Handbook Professional Vegetable Cultivation Bonaire

Arie Boers October 2016

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'A practical handbook for protected vegetable cultivation on Bonaire designated for (future) professional growers'

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PREFACE

After having cultivated vegetables on Bonaire for no less than 2.5 years, I decided to quit. Not because I was no longer successful in cultivating vegetables or no longer enjoyed it but because I believe it is time for something else. After having shared this decision, POP Bonaire (Rural Development Programme) asked if I could establish the experiences gained in a practical handbook. I complied with this question and in the past months I have included as many experiences as possible in this handbook.

The handbook vegetable cultivation Bonaire is designated for the (semi-)professional grower. The high price level of vegetables, the moderate quality of imported vegetables but perhaps even more the possibility of personally growing vegetables imply that many people are involved in this or want to start with it. This handbook can already be useful if you have a small greenhouse and if you do not then it may provide an additional stimulus to start building a greenhouse and to start growing vegetables yourself.

The handbook has the following layout. First of all it is described what circumstances are important to succeed on Bonaire with the cultivation of vegetables. After that it is discussed what is required to create, water and fertilise a soil that is as healthy as possible. Then the most frequently occurring diseases and pests are described, followed by relevant preventive measures. It is also described what the experiences in the area of labour, packaging, specific cultivation costs and important suppliers are. In the last two chapters about ten crop cultivation descriptions are provided and practical sustainable soil tips are given with regard to the rotation of these ten crops. Finally, conclusions are drawn and recommendations are provided in terms of what is important to set up a commercial agricultural industry on Bonaire.

I would like to thank a number of people for making this report possible. First of all, Jan Jaap van Almenkerk at Wayaká Advies, project leader at POP Bonaire, who was the reason and who gave me the opportunity of writing down the information. The objective of POP Bonaire is basically that the knowledge (mostly gained through trial and error) is retained for other people who live on Bonaire or who arrive in the future and who want to grow vegetables. Moreover, I would also like to thank Jaap van der Wel with whom I cooperated pleasantly and intensively in the past years and from whom I have learnt a lot. It was not always easy, because growing vegetables also means setbacks, but you stand stronger and you get further together. I would also like to thank Adrian Goedegebuure with whom I always worked together pleasantly during my time at Krusada.

I hope that this handbook contributes to a more solid agricultural industry on Bonaire. My wish would be for more people to start the cultivation of vegetables and fruit for personal consumption but mostly also for the local population.

I wish you ample reading, but mostly growing, pleasure!

This handbook was compiled as diligently as possible based on three years of experience with the horticulture on Bonaire. Use of the information is at one’s personal risk.

TABLE OF CONTENTS

Summary 7
Introduction 9
1. Infrastructure 10
1.1 Water 10
1.2 Greenhouse 12
2. Soil 17
3. Water and nutrition 20
4. Pests 22
4.1 Ants 23
4.2 White fly 23
4.3 Thrips 26
4.4 Spider mite 27
4.5 Aphid 28
4.6 Mealybug 28
4.7 Citrus mealybug 30
4.8 Rats and mice 30
4.9 Lora 31
4.10 Lizards and iguanas 31
4.11 Crickets 31
5. Labour, packaging, cultivation costs and suppliers 33
6. Crop cultivation manuals 36
6.1 Basil cultivation manual 36
6.2 Malabar spinach (basella) cultivation manual 38
6.3 Mint cultivation manual 40
6.4 Rocket cultivation manual 43
6.5 Chinese cabbage cultivation manual 45
6.6 Mustard cultivation manual 46
6.7 Yardlong beans cultivation manual 47
6.8 Cherry tomato cultivation manual 50
6.9 Cucumber cultivation manual 52
6.10 Hydroponic lettuce cultivation 54
7. sustainable soil management 56
7.1 Crop rotation 56

7.2 Herbie method 57
Conclusions and recommendations 58
Conclusions 58
Recommendations 58
Literature 60
Appendix 1 – Creating soil analyses 61
Appendix 2 - farmers house 63
Appendix 3 – Cucumber cultivation Curacao at Soltuna 64

SUMMARY

In this handbook it is elaborated in the easiest way possible how vegetables can be grown on Bonaire. The basis for the handbook is provided by the experiences of Arie Boers who has actively grown vegetables for 2.5 years. This was a process of trial and error. His experiences and knowledge were bundled in this handbook.

To be successful in the cultivation of vegetables it is important to examine properly:

- whether it is possible to deliver continuously;
- whether the product is profitable for production;
- whether the required circumstances (e.g. a greenhouse, water and nutrition) for this crop / these crops can be realised;
- whether there is sufficient demand for production and whether the required market is also available;
- whether the required labour is available.

