of a closed system leads to approximately 25% reduction of water use. Informal discussions with the farm manager (held earlier) indicated that reduction of the drain fraction negatively influenced crop growth, for reasons that are not clear. It is therefore advised to be cautious.

While the calculations use sodium as example salt, the same principles hold for other salts: accumulation of salts require additional leaching and therefore extra water use.

Recirculation of water, in combination with use of rain water, can reduce the amount of ground water used by another 35-40%, bring the total water savings to 60-65%. Even if water is cheap (in a strict monetary sense) and sufficiently available, the amount of wasted nutrients can be reduced dramatically.

With an estimated water use of  $23,250 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  bore hole water in open systems, the savings are 14,050 to  $15,050 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$ . For each 100 ha of greenhouses, this equals 1.4-1.5 million  $\text{m}^3 \text{ y}^{-1}$ .



## 5 General Discussion

Water use can be reduced through implementation of the following technologies:

*Table 4. Summary of water saving options.*

Technology	Olij Roses at Debre Zeit	J.J. Kothari at Sululta
Reduction of drain	20 %	25 %
Usage of rain water in water storage	20 %	35-40%
Re-circulation of drain water, possibly in combination with reversed osmosis to purify the water	20-40 %	
Combination of all technology	60-80%	60-65%

If these figures are accumulated, then total water savings of 60-80% are possible. In absolute numbers, this equals for each 100 ha of greenhouses to 1.5-2.0 million m<sup>3</sup> y<sup>-1</sup>. At other locations, with other parameters, savings may be different, however, it can be safely assumed that considerable water savings are possible in the Ethiopian protected rose industry if adequate technology is adopted.

Not only water can be saved, but also nutrients. This has positive effects on the environment, and saves the grower expenses. Measurements and computations always show that the relative savings of nutrients is greater than the relative savings of water. This has to do, amongst others, with the higher nutrient concentration in the leaching water than in the irrigation water.

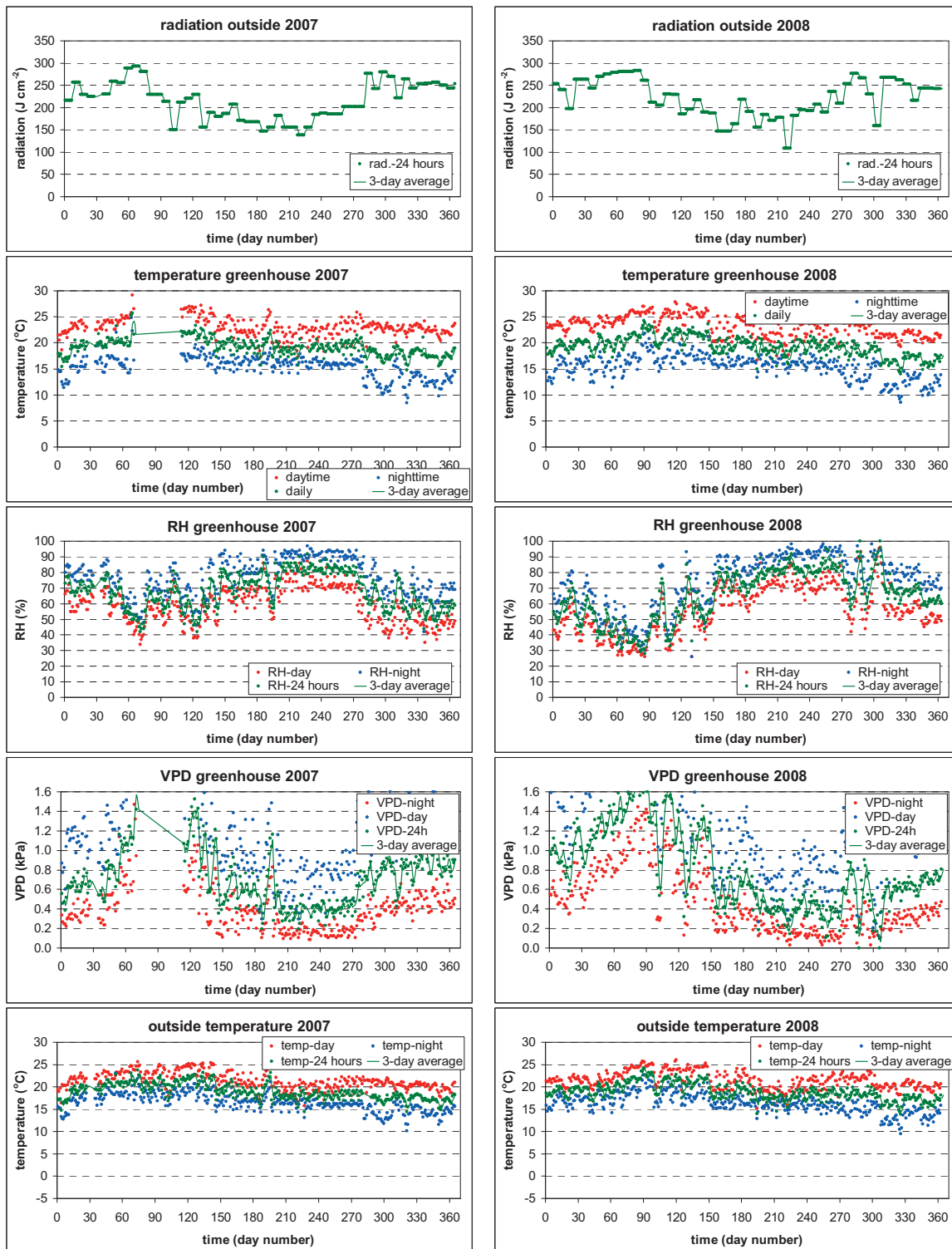
In additions, leaching of pesticides will reduce (as has been observed in The Netherlands).

