



Uptake and distribution of iodine in cucumber, sweet pepper, round, and cherry tomato

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Rapport GTB-1329



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Referaat

Eénderde van de wereldbevolking lijdt aan een tekort aan het essentiële voedingselement jodium (I). De verrijking van groenten met jodium (biofortificatie) kan dit jodiumtekort helpen voorkomen. Daarom werd het effect bestudeerd van toediening van jodium-verrijkte meststoffen op de jodiumgehalten in komkommer, ronde - en kerstomaten en paprikavruchten, opgekweekt in steenwol met hergebruik van het drainwater. De jodiumgehalten (mg I/kg vruchtversgewicht) varieerden van 0.01 in paprika tot 0.12 in komkommer bij 125 ppm I in de toegediende meststoffen. Een dagelijkse portie van 80 gram komkommer, tomaat of paprika (bij 125 ppm I in de meststoffen) resulteert in 3-10 µg jodiuminname, wat overeenkomt met 2-7% van de dagelijkse jodiumbehoefte van een volwassene.

Abstract

Iodine is an essential element for human health. Biofortification of vegetables by application of iodine-enriched fertilizers may help prevent iodine deficiency disorders. In a trial with cucumber, tomato (cherry- and round type), and sweet pepper, grown in rockwool in a closed growing system with re-use of drainage water, iodine was applied as IO_3^- (Iodate) at a level of 0, 12.5 and 125 ppm I of the total fertilisers. Average concentrations for the three Iodine (I) levels were 5, 23.4 and 148 ppm in the nutrient solution, and 9.1, 38.9 and 171.8 ppm in the drainage. Iodine concentrations in plant material strongly correlated with Iodine supply. The majority of the Iodine was detected in vegetative parts. Average concentrations in fruits (mg I/kg fresh weight) for the 12.5 and the 125 ppm level were: 0.02 and 0.12 (cucumber), 0.01 and 0.04 (sweet pepper), 0.01 and 0.05 (round tomato), 0.03 and 0.12 (cherry tomato), respectively. Total biomass, yield and fruit quality were not affected by Iodate application. The outcomes demonstrate that a portion of 80 grams of these fruiting vegetables, grown with fertilizers containing 125 mg I/kg fertilizers, constitutes 3-10 µg of iodine intake, i.e., 2-7% of the daily iodine requirement for an adult.

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1 Introduction and problem definition

Iodine is a micro-element that is fundamental for human health and well-being. For adults the adequate intake for iodine is 150 µg per day (EFSA NDA Panel, 2014). About 2 billion people, both in developing and developed countries, are affected by iodine deficiency (Andersson *et al.* 2012). The main strategy for controlling and preventing iodine deficiency is the universal fortification of salt with iodine, which has dramatically reduced the prevalence of IDD (Zimmermann, 2009; Andersson *et al.* 2010). However, a further boost to the consumption of iodized salt is becoming increasingly untenable as it conflicts with other important public health objectives, such as the prevention of cardiovascular diseases (Kiferle *et al.* 2013). Alternatively iodine enriched vegetables, also known as biofortification may help to control this malnutrition. Agronomic biofortification through the application of micronutrient-enriched fertilizers, has been successfully studied in various crops.

Positive results with iodine, both applied as iodate (IO_3^-) and iodide (I^-), have been obtained in trials carried out in leafy vegetables, like lettuce and spinach, particularly in hydroponic culture (Zhu *et al.* 2003; Dai *et al.* 2004; Blasco *et al.* 2008; Hong *et al.* 2008; Weng *et al.* 2008; Voogt *et al.* 2010; Voogt and Jackson, 2010). With respect to fruit vegetables, tomato was found to be a good candidate for iodine biofortification programme (Gonda *et al.* 2007; Caffagni *et al.* 2011; Landini *et al.* 2011; Kiferle *et al.* 2013), due to its widespread distribution and possible consumption as a fresh fruit. Indeed, effective iodine accumulation within the fruits was achieved, when tomato was grown in potting soil in a greenhouse. In tomato fruits, levels up to 10 mg iodine per kg of fresh fruit weight were reported when plants were submitted to nutrient solutions containing up to 10 mM KI (Kiferle *et al.* 2013). However, so far agronomic biofortification studies were conducted with short cropping periods only. In addition, when it comes to fruit vegetables as a selected target crop, these studies were conducted on round tomatoes only.

The purpose of this study is to assess the iodine uptake and distribution among the various plant parts of fruit vegetables, grown in soilless-culture in a closed growing system, when the crop is constantly exposed to iodate concentrations in the diluted nutrient solution. Soilless culture with fully closed growing system means that no discharge or leakage of water and dissolved nutrients and iodine is supposed to take place. In other words, plant roots are constantly exposed to all iodine supplied via the nutrient solution. The selected crops are: cucumber, sweet pepper, round tomato and cherry tomato, which are the main fruit vegetable crops, grown in greenhouses, worldwide. The growing system follows common growing practices of professional Dutch fruit vegetable growers, for the greenhouse climate control a compromise was made between the specific conditions for the four crop. In this trial the treatments with iodate (IO_3^-) were combined with ClO_4^- supply in the nutrient solution. In this report we concentrate on iodate. The motivation to incorporate ClO_4^- and the effect of the ClO_4^- supply on uptake and distribution is discussed in another report (Voogt *et al.* 2014).

Each crop will be evaluated on its suitability for iodine biofortification programs by comparing the iodine concentration in the fruits of the selected crops to the adequate intake level of 150 µg iodine per day for an adult.

2 Materials and methods

2.1 Treatments

The trial consisted of three iodine levels, in combination with three ClO_4^- levels. The iodine levels were 0 ppm, 12.5 ppm and 125 ppm in the fertiliser solution, expressed on the total weight of fertilisers as used for the standard nutrient solution for tomato in rockwool (Sonneveld and Voogt, 2009) (Appendix II). Iodine was added in the form of iodate (IO_3^-) by dissolving potassium iodate salt (KIO_3). Each treatment had two replicates in the greenhouse.

The concentrations of iodate used in this experiment as well as the expected concentrations in the diluted nutrient solution to be supplied to the irrigation water are shown in Table 1.

Table 1

The ClO_4^- and IO_3^- levels, expressed in ppm of the total fertilisers applied in fruit vegetable crops in soil-less culture with recirculating nutrient solution and expressed in mg/litre of the diluted nutrient solution (NS) supplied.

Treatment	ClO_4^- , ppm mg/kg fertilisers applied)	IO_3^- , ppm (expressed as I) mg/kg fertilisers applied	Expected concentration in nutrient solution ClO_4^- mg/l	Expected IO_3^- concentration in NS (expressed as I) mg/l
1	0	0	0.000	0.000
2	12.5	12.5	0.019	0.019
3	25	12.5	0.038	0.019
4	0	125	0.000	0.190
5	12.5	12.5	0.019	0.019
6	25	12.5	0.038	0.019

Four fruit vegetable crops were used in the experiment, with the following varieties :

1. Cucumber, a standard variety English cucumber: cultivar 'Proloog', (Rijk Zwaan),
2. Tomato, course vine type: cultivar 'Komeett', (De Ruiter Seeds),
3. Tomato, cherry type: cultivar 'Sassari', (Rijk Zwaan),
4. Sweet pepper, red type: cultivar 'Maranello', (Enza Zaden).

2.2 Crops and growing conditions

Four fruit vegetable crops (cucumber, sweet pepper, round- and cherry tomato), were grown in a standard greenhouse compartment at location Bleiswijk of Wageningen University and Research in the Netherlands. To compromise the different optimal climatic conditions for these crops, average set points for greenhouse climate (heating, ventilation, humidity, and screening) were used. Because the natural lighting conditions in the fall decreased, additional artificial light was given to the crop from mid-September onwards. For this the individual plots were split in four identical areas as described in 2.4. The total net cropping area was 120 m². For each crop 30 m² area was available. The plant density for each crop was 2.5 plants per m². The experiment started on July 11th 2013 and the crop was terminated on November 6th 2013. The crops were grown in rockwool slabs (15 * 7.5 * 133 cm), placed in coated steel gutters. Drainage water was collected in reservoirs and pumped (volume dependent) to the buffer tank with irrigation water. Irrigation was controlled by computer and was scheduled according to commercial practice: first event at sunrise, then consecutive events until 2 hours before sunset. The total irrigation was aimed to reach on average a drainage fraction of 0.25 (drainage / irrigation v/v) on a daily basis.

2.3 Nutrient solutions

The water source for the nutrient solutions was 100 % by reverse osmosis desalinated well-water. The nutrient solution was composed from a specific mixture of fertilisers: aiming at zero ClO_4^- and zero iodine. The following fertilisers, free of perchlorate and iodine, were used: $5(\text{Ca}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}) \cdot \text{NH}_4\text{NO}_3$, NH_4NO_3 (liquid), $\text{Mg}(\text{NO}_3)_2$ (liquid), KNO_3 , KH_2PO_4 , $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ and K_2SO_4 . Additionally some CaCl_2 or KCl was used.

Micro elements: Fe as Fe-EDDHA 6%, furthermore $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{NaMoO}_7 \cdot 2\text{H}_2\text{O}$, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$. The nutrient solution chosen was a compromise between the standard nutrient solutions for the four crops. During the growing cycle a few adjustments were made. Before planting the rockwool slabs were saturated with a standard solution composed as such to reach the target values for nutrients in the root environment. At the start during the first three weeks, a starter solution was used, with additional Fe. From early August onwards the "standard" solution was used, with sometimes adjustments with micro elements. In the last week of September and the first week of October additional KCl was added in the buffer tanks to correct for the gradually decreased K level; during three weeks 4 mmol/l K was added.

The basic compositions of the nutrient solutions which have been used in this trial are listed in Table 2. These nutrient solutions – except for the "saturation" solution - are expressed in mmol/l and represent the relative concentrations which will be added to the system. The average concentrations in the (drip-) irrigation water then will be a mixture of the composition of the drainage solution and the nutrient solution freshly added. This concept of nutrient solution has been designed in such a way that equilibrium is reached between the concentrations and nutrient ratios in the root environment, the drainage and the irrigation water as required by the nutrient recommendation system (De Kreij *et al.* 2003).

The fertiliser nutrient solution was prepared in 100 times concentrated stock solutions A and B (Appendix I) by which the EC and pH in the irrigation tanks were controlled. The setpoint ranges for EC and pH were between 3.5 and 4.5 mS/cm and between 5.5 and 6.5 respectively for the root environment. The EC and pH in the irrigation were adjusted accordingly. The iodine and perchlorate treatments were effectuated by addition of the required quantities of KIO_3 and KClO_4 , by using concentrated solutions of these salts (Appendix II).

Table 2

The basic composition of the different nutrient solutions for supply to the recirculating nutrient solution used for this experiment.

Elements	Nutrient solution		
	to saturate the rockwool	start	standard
	Used from		
	8-July-13	11-July-13	7-Aug-13
EC, mS/cm	3.00	1.50	1.50
NH ₄ , mmol/l	0.50	1.20	1.20
K, mmol/l	6.50	5.00	5.00
Ca, mmol/l	7.50	3.30	3.30
Mg, mmol/l	4.00	1.10	1.10
NO ₃ , mmol/l	20.10	11.25	11.25
Cl, mmol/l	1.50	0.00	0.00
SO ₄ , mmol/l	3.63	1.25	1.25
P, mmol/l	1.25	1.25	1.25
Fe, umol/l	25.00	25.00	15.00
Mn, umol/l	7.00	10.00	10.00
Zn, umol/l	7.00	4.00	4.00
B, umol/l	60.00	25.00	25.00
Cu, umol/l	1.10	0.80	0.80
Mo, umol/l	0.50	0.50	0.50

2.4 Experimental setup and technical design

Each of the six treatments (nutrient solutions) consisted of two individual plant rows, which were considered as replicate plots (Figure 1). The individual crops were grouped together in sections, which were situated longitudinal of the compartment. As a consequence, all four crops were placed in sequence on the gutters, so all four crops are irrigated with exactly the same quantity and concentrations. Drainage water could not be segregated per individual crop.

Each plant row had a drainage gutter which was split in a front and a back half, each of them sloping down to the middle of the greenhouse. The drainage was collected from the two halves and transported to the drainage tank (Photo 1). The total drainage from two replicate plant rows was collected in one drainage tank. As on each plant row four crops were grown, neither irrigation – nor drainage water could be allocated to individual crops. The drainage collection tanks were underground in the greenhouse. The water from the specific drainage tank was pumped to the specific irrigation tank in the technical corridor outside the greenhouse (Photo 2). This was controlled by a float valve in the drainage tank. The irrigation and drainage system was regularly checked for leaks. If there was leakage, the leaks were sealed. Eventually the leakage from the system was negligible.

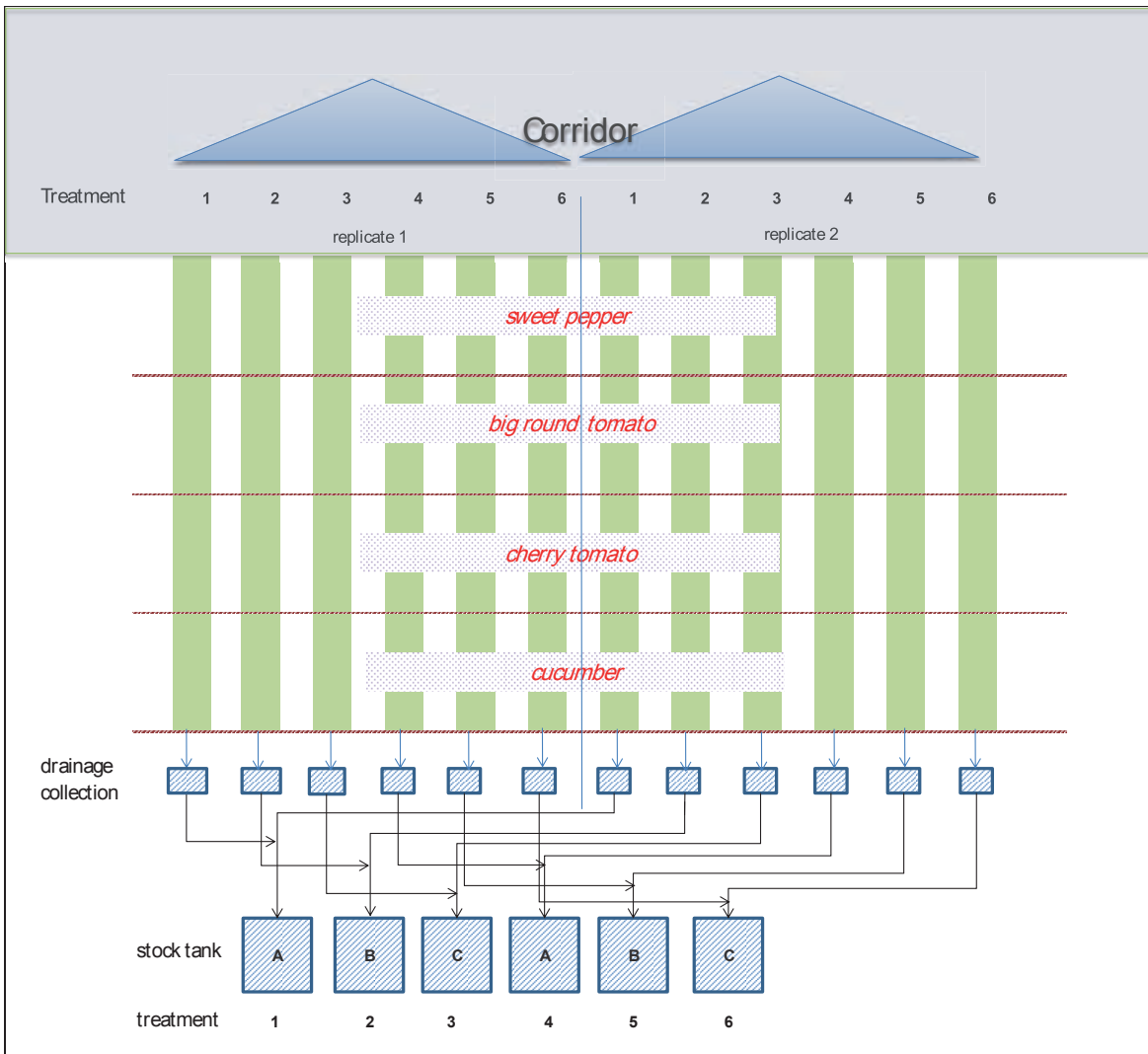


Figure 1 Map of the greenhouse with experimental lay-out of crops and gutters.



Photo 1 The drainage tank half under the ground in the greenhouse collects the drainage from two plant rows. The water from the drainage tank was pumped to an irrigation tank in the technical corridor outside the greenhouse. This was controlled by a float valve in the drainage tank.



Photo 2 Irrigation tanks in the technical corridor outside the greenhouse. Irrigation was controlled by computer and was scheduled to reach on average 25% drainage water on a daily basis.