If all five questions can be answered affirmatively then it is worthwhile to start growing vegetables.

If you can deliver a locally grown, fresh product continuously on Bonaire then you have a sustainable competitive advantage. You can deliver the vegetables on the day of harvest and it is not necessary to pay import duties. It is possible to maintain short lines with the buyers. Distribution and transport are, unlike in case of imported food, far less complex. The strength of the climate of Bonaire is the consistently high temperature and the many hours of sunshine. This creates ideal growing circumstances for several crops or rather not at all for others. Due to the consistency of the climate delivery is possible the whole year round.

An important condition for cultivation is the availability of (affordable) water and, in case of soil cultivation, a good soil. The latter can be realised through (organic) fertilisers and cultivation. This handbook provides tips how to handle the soil well on the basis of cultivation manuals, a crop rotation system and a soil decontamination system.

It follows from my experiences that, for the time being, protected, intensive cultivation is the only possibility on Bonaire. The open air cultivation of vegetables is not, or barely, possible due to goats, donkeys, birds, bats, lizards and iguanas. The greenhouses appear to be suitable for Bonaire. They can moreover be set up without difficulty. In addition, these constructions are strong and should be able to withstand a tropical storm. The greenhouses are covered with nets. Both insect nets and shade nets are possible, the choice depends on the cultivation.

The experiences were gained with cultivation in the open soil and on hydroponics. In particular leafy vegetables are successful. This handbook contains cultivation descriptions for the leafy vegetables Malabar spinach, Chinese cabbage, mustard, lettuce and rocket, the herbs mint and basil, the fruiting vegetables cherry tomatoes and cucumber and the leguminous crop yardlong beans. Continuity was realised for the crops Malabar spinach, mint, basil, rocket, lettuce and yardlong beans. It is also possible for Chinese cabbage. Probably also for cherry tomatoes, but continuity is more difficult to realise. Cucumber is grown successfully on Curacao the whole year round. To date this has not been possible on Bonaire. More research is required for cucumber and (cherry) tomatoes.

One of the difficulties of vegetable cultivation on Bonaire is the pressure of pests. Due to the heat insects develop rapidly and reproduce quickly. Unfortunately, it appeared to be impossible to import biological pesticides. Some natural pesticides are available. However, it is very important to start the cultivation clean, to select crops that are not very susceptible and to create an ideal environment for the plant in the course of which infestation occurs less quickly. In case of an infestation, the infestation must be removed as soon as possible.

INTRODUCTION

This handbook vegetable cultivation Bonaire was realised following a request of POP Bonaire (Rural Development Project). I was asked to prepare a report containing all the knowledge gained on the basis of 2.5 years of pioneering with food crops on Bonaire.

In the past people pioneered in the area of vegetable and fruit cultivation on Bonaire before. These periods often had a start and an end and continuity always appeared to be difficult to realise. The experiences were not documented as a result of which new people had to reinvent the wheel, which was unnecessarily time-consuming.

The objective of this report is to transfer knowledge in the area of vegetable cultivation on Bonaire. Eventually we hope that a number of vegetables are going to be produced on Bonaire by Bonerians for the island.

The structure of the report is an extensive elaboration of what is required to enable vegetable cultivation on Bonaire. In addition, practical guidelines are provided that may lead to success. This is based on the practical experience of Bonaire. It starts with an overview of the expected investments and the preconditions that are necessary for cultivation. Then, it zooms in on a number of cultivations that are practically feasible on Bonaire in open soil and on hydroponics. In addition, attention is paid to diseases and pests and tips are provided for solutions. Finally, some conclusions are drawn and recommendations are provided.

1. Infrastructure

1.1 Water

Without a solid water supply it is not possible to grow vegetables on a commercial basis. The availability of the purified sewage water is a considerable improvement for the horticulture and arable farming on Bonaire. In the last two years, ever since the purified sewage water has become available, the costs for water have decreased considerably at WEB from USD 10/m^3 to USD 1.5/m^{3}s.

Construction of the silo on a level surface

At the same time, the cultivation of vegetables is approached in an enterprising manner. Krusada and GreenBonaire, both at the Guatemala estate at the Kaminda Lagun, have been active in the cultivation of vegetables since 2014. The water required for this partly originated from the water purification. This water is picked up at the LVV premises by an army lorry with a 7m^3 tank.

Army lorry with 7m^3 tank

Water storage

If water is not pumped to the location where vegetables are grown with pipes then it needs to be transported in a different way.

Krusada and GreenBonaire decided to purchase a small lorry and to pick up water with it and have it unloaded in a silo. It takes about a 30-minute drive between the moment of departure and the moment of return.