The high drainage fractions are mainly caused by the belief of most rose growers that this improves production. Part of the yield reduction for some cultivars (and certainly not all) may be caused by accumulating root exudates in the recirculating water. Recent research (van Os, personal report) shows that adding hydrogen peroxide in combination with UV radiation to reduce pathogens may reduce growth inhibition dramatically.



# Annex I.

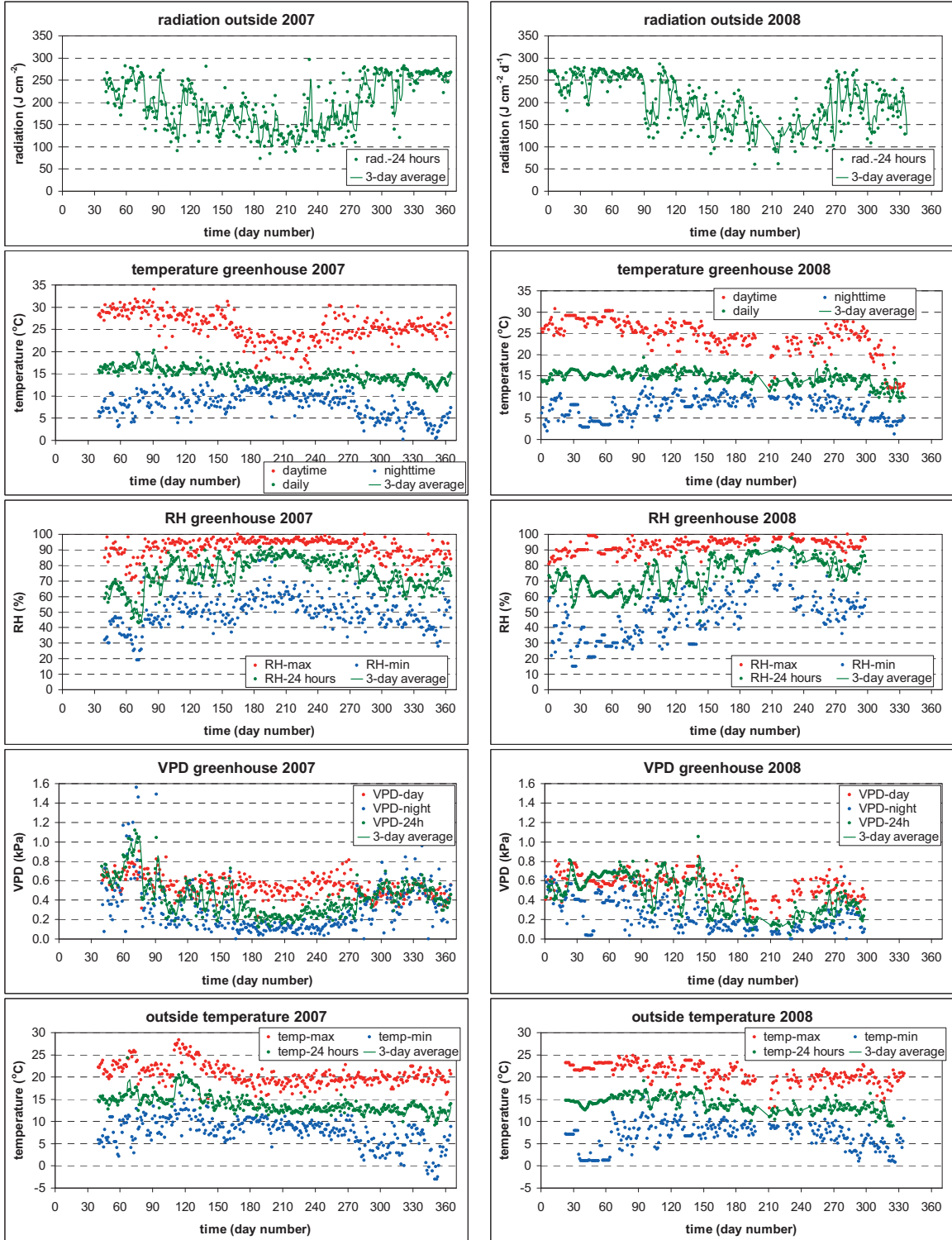
## Climate overview of Olij Roses at Debre Zeit