The irrigation tank was topped up one to three times a week, depending on the water consumption. The treatments were pro ratio supplied to the input of water into the irrigation tank. The required dosage of concentrated fertiliser was determined each time by: target values for EC and pH in the root environment, development in time of the EC and pH in the drainage, expected weather and time of the year. In all cases the rate between ClO_4^- , IO_3^- and the fertiliser solution supplied was kept constant, by keeping the ratio between concentrated fertilisers solution (A and B) and KClO_4 and KIO_3 according to the different treatments.

2.5 Samples and analysis

The following data and measurements were monitored throughout the experiment (next to routine greenhouse climate and meteorological data).

- EC and pH of irrigation and drainage water
- The total water supply per treatment
- Net water use per treatment
- Total nutrient supply
- Net nutrient uptake
- Total IO_3^- supply
- Nutrient concentrations in the
 - drainage (biweekly)
 - supply (four weekly)
 - stock solution (once)
- Concentrations IO_3^- in:
 - supply (four weekly)
 - drainage (biweekly)
 - raw water (four weekly)
- Biomass production:
 - pruned old leaves, side shoots: fresh matter, dry matter
 - final total plant: stem, leaves: fresh and dry matter
 - harvested fruits: fresh and dry matter
- Biomass contents: I total and nutrients (K, N-total, Ca, Mg, S-total, P-total) in dry matter in subsamples from:
 - all above ground biomass: pooled subsamples from weekly pruned side shoots and old leaves and final crop residuals
 - fruits at three intervals, pooled subsamples from first yield, from halfway yield and from final yield

Dry matter determination

Fresh matter was gathered and subsamples were dried. For vegetation, the samples were dried for 24 h at 80°C. Fruit samples were dried during 48 h at 80°C. All samples were grinded to very fine powder with a hand coffee-mill (Moulinex, type 505), with stainless steel housing and blade.

Analysis tissue content

The dried plant samples are investigated for iodine by ICP-MS by UT2A the analytical laboratory of Pau University (France). The method followed was described as EN11-115. With this method no discrimination between I^- and IO_3^- is possible. The quantification limit (LQ) for I in plant tissue was 0.1 mg/kg. The major and trace elements were analysed by Groen Agro Control, Delfgauw (The Netherlands).

Analysis nutrient solutions

The nutrient solutions are investigated for perchlorate and iodine by UT2A (France). Total iodine concentrations were determined in filtrated solutions by ICP-MS. The quantification limit for the nutrient solution was 0.1 µg/L. The major and trace elements in the nutrient solutions were analysed by Groen Agro Control, Delfgauw (The Netherlands). The routine macro and micro elements were determined in filtrated solutions using ICP.

Protocol for plant samples

During the trial the pruned parts i.e. side shoots for all crops, as well as leaves for cucumber and both tomato crops were monitored (by weight) collected and sampled. Note: sweet pepper leaves were not pruned. All pruned side shoots of each crop were collected per gutter and directly put in plastic bags and cool stored, later on weighted per gutter. The same for pruned leaves. The materials – or in case of too much biomass, subsamples – were taken each time for determination of dry matter content. These dry matter samples were stored and later on pooled together to compose samples for determination of iodine and minerals. For the iodine analysis, per crop and per treatment all pruned leaf subsamples taken during the crop cycle were pooled together.

All harvested fruits were weighted each time and subsamples were taken for dry matter determination. Cucumber: four fruits at each harvesting session were cut transversal into four sections, from each fruit one section was used to compose the sample, sections taken equally over the whole 'fruit'. Tomato: five fruits per harvesting session were cut in halves (radial), five halves were used for the sample. Cherry tomato: ten complete fruits were used for the sample. Sweet pepper: five fruits were cut in halves (radial), five halves were used in the sample.

For determination of iodine in fruits samples were taken at three moments during the harvesting period for all four crops. (Table 3). The sampling and preparation were carried out as described above. For iodine analysis, the dry matter of the three harvesting dates were pooled together, the two replicate treatments were analysed separately.

At crop termination all remaining plant parts, leaves and stems (except roots) were harvested and weighted per plot. Subsamples were taken for determination of dry matter content and total I analysis.

Table 3

Sampling schedule of fruits harvested for dry matter, IO_3^- and mineral determination.

Crop	Harvest	Week	Date(s)	Truss numbers, (harvest)	
Cucumber	1	31	2-Aug-13	first cucumbers	
	2	38-39	18-Sep-13 20-Sep-13	two harvest dates	pooled samples
	3	44	28-Oct-13 30-Oct-13	two harvest dates	
Sweet pepper	1	40	1-Oct-13	first red sweet peppers	
	2	41	10-Oct-13	one harvest date	pooled samples
	3	44	28-Oct-13	one harvest date	
Tomato, round	1	37-38	11-Sep-13 16-Sep-13	truss number 1 (two harvest dates)	
	2	40-41	1-Oct-13 10-Oct-13	truss number 4 (two harvest dates)	pooled samples
	3	44	28-Oct-13	truss number 6 (one harvest date)	
Tomato, cherry	1	35-36	27-Aug-13 2-Sep-13	truss number 1 (two harvest dates)	
	2	40	1-Oct-13	truss number 6 (one harvest date)	pooled samples
	3	44	28-Oct-13	truss number 9 and 10 (one harvest date)	

2.6 Balance calculation

At crop termination all crop residuals were measured and sampled for dry matter determination and analysis for iodine and mineral content. An estimate of the balance of iodine was calculated as an indicator for the accuracy of the approach of the balance calculation.

Input

The sources in water, fertilisers were taken into consideration as well as the supply of KIO_3 in the treatments. For IO_3^- the presence in rockwool, plant material and other materials at start were considered to be zero.

Output

Crop removal: The dry matter quantities derived from the monitored leaf and side shoot prunings were multiplied with the analysed total iodine (I) in the corresponding samples. The same was done for the fruits harvested.

In this case using the cumulated dry matter until each of the three sampling session dates and multiplied with the total iodine (I) levels of the corresponding session. The dry matter contents of crop residues in the plant at the end of the experiment were multiplied with the analysed total iodine (I) in the dry matter samples taken at termination. The total sum of total iodine (I) was considered as output.

Residuals: The residual IO_3^- in the growing system i.e. the remaining drainage water, the stock tank as well as the water in the rockwool slab (estimated by considering 40 % water saturation) was calculated by multiplication of the total volume water with the last known iodine (I) concentration analysed in the drainage.

The balance was closed by deducting the output from the input, leaving the difference as the unexplained quantity. The quantity of total iodine (I) and minerals present in roots could not be determined, as it was practically impossible to quantify the root mass in a rockwool slab.

3 Results

3.1 Growth and development

Young plants were purchased from a commercial nursery, and were raised in rock wool cubes (0.75 l). After saturation of the rock wool slabs, the plants were placed on July 11th on the rock wool slabs. The plant density of each crop is 2.5 plants per m² (Photo 3).



Photo 3 The four different crops on July 18th, one week after planting. In front sweet pepper, then tomato round, cherry tomato and at the end cucumber.



Photo 4 The four different crops on August 8th, one month after planting. In front sweet pepper, then tomato round, cherry tomato and at the end cucumber.

In sweet pepper three stems per plant were used. Both tomato crops and the cucumber were grown by high wire system: the main stem was kept only and the top was always kept upright (Photo 4).

From July 18th for cucumber and both tomato varieties and from August 5th for sweet pepper, side shoots were pruned weekly. After the first harvest of the cucumbers on August 2nd old leaves were pruned weekly. For both tomato varieties, from August 14th old leaves were pruned weekly. In sweet pepper no leaves were removed during cultivation.

Cucumber fruits were harvested two times a week from August 2nd (Photo 5). Tomatoes were harvested once a week, starting at August 27th for cherry tomatoes and September 11th for the round tomatoes. Sweet peppers were harvested weekly from October 1st (Photo 6).



Photo 5 Left the first fruits of cucumber on July 29th and right the first trusses of cherry tomatoes on August 26th.



Photo 6 Left the first trusses of tomato round on September 4th and right the first fruits of sweet pepper on September 30th.

During the growing cycle no visual differences could be observed in growth or development of the crops which could be related to the treatments. Blossom end rot (BER) in fruits of round tomato was occurring in the 2nd and 3rd cluster. Some BER was found in sweet pepper as well. This symptom is caused by Ca deficiency in the tissue, due to transport problems, obviously caused by a combination of factors as: the start with young plants in summer, the extreme hot weather in July and the compromise in climate conditions for the four crops. Clearly these BER symptoms are not related to the treatments.

3.2 Yield and biomass

The total production of fresh and dry matter per crop and per specific organ, i.e. leaves, pruned side shoots and fruits are listed in table 4 and 5. In Appendix VII the dry matter contents of different plant parts are listed.

Table 4

Fresh weight production of cucumber (C), sweet pepper (P), round (Tr)- and cherry tomato (Tch). Production of leaves, shoots, stem, fruits and total in kg fresh matter per m² and in % of the total biomass.

		Absolute				Total	Relative			
		Leaves	Shoots	Stem	Fruits		Leaves	Shoots	Stem	Fruits
C	1	5.48	1.31	2.08	32.63	41.50	13%	3%	5%	79%
	2	6.02	1.44	2.20	31.16	40.81	15%	4%	5%	76%
	3	5.60	1.37	2.10	29.34	38.42	15%	4%	5%	76%
	4	6.23	1.53	2.24	33.14	43.14	14%	4%	5%	77%
	5	5.36	1.41	2.13	29.20	38.10	14%	4%	6%	77%
	6	5.83	1.26	2.20	32.34	41.63	14%	3%	5%	78%
P	1	1.89	0.41	0.94	7.81	11.04	17%	4%	8%	71%
	2	1.89	0.48	0.97	7.66	11.01	17%	4%	9%	70%
	3	1.68	0.43	0.94	7.60	10.65	16%	4%	9%	71%
	4	1.84	0.41	0.97	7.35	10.57	17%	4%	9%	70%
	5	1.78	0.49	0.99	7.34	10.60	17%	5%	9%	69%
	6	1.92	0.37	1.02	7.34	10.65	18%	4%	10%	69%
Tr	1	2.96	0.49	1.29	14.71	19.45	15%	2%	7%	76%
	2	3.06	0.52	1.34	15.63	20.55	15%	3%	7%	76%
	3	2.97	0.49	1.34	14.69	19.49	15%	3%	7%	75%
	4	3.08	0.54	1.40	14.92	19.95	15%	3%	7%	75%
	5	2.80	0.50	1.27	13.88	18.45	15%	3%	7%	75%
	6	3.00	0.54	1.32	15.18	20.04	15%	3%	7%	76%
Tch	1	2.33	0.33	1.47	9.40	13.53	17%	2%	11%	69%
	2	2.34	0.35	1.57	10.20	14.47	16%	2%	11%	71%
	3	2.39	0.32	1.55	9.40	13.66	18%	2%	11%	69%
	4	2.26	0.38	1.51	10.00	14.14	16%	3%	11%	71%
	5	2.25	0.33	1.44	9.23	13.26	17%	2%	11%	70%
	6	2.30	0.36	1.52	10.23	14.41	16%	3%	11%	71%

The total dry matter production of the different plant parts (leaves, shoots, stem and fruits) are given in Table 5.

Table 5

Dry weight production of cucumber, sweet pepper, round- and cherry tomato. Production of leaves, shoots, stem, fruits and total in kg dry matter per m² and in % of the total dry biomass.

		Absolute				Total	Relative			
		Leaves	Shoots	Stem	Fruits		Leaves	Shoots	Stem	Fruits
C	1	0.40	0.09	0.14	1.05	1.68	24%	6%	8%	62%
	2	0.39	0.11	0.13	0.95	1.59	25%	7%	8%	60%
	3	0.39	0.10	0.13	0.91	1.52	25%	6%	9%	60%
	4	0.41	0.10	0.14	0.96	1.61	25%	6%	9%	60%
	5	0.39	0.10	0.13	0.90	1.52	25%	7%	9%	59%
	6	0.41	0.09	0.14	1.02	1.66	25%	6%	8%	61%
P	1	0.22	0.04	0.14	0.55	0.96	23%	5%	15%	57%
	2	0.21	0.05	0.14	0.59	0.99	21%	5%	14%	60%
	3	0.18	0.05	0.13	0.49	0.86	21%	6%	15%	58%
	4	0.20	0.05	0.15	0.50	0.90	23%	5%	16%	56%
	5	0.19	0.06	0.14	0.52	0.91	21%	6%	16%	57%
	6	0.20	0.04	0.14	0.49	0.87	23%	5%	16%	56%
Tr	1	0.31	0.05	0.16	0.75	1.27	24%	4%	13%	59%
	2	0.33	0.05	0.17	0.83	1.38	24%	4%	13%	60%
	3	0.31	0.05	0.16	0.75	1.27	24%	4%	12%	59%
	4	0.33	0.06	0.17	0.79	1.35	24%	4%	13%	59%
	5	0.28	0.05	0.15	0.68	1.15	24%	4%	13%	59%
	6	0.33	0.05	0.18	0.80	1.35	24%	4%	13%	59%
Tch	1	0.25	0.03	0.18	0.76	1.22	20%	3%	14%	62%
	2	0.24	0.04	0.19	0.82	1.28	18%	3%	15%	64%
	3	0.24	0.03	0.18	0.74	1.20	20%	3%	15%	62%
	4	0.23	0.04	0.17	0.81	1.25	19%	3%	13%	65%
	5	0.23	0.03	0.16	0.74	1.16	20%	3%	14%	64%
	6	0.24	0.04	0.18	0.84	1.30	19%	3%	14%	65%

3.3 Water, pH and EC and nutrients

3.3.1 Water

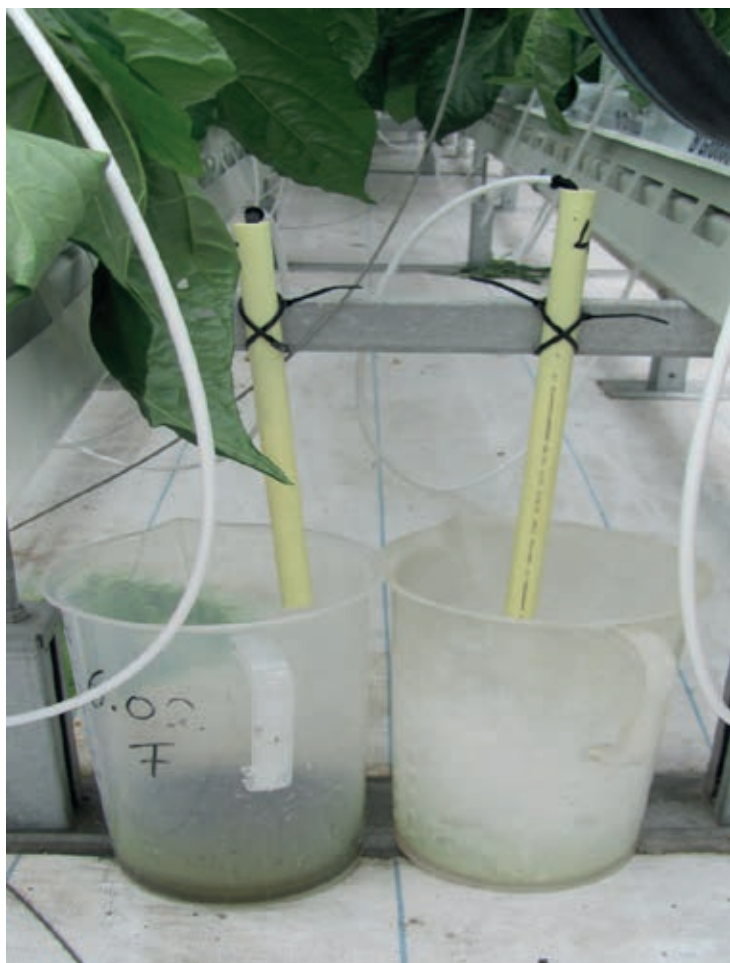


Photo 7 The nutrient solution which passed through one dripper was collected in a measuring cup per treatment. The collected amount of nutrient solution was recorded daily.

The irrigation water quantity was set equally for all treatments, the pattern of the daily irrigation showed an increase with plant size in the beginning and a gradual decrease later in summer towards autumn due to the decline in daylight (Day to day variations in irrigation due to weather conditions (radiation, humidity) caused fluctuations in irrigation (Fig. 2)). The cumulated irrigation showed a higher water consumption for treatment 3 and to a lesser extent for treatment 2 compared to the other treatments (Fig. 3). There is no clear indication for this higher use. Leakage is not likely the cause since comparison of the concentrations of nutrients as well as the perchlorate concentration do not indicate losses from the system. It might be due to location effects. Due to the shading effects of construction parts and neighbouring greenhouses (side walls, gutters, screens) the transpiration of plants on individual gutters may have been different. By the end of September a gradual increase of EC in the root environment necessitated to increase the irrigation and drainage rate. Data of irrigation and iodine supply are listed in Appendix IV.