At Krusada and GreenBonaire it was decided to let the water flow into a cistern from which a pump pumps it into the silo. The silo was purchased from Horticoop in the Netherlands and has a water storage capacity of 53 m^3.

The silo at Krusada was purchased from Horticoop. This silo can be installed without machines. The silo is constructed in a modular manner from corrugated steel panels with a thickness of at least 0.8 mm or 1.0 mm. The panel length is 3.05 metres. The high tensile strength renders the silo robust and eminently suitable for storage of water. Genap silos are available in diameters ranging from 2 to 31 metres and heights ranging from 1.5 to no less than 4.5 metres. All steel panels are galvanised, however a special coating is available for more durability and longer protection against corrosion.

http://www.horticoop.nl/media/wysiwyg/PDF/flyersTS/Watersilo_Genap.pdf

From silo to greenhouses

A water unit with a pump that pumps the water from the silo to the greenhouses is used for the transport of the water from the silo to the greenhouses.

Apart from water, the water unit can also disperse soluble fertilisers at a previously established concentration. It is also possible to reduce the pH with this water unit. The entire silo is acidified with this system.

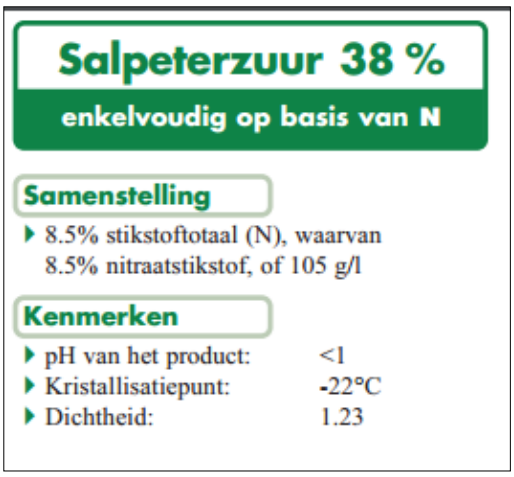
The water unit

The cultivation experience with crops in the open soil did, however, not give cause for acidification. There were no considerable cultivation problems despite a high pH for the cultivation.

In case of crops that are sensitive to a high pH this may, however, bring about difficulties.

Due to a high pH magnesium can, for instance, be absorbed with more difficulty. And with yardlong beans, cucumber or tomato this can sometimes be visible due to yellow discolouration of the leaves.

The chemical fertilisers are dissolved in the water. As not all dissolved fertilisers can be dissolved together in an increased concentration there are two 600-litre polyester containers next to the unit in which the chemical fertilisers are dissolved in water. The pump pumps from these two containers and irrigation takes place at the configured EC concentration. Namely, the unit has a setting where the salt concentration of the water can be measured and configured at the set value.



Salpeterzuur 38 %

enkelvoudig op basis van N

Samenstelling

- 8.5% stikstoftotaal (N), waarvan 8.5% nitraatstikstof, of 105 g/l

Kenmerken

- pH van het product: <1
- Kristallisatiepunt: -22°C
- Dichtheid: 1.23

The frequently used nitric acid can be used to acidify. This can adjust the pH of the water downwards.

A correct pH for most plants falls between 5.5 and 6.5. The pH of the WEB water is usually around 8.0 and thus on the high side. To date we have experienced little problems in the open soil with a high pH. However, feeding issues may become visible, e.g. a lack of magnesium and manganese in the leaves. The plant then has difficulty to absorb nutrients due to the high pH, for instance because other nutrients are absorbed too easily. In case of cultivation on hydroponics adjustment of the acidity is, however, important to realise optimal plant growth, hence in case of hydroponics we did adjust (reduce) this with nitric acid.

1.2 Greenhouse

Foundation
The foundation of the arched greenhouses at Krusada consists of ground anchors. These are placed every 2 metres. The ground anchors are poured 50 to 75 cm deep in the concrete. A possibility that may offer advantages is to fully pour the foundation in concrete with an elevated edge of 10 cm above the ground. This prevents unwanted animals (rats, iguanas) even better from entering. Moreover, it offers even more solidity to the entire construction.

Frame
The frame that we worked with was of an arched greenhouse. Other constructions are also possible, however in combination with nets this is a handy type of greenhouse. Because it happened at Krusada that a storm destroyed the greenhouse (Omar in 2008), it was decided to opt for an arched construction. This is usually more solid due to the said shape.

Setup of the frame of a double arched greenhouse from the air. The soil structure has already been optimised at this stage.

Mesh
It is very important to protect the crops against iguanas, lizards, goats, rats and mice (also see the chapter diseases and pests for this). Unprotected cultivation is not possible due to the presence of iguanas, goats and Amazon parrots (loras in Papiamento).

This is also related to the fact that the island has very few green areas. This particularly applies in the dry season. That is why animals go to places where green is present, e.g. in the greenhouse, on a large scale.