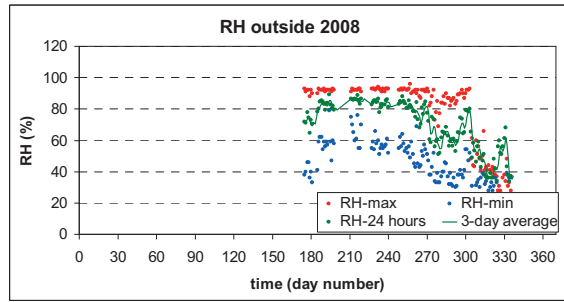
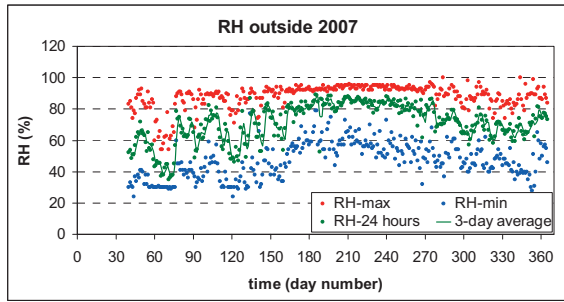




# Annex II.

## Climate overview of J.J. Kothari at Sululta







## Annex III.

# The 'WATERSTROMEN' (Water Streams) model

Model WATERSTROMEN , version 5.3

W. Voogt

The model WATERSTROMEN estimates the ingoing and outgoing water flows at a commercial nursery during a year or a growing cycle of a crop. The model uses the transpiration model from de Graaf (1988) and some modifications introduced by Voogt *et al.*, (2000) and parameters to simulate the water uptake for crop growth. Climate data such as temperature, the sum of radiation and precipitation as well as related greenhouse climate data are used as input. A number of parameters are used to calculate the various water fluxes on a daily base. The volume of the rain water collection is a fundamental parameter, because rainwater is used as the primary water source. The chosen year is a variable and can be characterized as a dry, a wet or a cold year (more variables available) following a real time dynamic year from last thirty years of the weather data from Naaldwijk (official KNMI weather station). The ten most important greenhouse crops can be chosen, amongst them tomato, sweet pepper, cucumber, rose and gerbera. For each crop some crop specific parameter values need to be chosen (day/night temperature, intensity and duration of artificial lighting, Na threshold value, Na specific uptake). Other parameter values to be chosen are: sources of additional water with their sodium concentration, the drain fraction, fraction of leakage and filter cleaning water, system values, etc.). As a result of the mentioned input data the model WATERSTROMEN calculates per day the amount of used rainwater, additional water and condensation water. Further the crop uptake, the required amount of discharge of the nutrient solution, resulting from Na accumulation above the threshold value and amounts of leakage and filter cleaning water are calculated. Results are presented in tables and graphs. Besides the emission of water with nutrients caused by high sodium levels, the emission of N and P and other elements can be estimated. As all parameters can be easily changed the model can be adapted to specific situations. The model WATERSTROMEN is still in development.