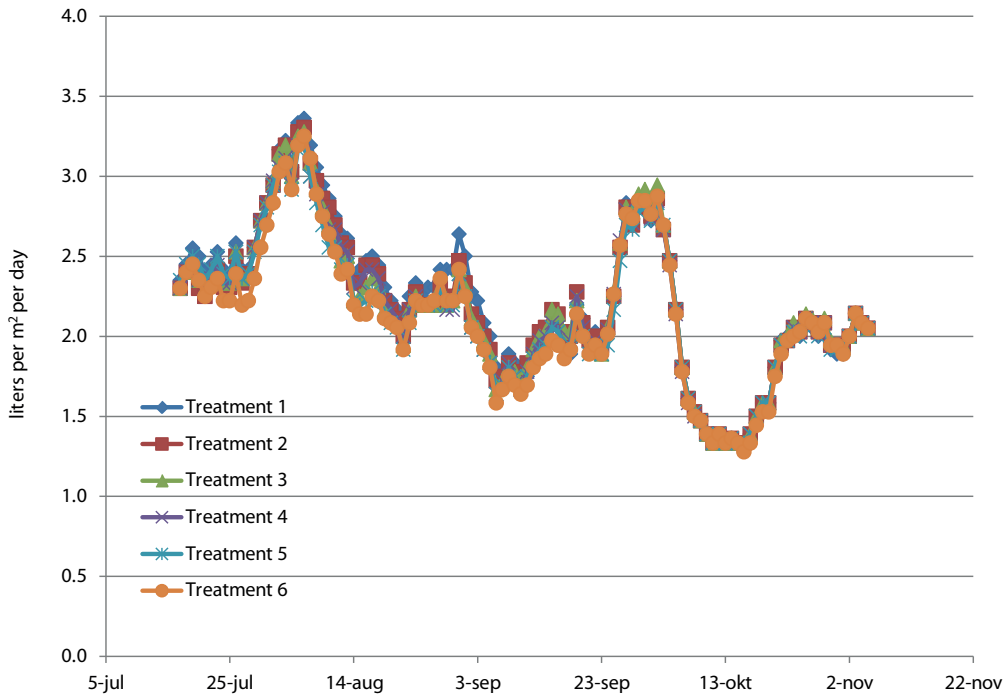


Figure 2 Pattern of daily irrigation quantity of the six treatments.

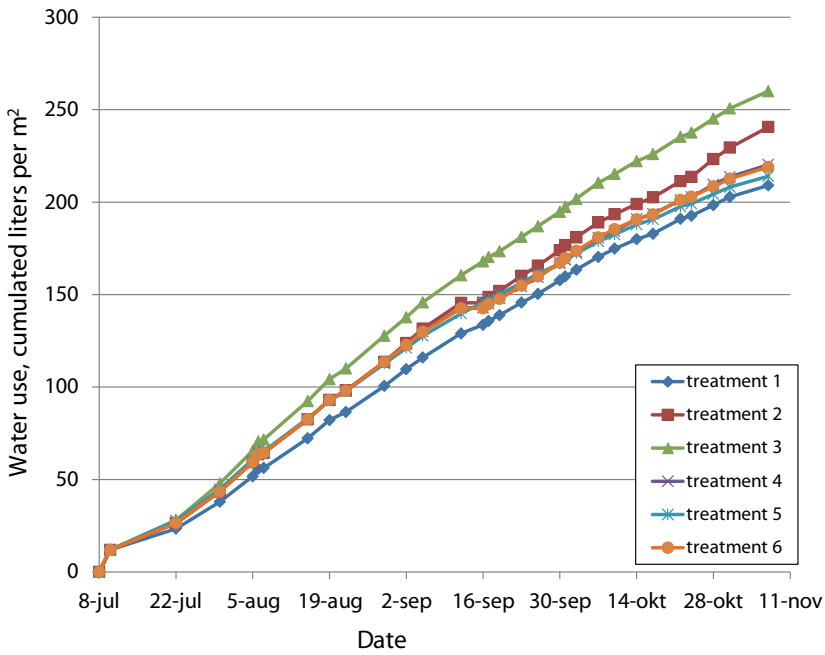


Figure 3 The water use of the six different treatments, as cumulated liters per m².

3.3.2 pH and EC

The evolution of the EC of the irrigation water and in the drainage show some fluctuations during the cropping cycle (Figure 4 and 5) striking is the gradual increase in EC of the drainage water from early September onwards. This EC increase of the drainage water necessitated to drastically decrease the irrigation EC, however due to time lag, this has caused some fluctuations in EC level. Likely the nutrient demand from early September onwards of all four crops was lower, probably due to a strong decrease in vegetative growth, which was forced by the crop management which was aiming at quick and strong fruit load. This was necessary to provide for sufficient fruit –sampling material.

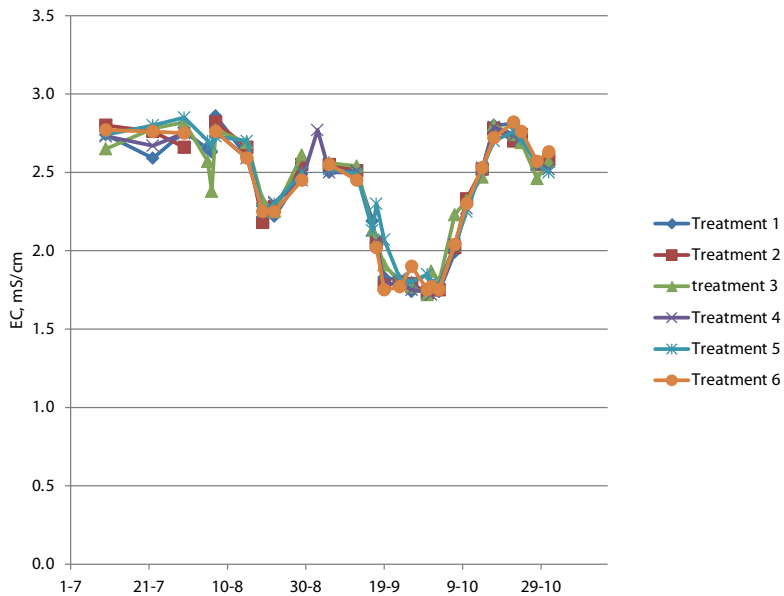


Figure 4 The course of the EC of the irrigation water.

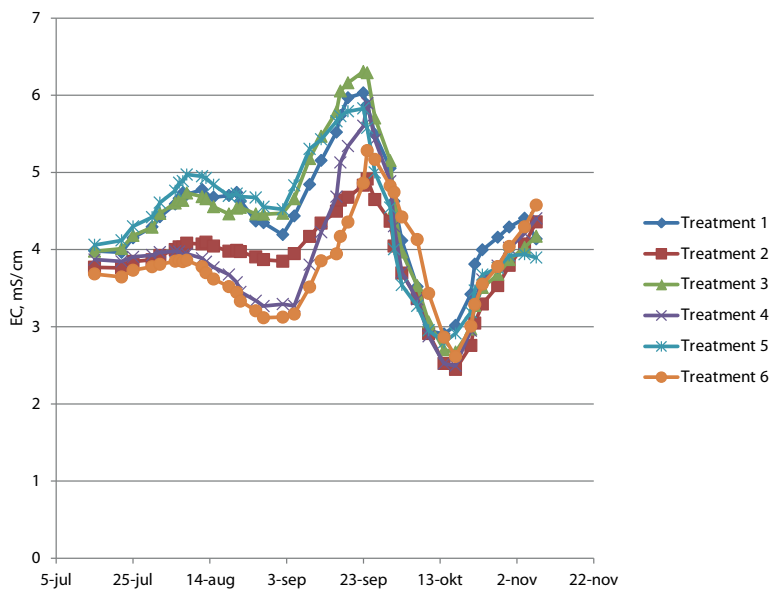


Figure 5 The course of the EC of the drainage water.

The pH of the irrigation solution was kept as much as possible between 5.0 and 6.0 (Figure 6). In the first weeks, the pH in the drainage water tended to increase (Figure 7), which was due to the strong vegetative development. After this initial period with steady increase, the pH in the drainage water went downwards and then stabilized around pH values of 6.0.

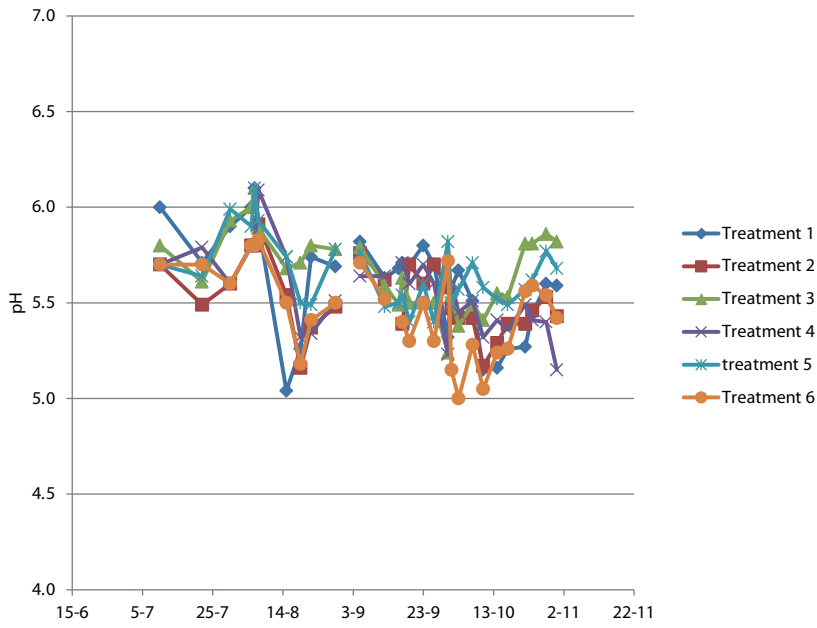


Figure 6 The course of the pH of the irrigation water

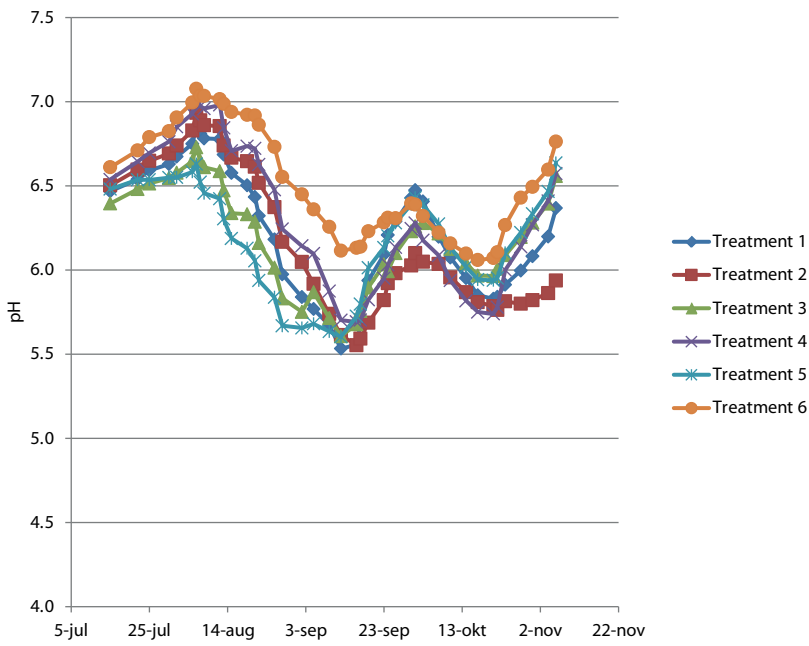


Figure 7 The course of the pH of the drainage water.

3.3.3 Nutrient concentrations in nutrient solutions

The analytical results per sampling date of the supply, drainage and stock solutions for analysis of main and trace elements and total iodine (I) are given in Appendix IV, V and VI. As to be expected and also desired, the nutrient concentrations in the drainage are higher than in the supply (Table 6), logically caused by the EC increase in the root environment (drainage) and dilution of fresh water and fresh A and B solution (supply tank). NH_4^+ is an exception as this ion will be absorbed rapidly. The P and Mn concentrations in the drain are much lower than supplied, due to higher pH conditions and are therefore prone to some precipitation in the root environment. The K concentration is also lower in the drainage water than in the supply tank, which is due to high plant uptake rates.

Table 6
Concentration of nutrient ions in supply and drain tank.

Element	Supply tank Treatment							Drain						
	1	2	3	4	5	6	Average	1	2	3	4	5	6	Average
mmmol per liter														
NH_4	1.1	1.3	1.1	1.1	1.1	1.1	1.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
K	7.0	8.1	7.1	7.1	6.8	7.2	7.2	5.7	6.9	5.8	5.6	5.4	5.1	5.8
Na	0.3	0.2	0.3	0.3	0.4	0.3	0.3	1.3	0.9	1.2	1.1	1.2	1.2	1.2
Ca	6.1	5.5	6.0	5.9	6.3	5.9	5.9	13.8	11.5	14.1	12.6	13.9	12.7	13.1
Mg	2.4	2.1	2.3	2.3	2.3	2.3	2.3	5.8	5.1	5.5	5.7	5.6	5.6	5.6
Si	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.4	0.4	0.4	0.4	0.4
NO_3	17.5	17.2	17.6	17.0	18.1	16.9	17.4	31.6	26.8	33.1	27.8	32.2	26.1	29.6
Cl	0.9	0.9	0.9	0.8	0.7	1.1	0.9	1.2	1.4	1.3	1.3	0.9	2.2	1.4
SO_4	2.2	2.1	2.1	2.2	2.0	2.1	2.1	5.1	4.7	4.6	5.7	4.5	5.8	5.1
HCO_3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.2	0.2	0.2	0.4	0.2
P	1.4	1.7	1.5	1.4	1.4	1.4	1.5	0.8	1.1	1.1	0.9	1.0	0.8	1.0
umol per liter														
Fe	28.3	23.0	24.5	25.3	25.4	25.4	25.3	70.2	53.7	63.2	62.3	58.4	72.0	63.3
Mn	11.7	13.6	11.9	12.1	11.4	11.8	12.1	7.3	8.6	8.1	7.5	8.5	7.1	7.9
Zn	6.0	6.6	6.0	6.2	6.0	6.0	6.1	5.4	6.6	5.4	6.5	6.2	7.5	6.3
B	53.5	43.0	52.2	50.3	55.2	49.0	50.5	134.1	103.3	138.1	125.4	138.6	128.4	128.0
Cu	1.1	1.2	1.1	1.1	1.1	1.1	1.1	1.5	1.5	1.4	1.8	1.5	1.6	1.5
Mo	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.0	0.6	0.8	0.8	0.8	0.8	0.8

In Appendix III, the total quantities supplied for N, P and K are listed.

3.4 Iodine in nutrient solutions

The input water source, which was well water, desalinated by Reverse Osmosis, was analysed for iodine with 1.9 $\mu\text{g I/l}$ found. Table 7 shows the concentration of iodine of the nutrient solution in the supply and drainage tank during the growing period.

Note: the concentration denoted as "supply" refers to the supply tank, which is a continuous mixing of fresh water and nutrient solution (with IO_3^-) and drainage water. During the whole trial, the iodine concentration in the supply tank at the zero treatment was higher than found in the water source, and was on average 5 $\mu\text{g I/l}$. Either the analysis of the water source was an underestimation, or it can be derived that another 3.1 $\mu\text{g I/l}$ was applied with the fertilizers. The iodine (I) concentration at treatment 4 should have been 10 times higher than with treatments 2, 3, 5 and 6. Taking into account the background concentration of iodine (5 $\mu\text{g I/litre}$), this factor was found in the supply at the start only (July 8). The other sampling dates showed considerable differences in the factor between treatment 4 with 125 ppm I and the treatments with 12.5 ppm I. On average this factor was 8.0, 6.7, 6.9 and 10.2 for treatment 2, 3, 5 and 6, respectively. The reason for this deviation is the continuous addition of drainage water, with deviating I concentrations in the supply tank, which will have affected the iodine concentration. Although the samples were taken right after the topping up of the supply tanks, a remainder of the previous mixture of supply + drainage was always present. In the drainage the differences in iodine concentration were much lower, compared to the supply tank. On average the concentration in the drainage at treatment 4 (125 ppm I in the fertilisers applied) was about 4 times the concentration analysed at the other treatments (12.5 ppm I in the fertilisers applied).

Table 7

Iodine concentration in the supply and drainage tanks of the six treatments during growth.