Usually, an obvious choice is, in our opinion, a greenhouse with protection of a mesh type. Compared to plastic or glass, mesh has better ventilation. When using mesh, two types of mesh can be chosen: shade mesh or insect mesh. It needs to be taken into account that when the nets get dirty they let through even less light. This may be harmful to the plant cultivation. Because a so-called imbalance may occur between light intensity and temperature in the course of which the plant can display an unwanted growth like, for instance, in case of lettuce. The lettuce started stretching and forming a stem because the circumstances in the greenhouse were too dark.

Setup of a single arched greenhouse (Rovero), with insect mesh (GreenBonaire).

Yardlong beans, mint, basil and spinach were grown most successfully under insect mesh with a mesh width of 0.27*0.88 mm (Ornata Plus white fly mesh from Howitec, see below). Lettuce and savoury mixed salad were grown under a 50% shade net. We had customised nets made for the greenhouses in the Netherlands.

When attaching the mesh it is important to do this as tightly as possible in order that it does not tear on the steel frame with the, often, hard wind. As a consequence the net may have a longer lifespan. It is also important to attach protective adhesive strips on the frame, also to avoid wear and tear of the net.

Double arched greenhouse with Ornata Plus white fly mesh) as protection.

Single arched greenhouses with 50% shade mesh.

Types of netting including prices* and where purchased

Type of net	Price	Website	Characteristics	Cultivations
Rovero: shade net	USD 2.0/m2	www.rovero.nl www.howitec.nl	Reflects 30-50-70% sunlight as a result of which less light arrives in the greenhouse.	Lettuce, rocket, tomato
Howitec: insect mesh	USD 2.5/m2	www.howitec.nl	White fly mesh Ornata Plus 2788 has a mesh width of 0.27*0.88 mm.	Chinese cabbage, mint, basil, spinach, yardlong beans

*Prices are indications and were applicable at the time of purchase and for a certain purchase and certain dimensions.

Inventory

Depending on what is grown in the greenhouse, the necessary material and machines are purchased. If it is decided to grow in pots or trays then other equipment is required than when growing takes place in the open soil. In case of small dimensions the use of a tractor is redundant. If large-scale cultivation in the open soil takes place then a tractor with a digging and milling tray is recommended.

For the large-scale cultivation of leafy vegetables cutting with (electric) grass shears is no longer feasible. This can, however, be realised in a profitable manner with the quick-cut greens harvester.

This relatively simply device is driven by a battery and makes the harvesting of leafy vegetables a lot easier and faster.

In the following table it is indicated what is required for hydroponics and open soil.

Cultivation	Hydroponics*	Open soil**
Cultivation water trays	X	
Tractor		X
Air pump	X	
EC meter	X	(X)
Organic fertilisers		X
Chemical fertilisers	X	(X)
(Nitric) acid to reduce pH	X	
Natron (caustic soda) to increase pH	X	
Rain bird irrigation system***		X
Drip system with water pump		X
Air pumps	X	
Hydrophor water pump		X
EC meter	X	X
pH meter	X	X
Cleaning agents	X	
Gravel to make / keep path accessible	X	
Syringe pump (in case of larger surfaces and high-yield cultivation)		X
(Electric) knapsack sprayer	X	X
Lorry for grey water transport		X
Sowing trays and cutting trays	X	X
Pegs	X	
Hydro grains	X	
Quick-cut greens harvester****		X
Precision sower*****		X
Water unit		X
*cultivation of the following is, in any case, possible on hydroponics: lettuce, Chinese cabbage, basil, mint.		
** in the open soil we were able to grow the following successfully; Malabar spinach, basil, rocket, yardlong beans and cherry tomatoes.		
***the rain bird irrigation system is suitable for leafy vegetables that receive water from the top (no grey water!), e.g. mixed salad and rocket.		
**** the quick-cut greens harvester is suitable for harvesting mixed salad and rocket.		
***** with the precision sower crops can be sown that do not need to germ in trays or pots first, e.g. mixed salad and rocket.		

Some investments and estimated amounts	
Water unit	USD 15,000
Silo 50 m^2	USD 2,000
Second-hand tractor (including digging and milling tray)	USD 15,000
Greenhouse (single arch, 9.30*50 metres)	USD 10,000

Water unit
The water unit is useful for cultivations in the open soil where regular watering is important. Certainly when much water (purified water) is used, this device is very useful. The water unit consists of two pumps, a number of sensors and a machine to configure everything.

The possibilities of the water unit are:
- The possibility to configure 20 individual automatic taps, in time span and frequency per week.
- Inclusion of chemical fertilisers in soluble form with 2 different fertilising trays (A and B tray).
- Configuration of the EC (fertiliser concentration).
- Configuration on / off watering per weekday.
- pH configuration.
- Configuration of time of watering and potential repetitions.

Agricultural machines and tools*

Inventory	Purchased where	Estimated price
Tractor	Netherlands	EUR 15,000
Quick-cut greens harvester	Farmer's Friend, USA	USD 560
Syringe pump	DS2	USD 1,200
Lorry	Van Vliet	USD 30,000
EC meter	Netherlands	USD 15
pH meter	Netherlands	USD 15
Thermometer	Netherlands	USD 15
Air pump	Netherlands	USD 50
Digging tray	Netherlands	Variable
Milling tray	Netherlands	Variable
Hydrophor pump	Netherlands	USD 180

Including prices and where purchased (if known).

Choice for water
When using water for the cultivation the following rules apply in case of purified water:
- Not suitable for leafy vegetables (if in contact with leaves).
- This water must be dripped.
- Cannot be in direct contact with the plant.

The water that is purified by WEB must be used very accurately in case of vegetable cultivation.

In case of hydroponics cultivation it is recommended to use WEB drinking water. For cultivations that are watered with a rain irrigation pipe at a height or another installation (e.g. rain bird irrigation) in the course of which plant components get wet, irrigation should always take place with rainwater or WEB drinking water.

Watering systems

If cultivation does not take place on hydroponics then watering should take place regularly (in the dry season daily in the morning). This can be done via a sprinkler or via a drip system, depending on the crop selection. See the following table what is recommended and/or what is possible per cultivation.

Cultivation	Hydroponics	Drip system (purified water)	Sprinkler / rain bird / sprayer (pure WEB water / purified rainwater)
Chinese cabbage	x	x	x
Mustard		x	x
Rocket			x
Tomato		x	x
Cucumber		x	x
Lettuce	x		
Yardlong beans		x	
Mint		x	x
Basil	x	x	x

2. Soil

The soil is an important pillar for all crops that are grown in the open soil in terms of whether or not a cultivation will be successful. At the moment most of the vegetables on Bonaire are (still) grown in the soil. It is important for the soil that there is a good balance between moisture retention, fineness of the material, airiness and chemical structure. In addition, it is important that this combination is geared ideally to the cultivated type of plant.

The roots of a plant must be enclosed sufficiently in order to absorb moisture and to provide firmness to the plant without rotting occurring. Rotting can be caused by excess water. In that case an oxygen deficiency occurs.

Ideal soil composition?
Plant roots do not have one preference for a certain type of soil, this may vary strongly per type and variety. It is important to always verify what the natural environment and in this case the soil of a plant is. Moreover, much about this can be found on the internet.

The existing soil should in many instances, to start the cultivation of vegetables, be enriched with organic substances (and fertilisers). This is an important step to create a good soil where fineness of the soil, airiness and moisture retention are balanced. Useful fungi, bacteria and soil insects moreover feed on this organic material. This kind of soil is optimal for many vegetables and fruits. Think about, for instance, fruiting vegetables but also leafy vegetables and cabbages grow well on a soil that is rich in nutrients from organic substances. Organic substances can be all sorts of things: compost, chicken manure, cow manure, donkey manure and goat manure, for example. A combination of different types of fertilisers is usually optimal in the course of which compost cannot easily be given in excess. Too much fertiliser is, however, also not a good thing. A plant will then not grow well. These organic fertilisers also give the plant directly the minerals that it needs: nitrogen, phosphor, potash, magnesium (N, P, K and Mg) and trace elements (minerals that the plant needs in small concentrations). When using organic substances nutrients gradually become available to the plant.

Soil preparation
This is subject to ample research and many of the results advocate less intensive soil preparation. The organic substances, which are present in the topsoil, provide the best minerals to the plant. These organic substances are lost in case of deep digging. The topsoil also offers a safe climate for useful soil life that provides for underground networks and a peaceful digestion of organic material. Working with, for instance, a spading fork is a good alternative to digging. Digging results in fewer earthworms and other useful soil animals, spitting breaks through useful, thread-like fungi as a result of which there is a reduced balance between fungi and bacteria, digging (without mulching) provides for a harder topsoil and ultimately actually tighter soil (compaction). In this lower oxygen climate pathogens occur more easily. In short, the objective of digging is to add oxygen but this is occasionally not realised by digging. Namely, a 'living' soil provides for a more sustainable underground network as a result of which plants can root deeply.

Clearing
Certainly when cultivation on Bonaire takes place for the first time, it is recommended to dig. Then immediately add a reasonable concentration of organic material. This stimulates the soil life and results in more oxygen in the soil. Moreover, the soil on Bonaire often contains stones that should first be removed. They then surface automatically and can continuously be removed, which benefits the quality of the soil.