		Treatment					
		1	2	3	4	5	6
	IO ₃ ⁻ fertiliser ppm	0	12.5	12.5	125	12.5	12.5
	expected iodine (I) in nutrient solution µg/l	0	19	19	190	19	19
<i>date</i>							
Supply	8-7-2013	9.2	30.7	28.0	225.0	26.1	25.6
	16-7-2013	4.2	30.1	34.2	231.0	35.2	28.0
	7-8-2013	6.4	34.1	42.0	215.0	33.5	23.0
	12-9-2013	2.9	10.3	16.5	55.0	17.0	8.5
	3-10-2013	3.3	26.0	25.0	121.0	25.0	17.1
	28-10-2013	4.3	5.5	11.9	41.0	17.3	11.1
	Average	5.0	22.8	26.3	148.0	25.7	18.9
<i>date</i>							
Drainage	22-7-2013	14.0	58.0	60.0	256.0	54.0	49.0
	7-8-2013	10.6	39.2	60.0	260.0	52.4	49.3
	21-8-2013	13.2	37.5	57.0	157.0	53.0	34.9
	12-9-2013	6.1	17.0	33.0	128.0	31.0	30.7
	23-9-2013	8.1	27.0	52.0	185.0	47.0	24.0
	3-10-2013	7.9	37.3	53.0	147.0	52.0	37.6
	17-10-2013	7.7	20.9	34.2	129.2	38.6	28.0
	28-10-2013	9.3	28.1	43.9	195.0	44.2	39.0
	6-11-2013	4.7	12.2	20.5	89.0	25.6	19.1
	Average	9.1	30.8	46.0	171.8	44.2	34.6

3.5 Iodine in plant material

The dry matter samples of various plant organs gathered during the growing cycle were analysed for iodine, with ICP-MS. The standard quantification limit at the UT2A lab in Pau (Fr) was 0.1 ppm.

The iodine contents in dry matter of plant material are presented in Table 8. Details can be found in Appendix VIII and IX.

Table 8

Average iodine (I) contents (averaged over three moments of harvesting) in the dry matter of leaves, pruned shoots, fruits, residual leaves and main stem of cucumber, cherry tomato, round tomato and sweet pepper, expressed in mg iodine (I) per kg dry weight.

Organ	Treatment	Crop (mg iodine (I) per kg dry weight)			
		Cucumber	Pepper	Tomato cherry	Tomato round
Fruit	1	0.66	0.14	0.49	0.23
	2	0.87	0.13	0.54	0.38
	3	0.89	0.19	0.57	0.43
	4	3.99	0.56	1.51	0.98
	5	0.75	0.24	0.61	0.24
	6	0.77	0.15	0.88	0.15
Leaf	1	0.75	ND	6.40	10.20
	2	3.40	ND	9.10	7.60
	3	2.53	ND	13.20	14.80
	4	43.40	ND	99.00	59.00
	5	1.59	ND	9.87	15.10
	6	3.00	ND	7.70	7.30
Shoots	1	0.14	0.51	0.10	ND
	2	1.70	1.50	1.50	1.49
	3	0.53	1.02	0.16	ND
	4	19.20	13.10	16.00	17.40
	5	0.27	0.92	0.35	0.29
	6	2.05	1.80	1.34	1.50
Residual	1	0.39	19.00	2.07	2.19
	2	1.20	20.50	4.44	5.10
	3	0.91	26.70	4.20	3.40
	4	4.50	53.00	18.40	11.20
	5	0.76	25.40	4.80	3.90
	6	0.98	23.00	3.50	3.45
Stem	1	0.50	1.04	0.55	0.43
	2	2.85	1.58	1.88	1.59
	3	2.94	2.02	2.45	2.22
	4	15.90	10.20	11.78	10.20
	5	2.99	1.75	2.43	2.10
	6	2.60	1.55	1.50	1.20

ND = not determined

Iodine analytical data are converted to fresh matter using the dry matter contents (Table 9). For fruits, the data of the three separate sampling dates are presented in Table 10.

Table 9

Iodine (I) concentration (averaged over three moments of harvesting) as converted to fresh matter in mg I/ kg fresh material of leaves, pruned shoots, fruits, residual leaves and main stem of cucumber, cherry tomato, round tomato and sweet pepper.

Organ	Treatment	Crop (mg iodine (I) per kg fresh weight)			
		Cucumber	Pepper	Tomato cherry	Tomato round
Fruit	1	0.022	0.010	0.038	0.012
	2	0.027	0.009	0.042	0.020
	3	0.028	0.013	0.043	0.022
	4	0.122	0.039	0.116	0.052
	5	0.024	0.017	0.046	0.012
	6	0.025	0.010	0.067	0.008
Leaf	1	0.054	ND	0.687	1.109
	2	0.231	ND	0.933	0.788
	3	0.175	ND	1.313	1.548
	4	2.712	ND	9.614	6.211
	5	0.115	ND	0.965	1.615
	6	0.224	ND	0.798	0.808
Shoots	1	0.010	0.061	0.011	ND
	2	0.128	0.168	0.163	0.147
	3	0.037	0.121	0.018	ND
	4	1.254	1.516	1.736	1.803
	5	0.019	0.109	0.038	0.028
	6	0.146	0.203	0.150	0.146
Residual	1	0.029	2.252	0.218	0.223
	2	0.075	2.225	0.445	0.546
	3	0.063	2.910	0.437	0.349
	4	0.303	5.867	1.922	1.205
	5	0.054	2.775	0.493	0.365
	6	0.067	2.406	0.371	0.373
Stem	1	0.033	0.160	0.066	0.054
	2	0.175	0.225	0.224	0.207
	3	0.182	0.283	0.285	0.261
	4	1.008	1.548	1.291	1.243
	5	0.189	0.255	0.268	0.240
	6	0.160	0.217	0.175	0.159

Table 10

Average iodine (I) concentration of the fruits in fresh product of cucumber, sweet pepper, cherry tomato and round tomato (mg I/kg fresh) at the three harvesting dates.

crop	Fruit harvest (mg iodine (I) per kg fruit fresh weight)			
	Treatment	First	second	third
Cucumber	1	0.023	0.021	0.021
	2	0.029	0.027	0.026
	3	0.030	0.028	0.027
	4	0.132	0.113	0.122
	5	0.026	0.023	0.023
	6	0.026	0.024	0.023
Pepper	1	0.010	0.010	0.009
	2	0.009	0.009	0.009
	3	0.014	0.013	0.011
	4	0.041	0.042	0.034
	5	0.017	0.018	0.016
	6	0.011	0.011	0.009
Tomato cherry	1	0.032	0.045	0.035
	2	0.036	0.049	0.042
	3	0.038	0.048	0.044
	4	0.095	0.137	0.117
	5	0.039	0.054	0.045
	6	0.055	0.078	0.069
Tomato round	1	0.012	0.011	0.012
	2	0.021	0.019	0.020
	3	0.024	0.021	0.021
	4	0.055	0.051	0.051
	5	0.013	0.012	0.011
	6	0.008	0.008	0.008

For all crops, the highest I concentrations in the fresh plant parts are found in the vegetative parts, in leaves in particular (Figure 8). The lowest I levels are found in fresh fruits (Figure 8). The I concentrations in the fresh matter of the vegetative parts in cucumber are lower than for tomato (both types) and sweet pepper (Table 9). The opposite situation can be seen in fruits where in cucumber 4– 7 times higher concentrations were found if expressed on the dry matter (Figure 9). On fresh matter basis, the I concentrations in cucumber are almost equal (cherry tomato) or 2 – 3 times higher (round tomato, sweet pepper), due to big differences in dry matter (Table 10; Figure 9).

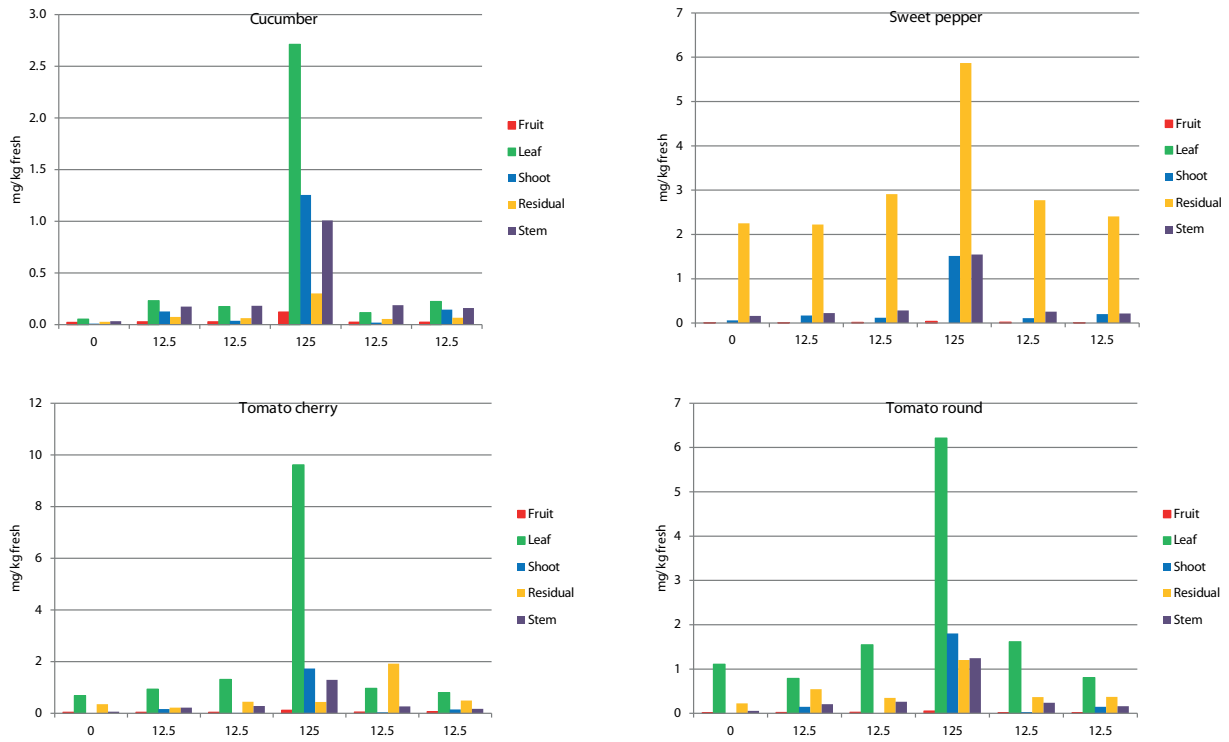


Figure 8 Average iodine (I) concentration expressed in mg I/kg fresh in fruits, leaves, side shoots, residual leaves and stems of cucumber, sweet pepper, cherry tomato and round tomato.

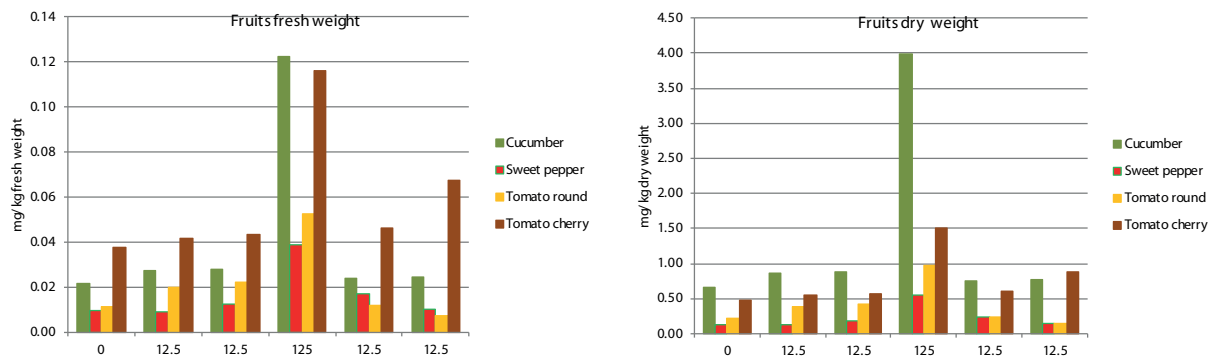


Figure 9 Average iodine (I) concentration (of three moments of harvesting) in fruits of cucumber, sweet pepper, cherry tomato and round tomato, expressed in mg I/kg fresh (left) and in mg I/kg dry matter (right).

3.6 Iodine balance

The result of the balance calculations for iodine is listed in table 11.

Table 11

Results of balance calculations on iodine inputs (water, fertilizers, plant material) and outputs (export by biomass in plant organs of four crops), corrected for residuals in the irrigation tank, drainage tank and substrate in mg I m⁻².

Input	1	2	3	4	5	6	Output	1	2	3	4	5	6
water	0.09	0.08	0.11	0.07	0.09	0.07	crop						
fertilizer	0.00	0.00	0.00	0.00	0.00	0.00	tomato round*	0.48	0.66	0.77	3.25	0.73	0.52
iodine	0.00	5.64	6.49	42.42	5.41	3.96	cherry tomato*	0.32	0.54	0.60	3.15	0.56	0.55
young plant	0.00	0.00	0.00	0.00	0.00	0.00	cucumber*	0.25	0.56	0.46	4.11	0.38	0.53
							sweet pepper*	1.13	1.14	1.33	3.29	1.34	1.24
sub total	0.09	5.72	6.60	42.49	5.50	4.03	sub total	2.17	2.91	3.16	13.79	3.01	2.84
							residual						
							irrigation tank	0.01	0.01	0.03	0.12	0.05	0.03
							rockwool	0.00	0.01	0.02	0.07	0.02	0.01
							drain tank	0.01	0.01	0.02	0.10	0.03	0.02
							unexplained	-2.11	2.77	3.37	28.41	2.39	1.12
saldo	0.09	5.72	6.60	42.49	5.50	4.03	saldo	0.09	5.72	6.60	42.49	5.50	4.03

* Each crop covering 0.25 m², data are expressed in mg/0.25 m²

The balances for iodine could not be closed. In treatment 1, the zero treatment, the gap is negative, which means that there seems to be more iodine taken up by the crop than supplied. However the very low values in both the input side and the output side could easily lead to a misleading interpretation. The treatments with I supply show a positive gap, with more I supplied than could be traced back in the crop. For treatment 2, 3, 5, 6 the results show missing quantities in the order of 1 - 3 mg/m², being 30 - 50 % of the total input. For the high I level, treatment 4, the gap is for more than 67 % unexplained.

4 Discussion

Although we found clear relations between the iodine supply and contents in above ground biomass, showing that iodine is explicitly taken up by the plant, there was a considerable gap in the estimated iodine balance, showing lower recovery in the plant than supplied. There are several explanations for these results.

- Missing roots. Neither roots nor the growing medium (rockwool) were sampled and analysed. However in studies with lettuce in hydroponics it was found that less than 5 % of the total I uptake was allocated to the root system (Voogt, unpublished data), Although the root biomass in fruit crops is relatively low (2 – 3 %) (Voogt, 1993), I content in root dry matter may be high, as was found in lettuce (Voogt *et al.* 2010).
- Missing biomass. Although prunings were collected carefully during the crop cycle and at crop termination all residuals were collected, it may happen that some material was lost. For this balance sheet item, errors are only one-sided, only losses, likewise any 'gain' in biomass is not possible.
- I volatilization. IO_3^- can be reduced under acidic pH conditions below pH 5 to finally I_2 , which is volatile and can be lost. In addition, iodine can be emitted as methyl iodide from the plant aboveground organs in certain species (Landini *et al.* 2012). If one of these processes would have been present in the growing system, i.e. from the nutrient solution or from the living plants, or during the process of sampling, pre-treatment of the samples (drying) or the analytical methods, then part of the iodine may have volatilized.

Furthermore it can be argued that the iodine background levels found in treatment 1, are not related to the specific iodine addition treatments. Therefore, these background levels, as found in treatment 1, should be deducted from each of the treatments 2 to 6, and for each of the four crops. Consequently, the "sub-total" in "Output" for treatments 2 to 6 will be reduced with 2.17 mg I/m². As a next step, this value of 2.17 mg/m² has to be added to the "unexplained". By doing this, the balance gap becomes even wider.

The uptake rate of iodine is largely a function of the evapotranspiration rate as has been clearly found in trials with lettuce (Voogt *et al.* 2010; Voogt and Jackson, 2010). It is also found that in the leaves of leafy vegetables, such as lettuce and spinach, more iodine accumulates than in the fruits of fruit vegetables per unit of dry weight (Kiferle *et al.* 2013). In this experiment the addition of iodine proportional to the fertilisers solution (12.5 and 125 ppm I of the total fertilisers) increased the content in all plant parts compared to the control treatments. The distribution of iodine in cucumber, sweet pepper, round- and cherry tomato among above-ground plant parts, i.e. the leaves, shoots, stem and fruits, was calculated and compared to the distribution of dry matter, K and Ca in the above-ground plant parts (Table 12). Roots are excluded from this study. With respect to the total absorption by the above-ground plant the majority of the iodine is translocated to vegetative parts. Compared to the distribution of assimilates (dry matter partitioning) this is even more striking, since for all four crops roughly 60 % of the dry matter is found in fruits. For IO_3^- at the 12.5 ppm level, 40 % of the total quantity of aboveground plant-absorbed iodine was found in cucumber fruit, whilst for sweet pepper only 2 % was found in the fruit. In cherry tomato 29 % of the total quantity of aboveground plant-absorbed iodine was found in the fruits, which is much more than in round tomato fruit, which contained 7 % of the total aboveground plant-absorbed iodine. Surprisingly, the high I dosage at 125 ppm in fertilisers, resulted in a lower portion distributed to fruits for cucumber (23 %) and cherry tomato (22 %), compared to the I dosage at 12.5 ppm in fertilisers with 40% in cucumber and 29% in cherry tomato, distributed to the fruits. For sweet pepper and round tomato no difference was found in the relative iodine distribution to the fruits at I dosage of 12.5 ppm and 125 ppm in fertilisers. In particular at the 125 ppm treatment, except for cherry tomato, these findings indicate that iodine is translocated primarily through the xylem by the transpiration flow. Likewise the Ca distribution, known to be transported exclusively by the xylem, has a similar distribution pattern as IO_3^- . Contrast to K, whose distribution is similar to the distribution of the dry matter. The differences in iodine distribution between the crops can partly be explained by the difference in transpiration behaviour of the fruits. Cucumber fruits are tube-shaped and have much higher surface to volume ratio than the ball-shaped tomato and, to a lesser extent, the blocked pepper. Moreover, the stomata density of the epidermis of the fruit is also much higher in cucumber, compared to the other fruit vegetables in the trial. Accordingly the higher transpiration rate may have caused higher iodine translocation in fruits in the cucumber crop, compared to the other fruit vegetables in the trial. However the substantial higher translocation in cherry tomato compared to round tomato cannot likely be explained by differences in transpiration.