Green manure
Green manure can be very useful to add organic material to the soil. Problem on Bonaire is, however, the high price for water. The yield must improve very strongly if this wants to lead to added value on Bonaire. A practical example that is, for instance, possible is to dig an old, low cultivation (e.g. rocket) through the soil. This also increases the organic material in the soil and yield can first be obtained from a cultivation.

Advantages of green manure are:
- These plants offer a considerable boost for the compost heap after a few months. It is also possible to leave mowed off plants like munch (a low organic material that you cover the soil with). Do take into account that diseases and pests can also settle in dead crop residues as a result of which this can become relevant with a new cultivation again.
- Due to the rooting of these plants the structure of the soil improves. Some fertilising plants have a side effect against too many pathogenic eels in the soil.

Practice on Bonaire
The soil is the basis in terms of whether the cultivation will be successful or not. On Bonaire it is important to check the following before the soil is being used for plant cultivation.
- Are there many stones in the soil?
- How saline is the soil? (The EC of the soil should be checked)
- What is the structure of the soil? Sand, clay, loam.
- What is the condition of the organic substance concentration of the soil?
- Is the soil not contaminated?
- What is the pH of the soil?

Before a plot of land is put to use for vegetable cultivation in the open soil, it is recommended to first have this plot of land checked on the five aforementioned matters. The structure and the chemical condition of the soil can be examined at a research laboratory in the Netherlands. This could, for instance, be done at a research laboratory like Eurofins Agro (http://eurofins-agro.com/nl-nl).

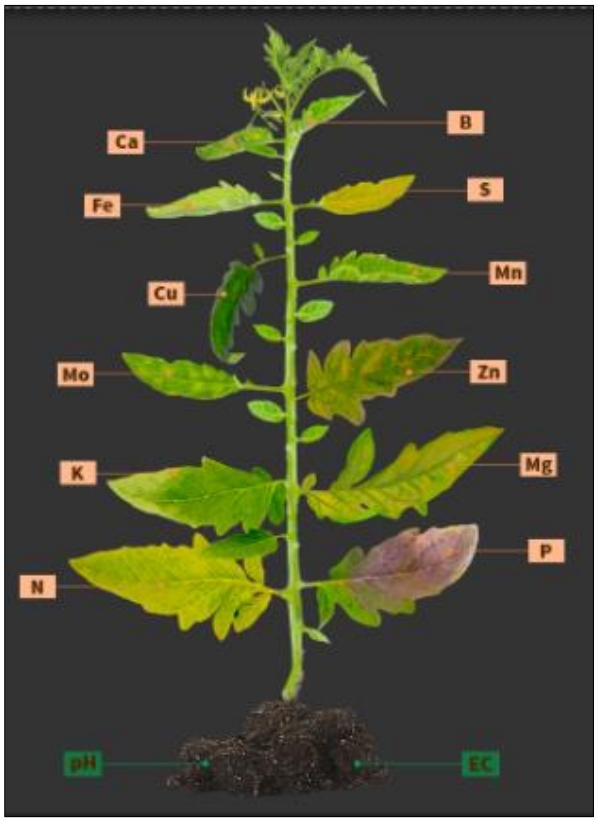
At Krusada a new piece of greenhouse was built. On a plot of land that was uneven and that contained a large amount of stones. The topsoil (good soil and fine structure) was first removed, then everything under it was levelled. Finally, the topsoil was supplemented with fine diabase soil distributed over the part on which the greenhouse would need to be built. The cultivation layer there is about 25 cm of good soil.

After that the greenhouse was set up. In general it can be assumed that soil from a river bedding is fertile and has a fine structure. To purchase soil or soil enriched with goat manure on the island, Alsy can be contacted. You pay a fixed price per m^3. His telephone number is +599-7865558

Summary
The soil is often the starting situation of the crop that is being cultivated. With the limited resources the soil can be treated the most easily in order to generate optimal growth. It is important that the soil structure, the soil life and the soil nutrition are optimal for the plant. This may differ strongly depending on the type of plant.

3. Water and nutrition

Water and nutrition are two very important things for the plant that determine whether in combination with light, temperature and CO_2 the plant grows well.



In the illustration above it is shown how deficiency symptoms can be detected on a plant. This can provide an indication as to what fertiliser is required.

Water is the means of transport that is required for the plant roots to properly absorb nutrients (nutrition). In addition, a plant can cool itself with water. Water and nutrition are always interrelated.

On Bonaire we cannot easily regulate many growth factors (light, temperature and CO_2) in arched greenhouses. However, steering with the growth factors nutrition and water is easier.

Use of fertilisers on Bonaire
In the time at Krusada and GreenBonaire the fertilisers calcium nitrate and Pavane polyfeed (NPK 9-15-38+2MGO) were mostly used. This combination was a fairly complete nutritional mix that was easy to include. Both fertilisers readily dissolve in water.

Occasionally some iron (when shoots did not sprout well) and urea (when the older leaves turned yellow) were included via the water unit.

In advance organic fertilisers were regularly added before the cultivation started (Farmers House, dried chicken pellets). The NPK ratio of nitrogen, phosphate and potassium of these dried chicken fertiliser pellets is 4.5-3 (-2MG). Apart from the nutrition that is required for the plant growth this also improves the structure of the soil.

Organic fertilisation is effective less quickly than chemical fertilisation but has a much longer effective duration.

Irrigation materials
Irrigation materials can be purchased from Horticoop or Brinkman in the Netherlands. At Krusada a PE 25 mm hose with tubes with a length of 80 cm with attached perpendicular stab pins every 20 cm is used. Capacity for the drip is 3 litres per hour. The supply tube to the greenhouse is 50 mm thick. This supply tube can be

Drip installation; PE 25 mm hose with a drip tube with stab pin every 20 cm.

purchased from Kooyman. Irrigation material that is easy to clean is preferred because contamination occurs frequently.

Irrigation: how much and when
Irrigation best takes place in the morning. Just after sunrise is a good time. Do in any case check every morning if the plant needs water, the afternoon when the plant is weak is not a good time. This is neither a good time to water. The leaves of the plants may then burn. In case of dripping this may take place in the afternoon, however it evaporates fasted than in the morning. Moreover, water that is too warm is not good for the plant. Hence this should also always be monitored. A potential underground water storage is therefore best. The water temperature consequently remains the lowest.

Inspection of drip system
It is important to regularly inspect the drip tubes. It may happen that blockages occur. This can be cleaned (with chlorine and then with acid) or replaced. It is also important to check the water release per dripper.

Research
In case of large-scale cultivation it is recommended to have the soil surveyed. This way the quality of the spoil can properly be analysed and it can be determined what else is needed to make it suitable for cultivation. Often appropriate advice can also be given on the basis of the previously communicated situation.

It should be taken into account that a soil sample cannot just be sent to the Netherlands. This requires a permit from the Food and Consumer Product Safety Authority, otherwise the soil sample cannot be imported and it needs to be surrendered at customs. This can be applied for with the organisation that conducts the survey. Via the following link you can see where you can have soil surveyed. Through this organisation it is also possible to apply for a permit from the Food and Consumer Product Safety Authority if a required soil analysis needs to be conducted in the Netherlands.
http://eurofins-agro.com/sites/blgg.nl/files/orderformulier_grond_diversen_2015.pdf

More information about a soil survey can be found in appendix 1.

4. Pests

One of the biggest problems to grow vegetables on Bonaire are (insect) pests. The constantly high temperatures ensure that the circumstances for pests are often ideal for fast expansion. Many pests on Bonaire occur everywhere in the world. Some also occur specifically in the tropics, e.g. iguanas and lizards. An overview of the most frequently occurring, harmful pests for us is provided in this chapter.

First of all, a few tips to experience as little nuisance as possible from pests. Namely, there are reasons why degradation occurs less quickly. A healthy plant is a plant able to resist.

- *A fertile soil*; provide for the correct basic manuring and properly incorporate this in the soil. Per crop much can be found about this on the internet. If only organic substances are used then it is important that these fertilisers, when used, have already mostly been subject to a digestive process. A soil survey prior to cultivation is important to determine what fertilisers must be added and to determine a strategy how to proceed with the cultivation. A good soil survey company can also prepare an opinion on this.

- *Work hygienically;* avoid litter in the greenhouse in between the plants. Also remove old pieces of twines and pots, etc. In case of hydropic cultivation it is recommended to refresh the water after every cultivation and to properly clean the cultivation trays. In case of a persistent pest in an old crop it may be necessary to combat this chemically for a fresh start of a new cultivation. Always keep the safety time into account.

- *Correct amount of water at the right time;* water is certainly very important and must also be given at the right time. A strong plant is a plant able to resist.

- *Alternate cultivations;* some cultivations that are sensitive to the same pest can best not be planted successively. For instance, Chinese cabbage and yardlong beans (spider mite) and Chinese cabbage and rocket (caterpillars) are difficult combinations. If the pest is still present then you experience ample nuisance during a successive new cultivation.

- *Start the cultivation clean;* a clean start is half the work. It is important to remove old crop residues. To dig the soil. To have the greenhouse empty (preferably for a few days). Potentially repair holes in nets. As a consequence the pressure of pests will reduce considerably. It is advised for young plants for, for instance, Chinese cabbage, yardlong beans, spinach, tomatoes to grow these in a different greenhouse (where pest insects are not or barely present) up to the plantable stage.