Although the transpiration of a smaller-sized fruit will be higher than the transpiration of a larger-sized fruit, when seen in relation to the total biomass, this is not at all reflected by the Ca content (as a perfect indicator of transpiration mass flow), which is not different between round and cherry tomato. Henceforth, the iodine distribution merely based on transpiration transport cannot be the only explanation. This study does not give indications for other clues.

Table 12

Relative distribution of dry matter, iodine, K and Ca among dried plant parts of the four crops at the three levels of iodine in the supply. For dry matter, K and Ca the overall average is given (absolute data in appendix X).

			Fruit	Leaf	Shoot	Stem
Dry matter distribution	Cucumber		60%	25%	6%	9%
	Sweet pepper		56%	23%	5%	16%
	Tomato cherry		64%	20%	3%	14%
	Tomato round		59%	24%	4%	13%
		Iodine concentration (ppm I)				
Iodine distribution	Cucumber	0	70%	22%	1%	7%
		12.5	40%	35%	6%	20%
		125	23%	51%	12%	14%
	Sweet pepper	0	2%	95%	0%	3%
		12.5	2%	92%	1%	5%
		125	2%	82%	4%	11%
	Tomato cherry	0	29%	63%	0%	8%
		12.5	22%	62%	1%	15%
		125	10%	69%	5%	16%
	Tomato Round	0	9%	87%	0%	4%
		12.5	7%	83%	2%	9%
		125	7%	68%	9%	16%
K distribution	Cucumber		61%	23%	6%	10%
	Sweet pepper		43%	33%	6%	17%
	Tomato cherry		55%	26%	4%	15%
	Tomato round		53%	29%	4%	13%
Ca distribution	Cucumber		18%	67%	9%	6%
	Sweet pepper		3%	69%	7%	21%
	Tomato cherry		4%	79%	4%	13%
	Tomato round		4%	82%	5%	9%

Regression calculations were carried out to study the relationship between the IO_3^- concentration in the root environment the crops are exposed to, and the content in the fruit (Fig 10). For the contents in the fruit, for each crop both replicates are used. For sweet pepper, and both tomato crops more or less the same regression coefficients were found. For cucumber the regression coefficient was greater than for the other three crops as is a logical consequence from the difference in anatomy as has been discussed in the previous section.

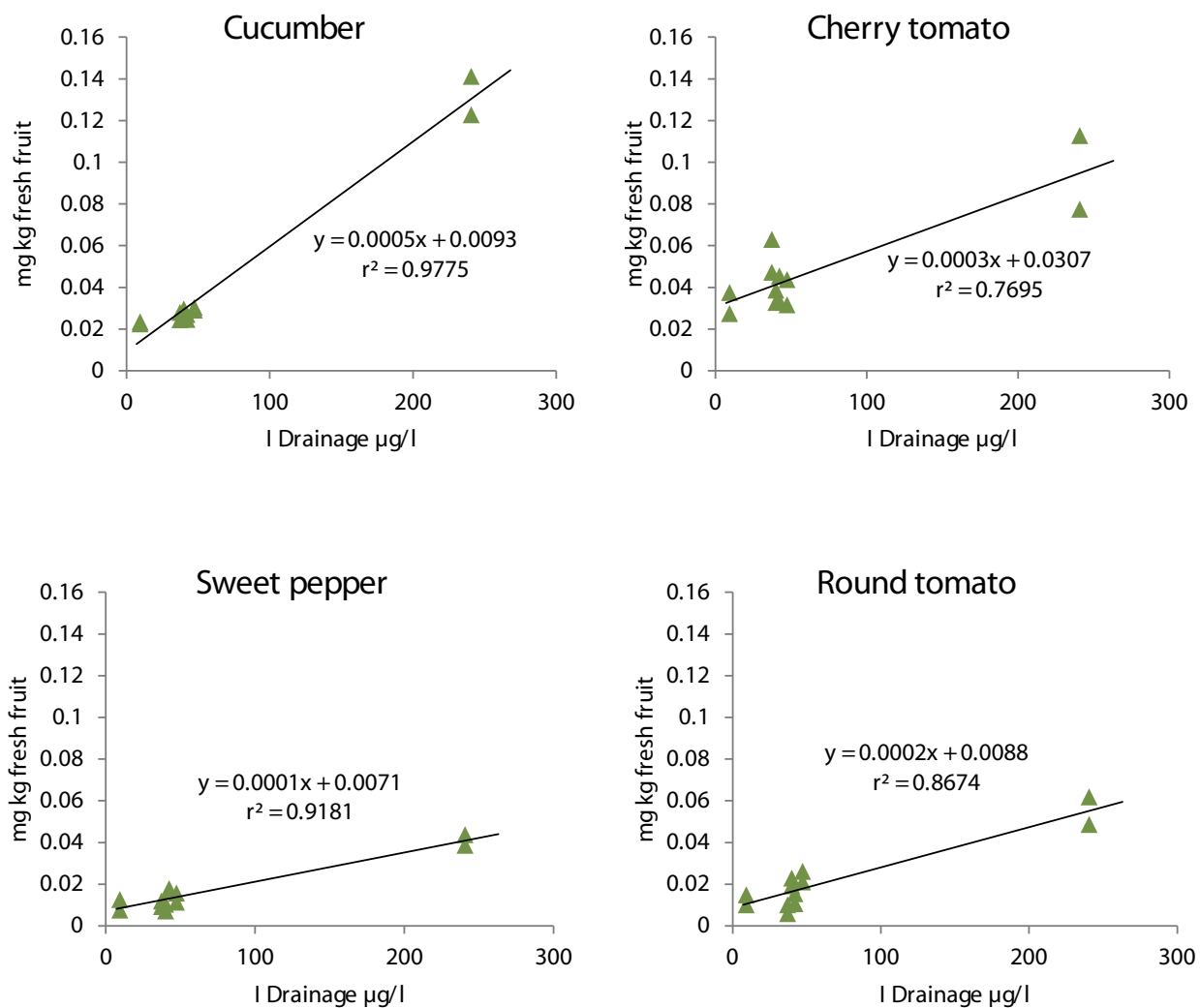


Figure 10 Relations between the average iodine concentrations in the root environment (drainage) in $\mu\text{g I/l}$, and the concentrations in the fruits in mg I/kg fresh matter, assuming reported analytical data at $\text{LQ} = 0.1 \text{ mg/kg}$ dry matter as 0, for the average of the three fruit sampling dates and corresponding analytical data of the root environment .

The experiment lasted for just about 1/3 of the usual length of greenhouse fruit vegetable crops (approx. 130 days instead of 340 days). Therefore long term effects on the accumulation of IO_3^- in the root environment and in the plant (i.e. fruits) could not have been investigated within this experimental period. These long term effects will probably result in higher quantities of IO_3^- in the root environment and consequently in plant material in standard practice. Based on the data in our experiment an extrapolation was made concerning the dynamics of IO_3^- in the nutrient solution in the root environment simulating a long cropping cycle of cucumber, tomato and sweet pepper. The uptake of IO_3^- depends on the concentration in the root environment (chapter 3.5) and the IO_3^- input may be assumed as a constant factor of the fertiliser input. As a consequence, equilibrium (steady state) will be reached between the input and the resulting concentration in the root environment and in the fruits on the long run in a closed growing system. The data acquired in this study made it possible to calculate these equilibrium IO_3^- concentrations for the four individual crops. For simulation of the IO_3^- concentration in time, a straightforward model was built. In the next section the methodology used is explained step-by-step.

1. We assumed a completely closed system, so water input is equal to the crop uptake (growth and transpiration) and there are no losses in fertilisers nor in IO_3^- due to leakage, precipitation, adsorptions, volatilization or others. The IO_3^- concentration was set as a fixed concentration in the fertilisers supplied. Since fertilisers, nutrient concentrations in the root environment and absorbed by plants, as well as IO_3^- inputs and uptake can all be related to water flows, we used a simulation model for the water flows 'WATERSTROMEN' (Voogt *et al.* 2012) to estimate the dynamics of IO_3^- in the root environment and hence the uptake.
2. The daily water and nutrient uptake by the crop was simulated by the model 'WATERSTROMEN', using a tomato crop as model crop, in a cropping cycle from Jan 1 until Nov 15, in a year with average radiation and temperature data. The simulated water uptake was assumed to be equal to the water input.
3. The fertiliser input was simulated by model runs with two different parameter settings, "standard" and "model". In the "standard" simulation, the fertiliser input was fixed at one value (g/l water) for all days during the whole growing season. This value was set equal to the average input in the experiment, which was derived from the total used concentrated stock solution, the composition (fertiliser recipes) and the dilution rate. This average fertiliser supply appeared to be 1.78 g/l. In the "model" simulation, the fertilisers input was the outcome from the standard model run with WATERSTROMEN, but parameters in such a way tuned that the average daily fertiliser supply for the growing season was equal to 1.78 g/l.
4. The iodine uptake rate (mg I per liter of water absorbed) was derived from the experimental data, i.e. the total iodine uptake (biomass data, mg/m²), divided by the total water consumption per treatment (l/m²). The result is the so called 'uptake concentration' in mg I/l. Note: although the data of biomass iodine for all four individual crops were available, the water uptake of the individual crops could not be measured separately in the experiment so the uptake concentrations are all related to the total water uptake for all four crops per treatment. The outcome of the six treatments was correlated with the average concentration in the root environment for the four individual crops. For this correlation we used the average I⁻ in the drainage. Correlation diagram and regression lines are listed in Fig. 11.
5. For every day a basic iodine balance, i.e. input (fertilisers) – output (crop uptake) was established to calculate the prevailing iodine concentration in the root environment. Initially the iodine concentration at the start derived from the fertiliser input for saturation of the substrate was used. For each consecutive day the iodine uptake concentration (mg I/l) was calculated by using the regression equations for the uptake concentration (Fig. 11). The total iodine uptake for that day was the outcome of multiplying the water uptake with the iodine uptake concentration. For each consecutive day, the residual iodine calculated as the initial iodine quantity in the root environment minus the iodine quantity being taken up by the plant, was added to the simulated input quantity (step 2, 3) of iodine by fertilisers and divided by the total water volume of the root environment, which resulted in a new iodine concentration. This determined the concentration in the root environment for the next day.
6. The evolution of the iodine in the root environment throughout the growing season was simulated for concentrations of 10, 12.5, 25, 50, 100 and 125 ppm I⁻ in the fertilisers. Simulations were carried out for the total average of the four crops as used in the trial as well as for the individual crops: cucumber, sweet pepper, cherry tomato and round tomato.
7. In the end, the simulation of the equilibrium concentrations was carried out for the following variants.

Tabel 13

Variants used for the simulations

I conc. in fert.	Fertiliser input									
	Standard					Model				
	All crops	Cu cumber	Sweet pepper	Cherry tomato	Round tomato	All crops	Cu cumber	Sweet pepper	Cherry tomato	Round tomato
10	x	X	x	X	x	x	x	x	x	x
12.5	x	X	x	X	x	x	x	x	x	x
25	x	X	x	X	x	x	x	x	x	x
50	x	X	x	X	x	x	x	x	x	x
100	x	X	x	X	x	x	x	x	x	x
125	x	x	x	x	x	x	x	x	x	x

8. In the next step the outcome of the equilibrium calculations were used to extrapolate the translocation of iodine to fruits. For this step we made use of the previously calculated relation between the concentration in the root environment (i.e. the drainage) and the concentrations in the fruits as presented in Figure 11. The results of the extrapolation are listed in Table 14 and the regression lines are shown in Figure 13. Note that the end points of the regression lines in Figure 13, are derived for the steady state conditions at application of fertilizer of 125 ppm iodine content, hence iodine content would not increase in the fresh fruit beyond these end points. Taking cucumber as an example, Figure 12 shows that with steady application of fertilizer with 125 ppm iodine - equilibrium is reached at (circa) 440 µg/L in the root environment for the cucumber. This figure 13 shows that at 440 µg iodine/L root environment, the iodine content in the fresh fruit is (approx.) 0.26 mg/kg.

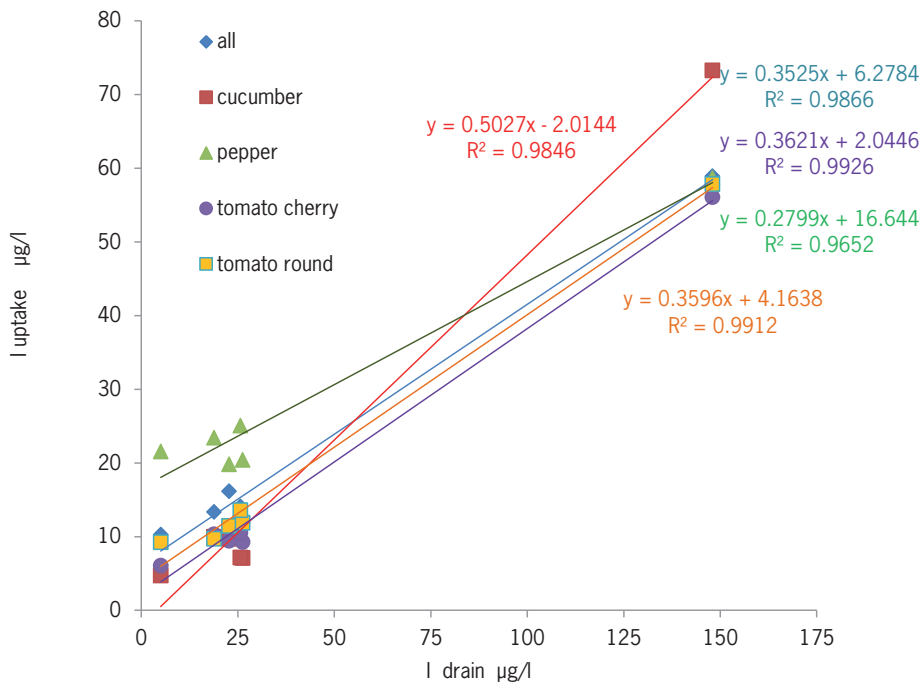


Figure 11 Correlation diagram of the relation between the uptake concentration (I in biomass / water uptake in $\mu\text{g/l}$) and the average I measured in the drainage ($\mu\text{g/l}$), calculated for all crops (total average), cucumber, sweet pepper, cherry tomato and round tomato.

As to be expected the simulation resulted in quite different equilibrium concentrations depending on the level of iodine concentrations in the fertilisers and depending on the crop. Some examples of the simulation results are given in Figure 12. The big differences in uptake concentration between the crops result in significant differences in the equilibrium level, the highest values were found for round tomato and sweet pepper and the lowest for cucumber. The simulated steady state was reached after approx. 100 days (cucumber) to 130 days (sweet pepper), which is quite soon after start. In this trial this took probably longer as the crop started to develop in the declining day-length and light intensity phase of the year (from July to November), whereas the simulation was done in the opposite phase (from January onwards). Therefore in the simulation the crops developed with an acceleration together with the increasing light intensity and day length, which obviously results in rapidly increasing water and nutrient uptake rates with increasing plant age, whilst in the experiment these were declining after the crops reached certain plant size.

Obviously the differences in IO_3^- - levels in the fertilisers resulted in clear differences in the equilibrium levels as well. The outcome of the "standard" and "model" simulation of the fertiliser input resulted in a quite different courses of the IO_3^- concentration in the root environment throughout the growing season. With the "model" the accumulation is strong in the first months then, after reaching a peak it decreases and increases again later. This pattern can be explained by the simulation of the EC (= fertiliser input) which in the "model" situation has a distinct pattern, as a crop development and light dependent EC algorithm is used in WATERSTROMEN. In short: decreasing input EC with increasing light intensity and with increasing plant-age. Hence the fertiliser input (in mg fertiliser per liter of water applied; not in mg fertilisers per day) is much higher in the dark early winter months and decreases in spring and summer. From early July, together with the decreasing light level the EC gradually increases again, however, due to ageing plants, not as fast as in the beginning of the growing season. Eventually the differences in equilibrium concentration between 'standard' and 'model' are negligible, therefore for evaluation the 'standard' approach is used.

For each crop equilibrium concentrations in the root environment were reached within the growing periods considered as normal (i.e. almost one year). So, since we have found linear correlations between the concentration in the root environment and the concentrations in fruits, it is logical to conclude that an equilibrium concentration will be reached for fruits also.

Table 14

The iodine concentration in fresh fruit in mg/kg being reached eventually at the equilibrium concentration of IO_3^- in the root environment in a closed growing system, obtained with fertilizers containing 10 ppm I to 125 ppm I.

Iodine (I) in fertilisers, ppm	Iodine concentration in fresh fruit in mg/kg				
	all	cucumber	sweet pepper	tomato cherry	tomato round
10	0.02	0.02	0.01	0.03	0.01
12.5	0.03	0.02	0.01	0.04	0.02
25	0.05	0.05	0.02	0.08	0.04
50	0.12	0.10	0.05	0.17	0.09
100	0.25	0.21	0.10	0.35	0.18
125	0.31	0.26	0.13	0.44	0.23

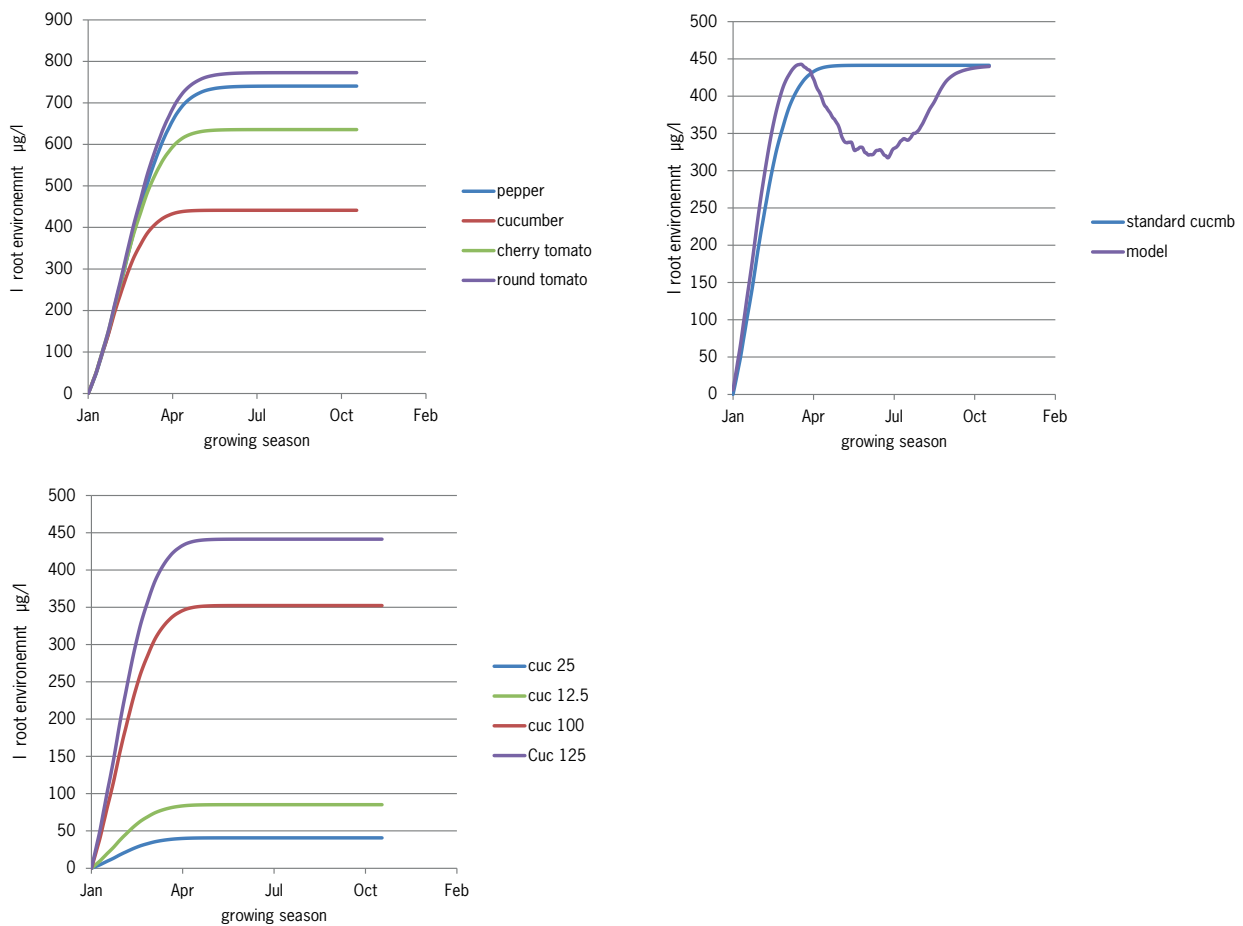


Figure 12 Equilibrium levels of I in the root environment after reaching a steady state condition in long term vegetable crops in closed systems, with 125 ppm in the fertilisers for all four crops (top left), with 12.5, 25, 100 and 125 ppm in cucumber (bottom left) and with 125 ppm in cucumber, using the "standard" and the "model" fertiliser input (top right).

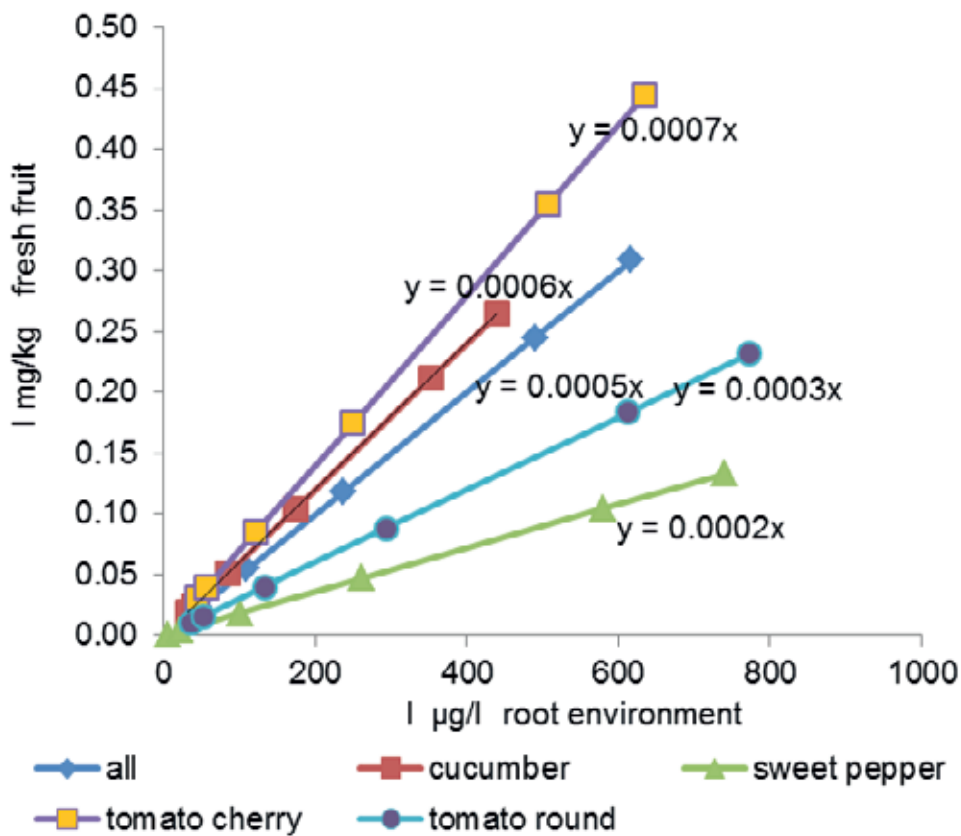


Figure 13 Estimated relation between the I concentrations in fresh fruit in mg/kg at the simulated equilibrium concentrations for 10, 12.5, 25, 50, 100 and 125 ppm IO_3^- in fertilisers, as extrapolated from the relation between I in the root environment and the content in the fruit (Fig 11), for the average of all four crops, cucumber, sweet pepper, cherry tomato and round tomato.

5 Conclusions

Based on the results of this greenhouse experiment with cucumber, sweet pepper, round- and cherry tomato, exposed to different IO_3^- levels in the fertiliser solution, it can be concluded that:

- Iodine, applied as IO_3^- , is absorbed relatively easily by these crops; since no iodine accumulation in the nutrient solution occurred over time.
- The majority of iodine absorbed by the plant, applied as IO_3^- , is translocated to the vegetative parts of the plants, mainly to the transpiring leaves and shoots.
- The quantity of iodine, applied as IO_3^- , translocated to the fruits differs a lot between the four crops and ranged from limited (2 – 5 %) for sweet pepper and round tomato to substantial portions (30 % - 40 %) for cherry tomato and cucumber of the total absorbed iodine.
- The contents of iodine, applied as IO_3^- , in sweet pepper and round tomato were on average 0.01-0.02 mg I/kg fruit fresh weight for the lowest (12.5 ppm) and 0.03 – 0.05 mg I/kg fruit fresh weight for the highest (125 ppm) level of iodine in the fertilisers applied.
- The contents of IO_3^- in cherry tomato and cucumber were on average 0.02-0.08 mg iodine (I)/kg fresh fruit weight for the lowest (12.5 ppm) and 0.10 – 0.14 mg/kg fruit fresh weight for the highest (125 ppm) level of iodine in the fertilisers applied.
- One adult portion of fruit or vegetables is 80 grams and five portions per day of fruit and vegetables are recommended (NHS UK, 2014). Only one portion of 80 grams of cucumber, cherry tomato, round tomato or sweet pepper, grown each with fertilizers containing 125 mg I/kg fertilizers, contributes between 3-10 μg of daily iodine intake, i.e., 2-7% of the daily requirement of iodine for an adult.

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Appendix I Recipes of nutrient solutions

				datum	03-jul-13
	Saturation substrate				
	Reverse osmosis water				
watersource		3.0			
dosage EC		30			
liters solution		100	times concentrated		
A tank					
Calciumnitrate	crystalline	4862		gram	
Ammoniumnitrate	liquid	-377		ml	
Ironchelate 6 %		70		gram	
Potassiumnitrate		966		gram	
Potassiumchloride		335		gram	
B tank					
Potassiumnitrate		171.13		gram	
Epsomsalt		2675		gram	
Magnesiumnitrate	liquid	333		ml	
Potssiumsulphate		0		gram	
Monopotassiumphosphate		510		gram	
Manganesesulphate		3549		mgram	
Zincsulphate		6038		mgram	
Borax		17154		mgram	
Coppersulphate		749		mgram	
Sodiummolybdate		363		mgram	

Start

Reverse osmosis
water

watersource
dosage EC
liters solution

3.0

30

100

times concentrated

A tank

Calciumnitrate	crystalline	7131	gram
Ammoniumnitrate	liquid	679	ml
Ironchelate 6 %		233	gram
		466	gram
Potassiumnitrate		3143	gram

Potassiumchloride 0 gram

B tank

Potassiumnitrate		344.75	gram
Epsomsalt		2706	gram
Magnesiumnitrate	liquid	0	ml
Potssiumsulphate		261	gram

Monopotassiumphosphate 1700 gram
0 gram

Manganesesulphate		16900	mgram
Zincsulphate		11500	mgram
Borax		23825	mgram
Coppersulphate		1873	mgram
Sodiummolybdate		1210	mgram

Standard

Reverse osmosis
water

watersource
dosage EC
liters solution

3.0

30
100

times concentrated

A tank

Calciumnitrate	crystalline	6483	gram
Ammoniumnitrate	liquid	503	ml
Ironchelate 6 %		140	gram
		279	gram
Potassiumnitrate		2390	gram

Potassiumchloride 0 gram

B tank

Potassiumnitrate		1906.27	gram
Epsomsalt		2460	gram
Magnesiumnitrate	liquid	0	ml
Potssiumsulphate		436	gram

Monopotassiumphosphate 1700 gram
0 gram

Manganesesulphate		16900	mgram
Zincsulphate		11500	mgram
Borax		23825	mgram
Coppersulphate		1873	mgram
Sodiummolybdate		1210	mgram

August

Reverse osmosis
water

watersource
dosage EC
liters solution

3.0

30

100

times concentrated

A tank

Calciumnitrate	crystalline	7131	gram
Ammoniumnitrate	liquid	679.4	ml
Ironchelate 6 %		140	gram
		279	gram
Potassiumnitrate		3143	gram

Potassiumchloride		0.0	gram
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B tank

Potassiumnitrate		344.7	gram
Epsomsalt		2706	gram
Magnesiumnitrate	liquid	0	ml
Potssiumsulphate		261.5	gram

Monopotassiumphosphate		1700	gram
		0	gram

Manganesesulphate		16900	mgram
Zincsulphate		11500	mgram
Borax		0	mgram
Coppersulphate		1998	mgram
Sodiummolybdate		1210	mgram

Appendix II Calculation of iodine dosage

Concentrated solution				
10 000 * concentrated				
5 liter	5	liter	ClO_4^- ppm	
<hr/>				
Total fertilisers	156	kg/m^3	12.5	
<hr/>				
Solution C			ClO_4	
KClO_4	1320	milligram	0.1895	mg/ml
<hr/>				
Solution D			IO_3 (as I)	
KIO_3	1598	milligram	0.1895	mg/ml
<hr/>				
	mol weight			
KClO_4	138.6			
ClO_4	99.5			
KIO_3	214			
IO_3	174.9			
I	126.9			
<hr/>				
factor $\text{KClO}_4 / \text{ClO}_4$	1.39296			

Appendix III Supply of N, P and K

Date	Treatment																	
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
	N, g per m ²						P, g per m ²						K, g per m ²					
8-jul	3	3	3	3	3	3	0.5	0.5	0.5	0.5	0.5	0.5	3	3	3	3	3	3
10-jul	5	5	5	5	5	5	1.1	1.1	1.1	1.1	1.1	1.1	7	7	7	7	7	7
22-jul	4	2	5	2	5	1	0.8	0.4	1.1	0.4	1.2	0.3	5	7	7	7	8	7
30-jul	3	2	5	1	4	2	0.7	0.4	1.1	0.3	0.8	0.4	5	6	7	6	5	6
7-aug	7	7	7	7	7	7	1.5	1.5	1.5	1.5	1.5	1.5	8	8	8	8	8	8
15-aug	3	1	5	1	4	1	0.7	0.2	1.1	0.2	0.9	0.3	4	5	6	5	4	5
22-aug	2	1	3	1	2	2	0.5	0.3	0.6	0.2	0.4	0.3	2	2	3	2	2	2
29-aug	3	3	4	2	3	3	0.7	0.7	0.9	0.5	0.8	0.6	4	4	5	4	4	4
5-sep	3	4	4	1	3	4	0.8	1.0	0.9	0.2	0.7	0.9	4	5	5	1	4	4
12-sep	3	3	3	3	2	3	0.6	0.7	0.7	0.7	0.5	0.6	3	4	4	4	3	3
26-sep	0	2	1	1	0	2	0.1	0.5	0.1	0.2	0.0	0.4	1	4	2	2	0	4
3-okt	1	2	1	1	0	0	0.1	0.4	0.1	0.1	0.0	0.1	1	3	1	1	0	1
7-okt	2	2	2	2	2	2	0.5	0.5	0.5	0.5	0.4	0.5	3	3	4	3	3	3
10-okt	2	2	1	2	1	2	0.4	0.4	0.3	0.3	0.3	0.3	2	2	2	2	2	2
14-okt	2	2	2	2	2	2	0.4	0.4	0.5	0.5	0.5	0.4	3	3	3	3	3	3
17-okt	1	2	2	1	1	1	0.3	0.3	0.3	0.3	0.3	0.3	2	2	2	2	2	2
24-okt	1	2	1	1	1	1	0.2	0.3	0.3	0.3	0.3	0.2	2	2	2	2	2	2
28-okt	0	2	1	0	0	0	0.0	0.4	0.1	0.0	0.0	0.0	0	3	1	0	0	0
31-okt	0	1	1	0	0	0	0.1	0.3	0.2	0.0	0.0	0.0	0	2	1	0	0	0

Appendix IV water and iodine supply

Date	Treatment											
	1	2	3	4	5	6	1	2	3	4	5	6
	Water, liters per m ²						mg I per m ²					
8-jul-13	0	0.0	0.0	0.0	0.0	0.0	0.00	0.22	0.22	2.21	0.22	0.22
10-jul-13	11.9	11.9	11.9	11.9	11.9	11.9	0.00	0.55	0.55	4.74	0.55	0.47
22-jul-13	11.5	14.5	16.1	14.5	15.9	14.5	0.00	0.18	0.55	4.74	0.59	0.47
30-jul-13	14.5	17.1	19.8	17.1	16.9	17.1	0.00	0.19	0.54	4.74	0.40	0.47
5-aug-13	13.8	15.8	17.6	15.8	16.0	15.8	0.00	0.00	0.00	0.00	0.00	0.00
6-aug-13	4.0	4.3	5.1	4.3	4.0	4.3	0.00	0.00	0.00	0.00	0.00	0.00
7-aug-13	0.5	0.7	1.0	0.7	0.7	0.7	0.00	0.74	0.74	4.74	0.74	0.47
15-aug-13	16.0	18.1	20.7	18.1	17.6	18.1	0.00	0.11	0.55	0.69	0.43	0.10
19-aug-13	9.9	10.5	11.9	10.5	9.6	10.5	0.00	0.00	0.00	0.00	0.00	0.00
22-aug-13	4.4	5.1	5.7	5.1	5.2	5.1	0.00	0.15	0.28	0.78	0.17	0.11
29-aug-13	14.1	15.5	17.7	15.5	14.8	15.5	0.00	0.34	0.46	1.73	0.38	0.18
2-sep-13	9.1	10.2	10.0	9.4	8.5	9.1	0.00	0.00	0.00	4.74	0.00	0.00
5-sep-13	6.3	7.8	8.1	7.0	6.5	7.0	0.00	0.47	0.46	0.53	0.35	0.28
12-sep-13	13.0	13.9	14.7	12.8	12.1	12.8	0.00	0.36	0.34	2.34	0.27	0.19
16-sep-13	4.7	0.0	7.4	0.0	6.1	0.0	0.00	0.00	0.00	0.00	0.00	0.00
17-sep-13	2.1	3.2	2.3	2.3	1.4	2.3	0.00	0.00	0.00	0.00	0.00	0.00
19-sep-13	3.1	3.2	3.1	2.9	2.9	2.8	0.00	0.14	0.00	0.00	0.00	0.01
23-sep-13	6.8	8.2	7.8	6.4	6.4	7.2	0.00	0.00	0.00	0.00	0.00	0.00
26-sep-13	4.7	5.5	5.7	5.1	4.7	4.9	0.00	0.22	0.06	0.55	0.00	0.11
30-sep-13	7.4	8.3	7.8	7.8	5.6	7.4	0.00	0.00	0.00	0.00	0.00	0.00
1-okt-13	2.1	2.8	2.7	1.6	2.3	2.4	0.00	0.00	0.00	0.00	0.00	0.00
3-okt-13	3.6	4.2	4.3	4.3	3.2	4.0	0.00	0.33	0.31	1.84	0.19	0.17
7-okt-13	6.9	8.0	8.7	7.6	6.5	7.3	0.00	0.26	0.26	1.60	0.21	0.14
10-okt-13	4.5	4.5	4.8	3.6	3.8	4.5	0.00	0.18	0.13	1.07	0.16	0.10
14-okt-13	5.1	5.6	6.8	6.5	5.4	5.3	0.00	0.22	0.25	1.58	0.23	0.12
17-okt-13	2.9	3.6	3.9	2.9	2.8	2.7	0.00	0.16	0.17	0.92	0.14	0.09
22-okt-13	8.1	8.8	9.4	7.4	7.0	7.9	0.00	0.29	0.32	1.67	0.23	0.16
24-okt-13	1.7	2.3	2.2	1.7	1.5	1.8	0.00	0.16	0.16	0.98	0.13	0.08
28-okt-13	5.7	9.7	7.6	6.7	5.2	5.5	0.00	0.22	0.07	0.13	0.00	0.00
31-okt-13	4.4	6.1	5.5	4.2	3.8	4.2	0.00	0.14	0.08	0.13	0.01	0.00
7-nov-13	6.2	11.1	9.3	6.6	5.9	6.4	0.00	0.00	0.00	0.00	0.00	0.00
Total	209	231	260	224	214	212	0.00	5.64	6.49	42.42	5.41	3.96

Appendix V Analysis of drain

Date	Drain Treatment					
	1	2	3	4	5	6
	EC, mS per cm					
22-7-2013	3.8	3.6	3.6	3.6	3.7	3.4
7-8-2013	4.5	4.0	4.9	4.0	4.9	3.9
21-8-2013	4.7	4.1	4.6	3.7	4.7	3.4
12-9-2013	3.8	3.9	4.6	3.7	4.6	3.5
23-9-2013	5.5	4.4	6.2	5.7	5.7	3.4
3-10-2013	4.2	3.7	3.9	3.6	3.6	5.1
17-10-2013	2.8	2.0	2.6	2.5	3.0	2.4
28-10-2013	5.4	5.6	5.1	5.7	4.8	6.1
6-11-2013	4.0	3.8	3.8	3.8	3.6	4.1
	pH					
22-7-2013	6.2	6.2	6.0	6.1	6.1	6.1
7-8-2013	6.6	6.8	6.4	6.9	6.2	7.0
21-8-2013	6.0	6.3	5.6	6.1	5.1	6.4
12-9-2013	4.7	4.7	4.9	4.8	4.9	5.5
23-9-2013	5.9	5.1	5.8	5.7	5.7	6.0
3-10-2013	6.3	5.8	6.2	6.3	6.4	6.2
17-10-2013	5.1	5.8	5.8	5.3	5.5	5.2
28-10-2013	6.3	5.4	6.2	6.1	6.1	6.1
6-11-2013	6.5	5.4	6.2	6.3	6.2	6.5
	NH ₄ , mmol per liter					
22-7-2013	0.9	0.8	0.8	0.7	0.7	0.7
7-8-2013	0.1	0.1	0.1	0.1	0.1	0.1
21-8-2013	0.1	0.1	0.1	0.1	0.1	0.1
12-9-2013	0.2	0.1	0.1	0.2	0.1	0.1
23-9-2013	0.1	0.1	0.1	0.1	0.1	0.1
3-10-2013	0.1	0.1	0.1	0.1	0.1	0.1
17-10-2013	0.1	0.1	0.1	0.1	0.1	0.1
28-10-2013	0.1	0.1	0.1	0.1	0.1	0.1
6-11-2013	0.1	0.1	0.1	0.1	0.1	0.1

Date	Drain Treatment					
	1	2	3	4	5	6
K, mmol per liter						
22-7-2013	9.7	8.8	8.6	8.9	8.8	8.3
7-8-2013	7.3	6.8	7.4	6.5	7.6	6.2
21-8-2013	8.1	7.5	8.5	5.9	9.3	5.5
12-9-2013	5.5	6.1	6.4	5.7	5.8	3.0
23-9-2013	6.4	7.1	5.6	6.7	5.7	3.5
3-10-2013	2.7	4.5	1.9	2.2	1.6	3.6
17-10-2013	1.8	2.3	1.2	2.2	1.3	1.6
28-10-2013	5.1	9.1	5.6	6.1	4.5	7.1
6-11-2013	4.9	10.2	6.8	5.9	4.2	7.4
Na, mmol per liter						
22-7-2013	0.7	0.6	0.6	0.6	0.7	0.6
7-8-2013	1.3	1.2	1.5	1.3	1.4	1.3
21-8-2013	1.3	1.1	1.1	1.0	1.1	1.0
12-9-2013	1.1	1.0	1.3	1.0	1.3	1.2
23-9-2013	1.6	1.1	1.8	1.8	1.7	1.2
3-10-2013	1.5	1.1	1.2	1.1	1.2	1.6
17-10-2013	0.9	0.6	0.9	0.8	1.0	0.8
28-10-2013	1.7	1.2	1.3	1.5	1.4	1.6
6-11-2013	1.2	0.6	1.0	1.1	1.2	1.2
Ca, mmol per liter						
22-7-2013	9.7	9.0	9.2	9.1	9.7	8.9
7-8-2013	14.0	12.3	15.1	12.0	15.3	12.4
21-8-2013	13.9	11.8	13.7	10.4	13.5	10.2
12-9-2013	12.2	12.3	15.3	12.0	14.9	12.6
23-9-2013	18.5	13.5	22.8	19.4	20.6	11.4
3-10-2013	15.6	12.3	13.9	11.7	12.3	17.1
17-10-2013	8.9	5.5	8.7	8.0	9.9	7.8
28-10-2013	18.7	17.1	17.1	19.0	16.7	21.8
6-11-2013	13.0	9.4	11.3	11.8	11.8	12.0

Date	Drain Treatment					
	1	2	3	4	5	6
Mg, mmol per liter						
22-7-2013	4.4	4.2	4.0	4.2	4.3	4.1
7-8-2013	6.4	6.4	7.0	6.2	6.9	5.9
21-8-2013	6.2	5.6	5.6	5.3	5.7	4.7
12-9-2013	4.9	5.4	6.0	4.6	6.1	5.4
23-9-2013	8.0	5.9	8.9	9.0	8.6	5.2
3-10-2013	6.6	5.4	5.3	5.3	4.8	7.7
17-10-2013	3.2	2.2	2.5	2.8	3.4	2.9
28-10-2013	8.0	7.9	6.7	8.8	6.5	9.5
6-11-2013	4.9	3.2	3.9	4.9	4.5	5.3
Si, mmol per liter						
22-7-2013	0.2	0.2	0.2	0.2	0.2	0.2
7-8-2013	0.3	0.2	0.3	0.2	0.3	0.2
21-8-2013	0.2	0.2	0.2	0.2	0.2	0.2
12-9-2013	0.1	0.2	0.3	0.1	0.3	0.1
23-9-2013	0.7	0.5	0.9	0.8	0.8	0.4
3-10-2013	0.6	0.6	0.6	0.5	0.4	0.7
17-10-2013	0.3	0.2	0.3	0.3	0.3	0.3
28-10-2013	0.6	0.7	0.6	0.7	0.5	0.7
6-11-2013	0.4	0.3	0.4	0.4	0.4	0.4
NO ₃ , mmol per liter						
22-7-2013	26.2	23.5	24.1	24.2	25.3	23.5
7-8-2013	32.2	24.2	35.3	23.4	36.6	23.9
21-8-2013	33.7	29.5	36.1	25.8	36.0	21.9
12-9-2013	28.8	27.9	38.3	27.2	36.2	23.5
23-9-2013	46.5	34.3	55.6	45.4	49.7	21.8
3-10-2013	34.0	29.3	30.4	27.5	26.6	40.3
17-10-2013	18.9	10.3	16.6	13.7	21.1	10.3
28-10-2013	39.3	39.3	37.4	40.4	33.7	46.5
6-11-2013	24.5	22.9	24.1	22.6	24.2	23.0

Date	Drain Treatment					
	1	2	3	4	5	6
Cl, mmol per liter						
22-7-2013	1.1	1.0	1.0	1.0	1.1	1.0
7-8-2013	1.0	1.2	0.8	1.4	0.8	1.2
21-8-2013	0.4	0.7	0.4	0.5	0.3	0.7
12-9-2013	0.5	0.4	0.4	0.5	0.3	0.5
23-9-2013	0.1	0.1	0.1	0.2	0.3	0.3
3-10-2013	0.5	1.1	0.7	0.8	0.3	1.6
17-10-2013	1.0	1.2	1.4	1.0	0.7	2.2
28-10-2013	3.0	4.2	3.7	3.2	2.2	6.8
6-11-2013	3.0	3.0	3.5	3.1	2.3	5.8
SO ₄ , mmol per liter						
22-7-2013	3.6	3.6	3.3	3.4	3.4	3.2
7-8-2013	6.8	8.1	6.8	7.6	6.4	7.5
21-8-2013	5.5	5.8	4.7	5.4	4.3	5.2
12-9-2013	4.5	5.0	4.9	4.7	4.7	7.5
23-9-2013	5.6	4.5	6.2	7.8	5.2	5.4
3-10-2013	4.8	4.4	4.5	5.5	4.1	7.0
17-10-2013	3.4	2.5	2.9	4.3	3.3	4.2
28-10-2013	6.5	5.8	5.1	7.8	5.1	7.5
6-11-2013	4.8	3.0	3.4	4.8	3.7	4.9
HCO ₃ , mmol per liter						
22-7-2013	0.4	0.4	0.1	0.2	0.2	0.3
7-8-2013	0.8	1.0	0.6	1.0	0.5	1.3
21-8-2013	0.1	0.4	0.1	0.1	0.1	0.5
12-9-2013	0.1	0.1	0.1	0.1	0.1	0.1
23-9-2013	0.4	0.1	0.4	0.1	0.1	0.4
3-10-2013	0.2	0.1	0.1	0.2	0.1	0.1
17-10-2013	0.1	0.1	0.1	0.1	0.1	0.1
28-10-2013	0.1	0.1	0.1	0.1	0.1	0.1
6-11-2013	0.3	0.1	0.1	0.1	0.1	0.3

Date	Drain Treatment					
	1	2	3	4	5	6
P, mmol per liter						
22-7-2013	1.4	1.6	1.6	1.6	1.6	1.5
7-8-2013	0.9	0.9	1.3	0.8	1.3	0.7
21-8-2013	1.1	1.0	1.5	0.9	1.6	0.9
12-9-2013	1.0	1.2	1.4	1.0	1.3	0.6
23-9-2013	1.4	1.7	1.9	1.6	1.6	1.1
3-10-2013	0.6	1.0	0.7	0.6	0.5	0.7
17-10-2013	0.5	0.6	0.3	0.6	0.3	0.4
28-10-2013	0.4	1.2	0.6	0.6	0.5	0.6
6-11-2013	0.3	1.2	0.7	0.5	0.4	0.4
Fe, umol per liter						
22-7-2013	35.2	31.6	30.1	32.8	32.0	32.1
7-8-2013	78.3	80.7	83.9	76.9	79.7	73.1
21-8-2013	64.6	58.9	53.8	60.4	50.9	56.2
12-9-2013	58.1	66.8	55.0	52.0	52.6	94.2
23-9-2013	84.5	55.4	90.4	79.3	73.2	68.7
3-10-2013	77.3	48.2	59.3	54.6	50.1	78.4
17-10-2013	64.9	34.9	53.2	57.0	50.2	73.8
28-10-2013	103.0	75.6	90.1	93.7	82.3	110.0
6-11-2013	66.0	31.6	53.3	54.3	54.4	61.8
Mn, umol per liter						
22-7-2013	11.1	10.8	11.1	11.0	11.3	11.3
7-8-2013	6.3	6.0	8.4	5.7	8.6	4.8
21-8-2013	10.4	7.4	11.8	8.0	13.2	7.8
12-9-2013	12.3	14.7	15.7	16.1	14.9	15.0
23-9-2013	7.4	11.5	8.2	7.1	7.9	5.3
3-10-2013	3.6	4.8	2.6	2.6	2.4	4.2
17-10-2013	4.7	3.4	3.1	4.8	5.1	3.9
28-10-2013	7.3	11.5	7.4	8.7	8.8	8.3
6-11-2013	2.4	7.4	4.5	3.8	4.1	3.7

Date	Drain Treatment					
	1	2	3	4	5	6
Zn, umol per liter						
22-7-2013	5.3	6.2	5.6	6.0	5.9	7.3
7-8-2013	6.0	7.9	5.8	7.2	5.5	6.9
21-8-2013	7.6	8.2	7.5	8.3	8.8	8.2
12-9-2013	9.1	10.6	10.1	10.7	10.5	16.6
23-9-2013	5.8	7.7	5.7	8.4	6.2	6.3
3-10-2013	3.8	4.6	3.0	4.0	3.1	6.1
17-10-2013	4.6	3.8	4.0	4.2	7.2	4.7
28-10-2013	4.4	6.7	4.7	7.0	5.3	7.8
6-11-2013	2.0	3.7	2.5	3.1	3.4	4.0
B, umol per liter						
22-7-2013	89.0	84.0	87.0	87.0	93.0	83.0
7-8-2013	135.0	120.0	157.0	120.0	158.0	120.0
21-8-2013	135.0	121.0	137.0	110.0	132.0	108.0
12-9-2013	119.0	120.0	148.0	114.0	147.0	129.0
23-9-2013	201.0	145.0	247.0	224.0	224.0	150.0
3-10-2013	173.0	138.0	158.0	139.0	146.0	196.0
17-10-2013	106.0	55.0	98.0	93.0	108.0	100.0
28-10-2013	154.0	114.0	139.0	159.0	142.0	181.0
6-11-2013	95.0	33.0	72.0	83.0	97.0	89.0
Cu, umol per liter						
22-7-2013	1.6	1.6	1.6	1.6	1.6	2.1
7-8-2013	1.7	1.9	1.8	1.7	1.7	1.5
21-8-2013	1.7	1.4	1.4	1.5	1.5	1.3
12-9-2013	1.7	1.8	1.6	2.0	1.8	2.0
23-9-2013	1.5	1.4	1.7	2.6	1.6	1.3
3-10-2013	1.4	1.4	1.2	1.6	1.0	1.6
17-10-2013	1.0	0.9	0.9	1.2	1.0	1.0
28-10-2013	1.8	2.1	1.9	2.5	1.9	2.1
6-11-2013	1.0	1.0	0.9	1.2	1.1	1.1

Date	Drain Treatment					
	1	2	3	4	5	6
	Mo, umol per liter					
22-7-2013	0.9	0.8	0.8	0.8	0.9	0.8
7-8-2013	1.2	1.0	1.2	1.1	1.1	1.1
21-8-2013	0.8	0.7	0.6	0.5	0.5	0.6
12-9-2013	0.5	0.3	0.3	0.3	0.4	0.5
23-9-2013	0.8	0.2	0.8	0.7	0.8	0.6
3-10-2013	1.1	0.7	0.8	0.8	0.8	0.9
17-10-2013	0.9	0.4	0.9	0.8	0.7	0.6
28-10-2013	1.7	0.9	1.4	1.6	1.3	1.4
6-11-2013	1.1	0.5	0.8	0.9	0.9	1.0

Appendix VI Analysis of nutrient supply

Date	Supply Treatment					
	1	2	3	4	5	6
	EC, mS per cm					
8-7-2013	3.6	3.4	3.5	3.6	3.6	3.6
16-7-2013	2.8	2.8	2.8	2.8	2.9	2.8
7-8-2013	2.7	2.7	2.7	2.7	2.7	2.7
12-9-2013	2.4	2.4	2.4	2.4	2.4	2.4
3-10-2013	1.8	1.5	1.7	1.8	1.7	1.7
28-10-2013	2.6	2.8	2.6	2.6	2.7	2.8
	pH					
8-7-2013	5.8	5.8	5.9	5.8	5.8	5.8
16-7-2013	5.7	5.7	5.8	5.7	5.8	5.5
7-8-2013	5.7	5.7	5.7	5.9	5.8	5.8
12-9-2013	5.3	5.3	5.3	5.3	5.1	5.1
3-10-2013	5.6	5.4	5.2	5.3	5.6	4.8
28-10-2013	5.4	5.3	5.6	4.9	5.5	5.1
	NH ₄ , mmol per liter					
8-7-2013	1.6	1.6	1.5	1.5	1.6	1.4
16-7-2013	1.6	1.5	1.6	1.7	1.7	1.6
7-8-2013	1.6	1.6	1.4	1.5	1.6	1.6
12-9-2013	1.0	1.2	1.1	1.1	0.9	1.1
3-10-2013	0.2	0.6	0.2	0.3	0.1	0.2
28-10-2013	0.5	1.2	0.7	0.6	0.5	0.5
	K, mmol per liter					
8-7-2013	7.1	7.0	7.0	7.2	7.0	7.0
16-7-2013	7.7	7.4	7.2	7.5	7.5	7.5
7-8-2013	9.6	10.1	9.6	9.4	10.0	9.3
12-9-2013	7.4	8.2	7.8	8.1	7.1	7.7
3-10-2013	2.9	4.9	2.7	2.9	2.1	3.6
28-10-2013	7.2	10.9	8.2	7.5	6.8	8.1

Date	Supply Treatment					
	1	2	3	4	5	6
Na, mmol per liter						
8-7-2013	0.2	0.2	0.2	0.2	0.2	0.2
16-7-2013	0.3	0.3	0.3	0.3	0.3	0.2
7-8-2013	0.2	0.2	0.2	0.2	0.3	0.1
12-9-2013	0.2	0.2	0.2	0.2	0.3	0.2
3-10-2013	0.4	0.2	0.4	0.4	0.5	0.4
28-10-2013	0.5	0.2	0.4	0.4	0.5	0.4
Ca, mmol per liter						
8-7-2013	9.4	8.7	9.2	9.3	9.2	9.5
16-7-2013	6.3	5.8	6.0	5.9	6.2	5.8
7-8-2013	5.1	5.3	5.1	4.9	5.3	4.8
12-9-2013	4.9	4.7	5.1	4.9	5.1	4.7
3-10-2013	4.9	3.7	5.0	4.5	5.2	4.3
28-10-2013	6.2	4.8	5.7	5.8	6.7	6.0
Mg, mmol per liter						
8-7-2013	4.2	4.0	4.1	4.1	4.2	4.3
16-7-2013	2.3	2.2	2.3	2.3	2.3	2.2
7-8-2013	1.7	1.7	1.7	1.7	1.6	1.3
12-9-2013	1.6	1.5	1.7	1.6	1.7	1.6
3-10-2013	2.0	1.4	2.0	1.9	2.0	1.7
28-10-2013	2.3	1.5	1.8	2.1	2.2	2.4
Si, mmol per liter						
8-7-2013	0.1	0.1	0.1	0.1	0.1	0.1
16-7-2013	0.1	0.1	0.1	0.1	0.1	0.1
7-8-2013	0.1	0.1	0.1	0.1	0.1	0.1
12-9-2013	0.1	0.1	0.1	0.1	0.1	0.1
3-10-2013	0.2	0.1	0.2	0.1	0.2	0.1
28-10-2013	0.1	0.1	0.1	0.1	0.2	0.2
NO ₃ , mmol per liter						
8-7-2013	24.4	23.4	23.9	24.7	24.3	26.0
16-7-2013	18.8	18.3	19.1	18.4	19.7	18.3
7-8-2013	17.6	18.1	17.6	16.8	18.0	17.2
12-9-2013	16.1	16.6	16.4	15.8	16.7	15.3
3-10-2013	12.3	10.9	11.8	11.3	12.6	10.1
28-10-2013	15.5	16.1	16.9	14.9	17.3	14.6

Date	Supply Treatment					
	1	2	3	4	5	6
Cl, mmol per liter						
8-7-2013	1.7	1.4	1.6	1.6	1.6	1.6
16-7-2013	0.3	0.5	0.4	0.4	0.4	0.3
7-8-2013	0.2	0.2	0.2	0.2	0.2	0.2
12-9-2013	0.3	0.5	0.5	0.3	0.3	0.3
3-10-2013	0.7	1.4	0.7	0.6	0.4	1.4
28-10-2013	1.9	1.5	2.0	1.7	1.5	2.9
SO ₄ , mmol per liter						
8-7-2013	3.0	3.0	3.0	3.2	3.0	3.2
16-7-2013	2.1	2.3	2.2	2.1	2.1	2.1
7-8-2013	2.2	2.3	2.2	2.1	2.1	2.0
12-9-2013	1.9	1.9	1.5	1.5	1.2	1.4
3-10-2013	1.8	1.6	1.6	1.7	1.7	1.6
28-10-2013	2.4	1.7	1.8	2.3	2.0	2.4
HCO ₃ , mmol per liter						
8-7-2013	0.1	0.1	0.1	0.1	0.1	0.1
16-7-2013	0.1	0.1	0.1	0.1	0.1	0.1
7-8-2013	0.1	0.1	0.1	0.3	0.1	0.1
12-9-2013	0.1	0.1	0.1	0.1	0.1	0.1
3-10-2013	0.1	0.1	0.1	0.1	0.1	0.1
28-10-2013	0.1	0.1	0.1	0.1	0.1	0.1
P, mmol per liter						
8-7-2013	1.3	1.3	1.3	1.3	1.3	1.3
16-7-2013	1.8	1.9	1.8	1.8	1.8	1.8
7-8-2013	2.1	2.2	2.1	2.0	2.1	1.9
12-9-2013	1.7	1.9	1.8	1.9	1.6	1.8
3-10-2013	0.7	1.1	0.7	0.7	0.5	0.7
28-10-2013	1.0	1.6	1.0	1.0	1.0	1.0
Fe, umol per liter						
8-7-2013	24.4	18.4	20.4	20.5	23.3	24.3
16-7-2013	28.1	24.7	23.6	25.2	25.2	24.2
7-8-2013	26.1	27.2	25.5	24.9	23.2	20.7
12-9-2013	23.7	20.5	21.6	27.6	22.2	24.9
3-10-2013	24.6	15.8	22.3	22.0	20.9	21.7
28-10-2013	42.6	31.3	33.3	31.5	37.6	36.6

Date	Supply Treatment					
	1	2	3	4	5	6
Mn, umol per liter						
8-7-2013	8.7	8.6	8.5	8.6	8.6	9.1
16-7-2013	15.7	14.8	15.2	15.7	15.7	15.6
7-8-2013	17.2	18.6	17.9	17.8	17.8	16.5
12-9-2013	14.8	16.1	15.6	16.0	13.8	15.5
3-10-2013	5.1	9.2	4.9	5.2	3.7	5.6
28-10-2013	8.7	14.4	9.3	9.3	9.0	8.7
Zn, umol per liter						
8-7-2013	8.0	7.8	7.9	8.2	8.0	8.1
16-7-2013	6.9	6.9	6.9	6.6	7.0	7.0
7-8-2013	7.4	7.8	7.4	7.3	7.3	6.6
12-9-2013	6.4	6.8	6.8	7.1	6.6	6.7
3-10-2013	2.9	4.1	2.6	3.1	2.3	3.2
28-10-2013	4.3	6.2	4.4	4.7	4.7	4.6
B, umol per liter						
8-7-2013	70.0	67.0	69.0	70.0	68.0	70.0
16-7-2013	53.0	51.0	55.0	50.0	53.0	48.0
7-8-2013	51.0	54.0	51.0	50.0	50.0	45.0
12-9-2013	50.0	48.0	52.0	50.0	52.0	48.0
3-10-2013	52.0	24.0	52.0	46.0	60.0	42.0
28-10-2013	45.0	14.0	34.0	36.0	48.0	41.0
Cu, umol per liter						
8-7-2013	1.2	1.2	1.2	1.2	1.2	1.3
16-7-2013	1.4	1.3	1.4	1.4	1.5	1.4
7-8-2013	1.4	1.4	1.4	1.3	1.4	1.3
12-9-2013	1.2	1.2	1.2	1.2	1.1	1.2
3-10-2013	0.6	0.7	0.6	0.7	0.5	0.6
28-10-2013	1.0	1.2	0.9	1.0	1.0	0.9
Mo, umol per liter						
8-7-2013	0.5	0.5	0.5	0.5	0.4	0.5
16-7-2013	0.7	0.7	0.8	0.7	0.8	0.7
7-8-2013	0.8	0.9	0.8	0.8	0.8	0.7
12-9-2013	0.6	0.7	0.7	0.7	0.6	0.7
3-10-2013	0.4	0.4	0.3	0.3	0.3	0.3
28-10-2013	0.6	0.6	0.5	0.6	0.6	0.6

Appendix VII Dry matter contents of plant parts

Dry matter contents of Fruits (F), Pruned leaves (PL), Pruned shoots (PS), Residual leaves (RL) and Residual stem (RS), of all sampling dates (F only) replicates (F, RL, RS) and treatments of Cucumber (C), Sweet pepper (P), Cherry tomato (Tc) and Round tomato (Tr).

organ	session	replicate	treatment	C	P	Tc	Tr	organ	session	replicate	treatment	C	P	Tc	Tr
F	1	1	1	3.4%	7.4%	7.4%	5.0%	PL	1	1	1	7.5%		11.0%	10.8%
			2	3.3%	7.0%	7.0%	5.2%				2	6.7%		10.0%	10.5%
			3	3.3%	7.4%	7.2%	5.1%				3	7.1%		9.6%	10.7%
			4	3.2%	7.4%	7.0%	5.5%				4	7.0%		9.8%	10.6%
			5	3.4%	7.4%	7.0%	5.6%				5	7.3%		9.4%	9.9%
			6	3.6%	7.1%	7.3%	5.1%				6	7.1%		10.6%	10.9%
		2	1	3.6%	7.6%	8.5%	6.2%	PS	1	1	1	7.2%	10.8%	10.6%	10.3%
			2	3.5%	7.1%	7.7%	6.0%				2	7.7%	10.8%	10.5%	10.1%
			3	3.4%	7.1%	7.3%	5.7%				3	7.0%	11.1%	10.4%	10.1%
			4	3.4%	7.4%	7.0%	5.8%				4	7.1%	11.0%	10.5%	10.3%
			5	3.5%	7.4%	7.3%	5.2%				5	7.2%	11.3%	10.5%	10.3%
			6	3.3%	7.5%	7.3%	4.3%				6	7.4%	10.9%	10.3%	10.1%
	2	1	1	3.0%	7.5%	6.7%	5.2%	RL	1	1	1	6.7%	11.5%	10.1%	9.4%
			2	3.0%	7.4%	7.7%	5.2%				2	5.7%	10.4%	9.5%	10.2%
			3	3.0%	7.3%	7.1%	5.0%				3	6.4%	11.0%	10.7%	9.2%
			4	3.1%	7.5%	6.6%	5.0%				4	6.3%	11.1%	10.5%	10.7%
			5	3.0%	7.4%	6.7%	4.6%				5	6.6%	10.3%	10.8%	10.3%
			6	3.2%	7.1%	7.3%	4.9%				6	6.6%	10.6%	10.7%	10.9%
		2	1	3.3%	8.1%	7.3%	4.5%			2	1	7.3%	12.2%	10.8%	10.9%
			2	3.1%	7.4%	7.5%	4.8%				2	5.9%	11.3%	10.6%	11.4%
			3	3.2%	7.4%	6.7%	5.0%				3	6.5%	10.8%	10.2%	11.0%
			4	3.1%	7.6%	7.1%	5.2%				4	6.7%	11.0%	10.6%	10.7%
			5	3.1%	7.7%	7.0%	5.0%				5	6.9%	11.5%	10.1%	9.5%
			6	3.1%	7.4%	6.9%	4.5%				6	6.1%	10.3%	10.6%	10.8%
	3	1	1	2.8%	7.9%	8.0%	5.5%	RS	1	1	1	6.4%	15.2%	11.7%	11.2%
			2	2.6%	7.5%	7.7%	5.4%				2	5.8%	14.1%	10.7%	12.4%
			3	2.8%	7.3%	8.0%	5.1%				3	5.8%	14.4%	11.7%	11.5%
			4	2.8%	7.6%	7.7%	5.2%				4	6.0%	15.0%	10.1%	12.2%
			5	3.0%	7.8%	8.2%	4.8%				5	6.2%	12.8%	11.3%	12.0%
			6	3.0%	7.2%	7.9%	5.1%				6	6.3%	14.0%	11.5%	13.1%

organ	session	replicate	treatment	C	P	Tc	Tr	organ	session	replicate	treatment	C	P	Tc	Tr
	2	1		3.1%	5.2%	7.4%	4.6%		2	1		6.9%	15.5%	12.2%	14.0%
		2		2.8%	7.6%	8.1%	4.3%			2		6.5%	14.4%	13.2%	13.7%
		3		2.8%	7.7%	8.0%	4.9%			3		6.6%	13.6%	11.6%	12.0%
		4		3.0%	7.9%	7.7%	5.1%			4		6.7%	15.4%	11.8%	12.2%
		5		2.7%	7.9%	7.5%	4.8%			5		6.4%	16.4%	10.7%	10.8%
		6		2.9%	7.8%	7.5%	5.6%			6		6.1%	14.0%	11.9%	13.4%

Appendix VIII Iodine content of Fruits

Iodine contents of Fruits (F) in mg/kg dry matter of all treatments and replicates of Cucumber (C), Sweet pepper (P), Cherry tomato (Tc) and Round tomato (Tr).

mg/kg dried			replicate	
crop	organ	treatment	1	2
C	F	1	0.70	0.63
		2	0.88	0.85
		3	0.92	0.85
		4	4.35	3.63
		5	0.73	0.77
		6	0.78	0.75
P	F	1	0.17	0.10
		2	0.15	0.10
		3	0.21	0.16
		4	0.52	0.59
		5	0.23	0.24
		6	0.13	0.16
Tc	F	1	0.49	0.48
		2	0.53	0.56
		3	0.58	0.56
		4	1.54	1.48
		5	0.61	0.60
		6	0.62	1.14
Tr	F	1	0.29	0.17
		2	0.36	0.40
		3	0.40	0.45
		4	1.11	0.84
		5	0.28	0.20
		6	0.18	0.11

Appendix IX Iodine quantities in plant parts

Quantity of iodine in mg/m² in the different plant organs as calculated from the quantification of the biomass and the iodine determination in plant tissue samples.

	Leaf	Shoot	Stem	Fruit	Total
Cucumber					
1	0.21	0.01	0.07	0.69	0.99
2	0.84	0.19	0.38	0.83	2.24
3	0.61	0.05	0.38	0.80	1.85
4	8.46	1.91	2.26	3.81	16.44
5	0.43	0.03	0.40	0.67	1.53
6	0.80	0.19	0.35	0.78	2.12
Sweet pepper					
1	4.26	0.02	0.15	0.07	4.50
2	4.21	0.08	0.22	0.07	4.58
3	4.90	0.05	0.27	0.09	5.31
4	10.80	0.59	1.50	0.28	13.17
5	4.94	0.05	0.25	0.12	5.36
6	4.61	0.07	0.22	0.07	4.98
Tomato cherry					
1	0.80	0.00	0.10	0.37	1.26
2	1.33	0.06	0.35	0.45	2.18
3	1.54	0.01	0.44	0.42	2.41
4	8.78	0.63	1.94	1.23	12.58
5	1.40	0.01	0.39	0.44	2.25
6	1.13	0.05	0.27	0.74	2.19
Tomato round					
1	1.68	0.00	0.07	0.17	1.93
2	1.98	0.08	0.28	0.31	2.65
3	2.37	0.05	0.35	0.32	3.09
4	9.49	0.97	1.74	0.78	12.98
5	2.42	0.01	0.31	0.16	2.91
6	1.66	0.08	0.21	0.12	2.06

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