- *Work with insect mesh;* with insect mesh it is avoided that pests can easily enter the greenhouse. Good experiences were gained with white fly mesh. There is, consequently, less degradation due to white flies. It is important for an optimally clean greenhouse to regularly check for holes and to (where possible) create a type of corridor where, when opening a door, a ventilator blows outwards as a result of which it is hard for insects to enter.

If degradation nonetheless occurs then it is important to observe the following.
In case of aphid, spider mite it is wise to remove the affected plants (and potentially some surrounding plants) at an early stage. Do this by removing the plants in a trash bag in order that the pest insects cannot escape from the plant. Also avoid that you transfer pests through people. Hence, do not let

everybody walk around the greenhouse. If you were in affected areas then it is wise to quickly change clothing after that. Start every day with clean clothing.

4.1 Ants

Ants are part of the "wasp-like insects", they originate from digging wasp species of which the working insects lost their wings. This also explains that some ants that also occur on Bonaire can sting hard.

Damage

Ants cause damage by assisting aphids in their work. For instance, they kill the larvae of the ladybugs. The ladybug is the natural enemy of aphids. In case the aphids are under threat, these insects are also taken by ants and protected and milked (see photo). The damage of ants themselves is minimal. They may create tunnels in the plant stems and they can steal small seeds. They use the oil from it. They may also dig tunnels in the soil as a result of which roots can be exposed and cannot absorb water. Ants do stimulate the system that they build.

Ant 'milking' aphids.

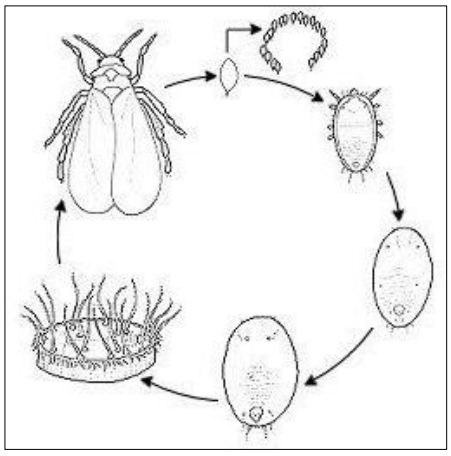
Prevention

Ants hate the scent of African Marigolds (Tagetes) or chives. It may be useful to use these plants as intermediate planting.

4.2 White fly

White fly is the name of small white flies that feed on the bottom of various crops by sucking away plant liquids. The white fly may form a considerable pest.

The plant loses plant liquids and reacts to the toxic saliva of the white fly. Because white flies live in large groups they can destroy a plant entirely. In case of large colonies, large colonies emerge from the bottom of the leave when touched. On Bonaire the white fly mostly occurs in cucumber and tomatoes. Aubergine is also a crop that is easily affected by white fly degradation. This crop can also be grown on Bonaire, however we have little experience with it.



Lifecycle of the white fly. Four larvae stages and one pupal stage.

Damage

The small quantities of plant liquids that a fly absorbs are not immediately harmful, however due to the large colonies of white flies this does cause growth inhibitions and deformation of the leaf. Moreover, the affected leaf obtains a dark (black) colour as a result of which the photosynthesis decreases.

Apart from the absorption of plant liquids, the white fly secretes a sweet substance on which sooty moulds can grow. As a consequence the plant loses even more energy for the development of harvestable parts.

The white fly has, like most insects, different development stages. For the white fly there are five (four larvae stages and one pupal stage). Although only the adult stages can be seen with the bare eye. This means that many more eggs (in the form of circles) are present.

Prevention

It is difficult to combat the white fly. It is important to work preventively because once white flies usually means always white flies. It may help to hang up yellow sticky catch strips to catch the white flies. It is also recommended to use insect mesh (white fly mesh). In greenhouses with insect mesh the problems with the white fly are many times smaller. By using ventilators and a corridor at the entrance it is hard for the white fly to penetrate the greenhouse from the outside.
The eggs of the white fly are also eaten by the delphastus bug. This is a natural enemy of the white fly that occurs on Bonaire.

Tips to catch the white fly

- Hang up glue strips. The white fly is attracted by the yellow colour and because they are glued to these strips they will die.
- The delphastus catalinea is a beetle that eats white flies and occurs in, for instance, tomatoes. Unfortunately this beetle is not attracted by every outbreak of white fly. For instance, not in case of cucumber. In addition, the delphastus bug only truly gets going in case of a very large outbreak of white fly.
- Remove affected leaves (often at the bottom) and/or plants.

This beetle is the Delphastus catalinae, a predatory beetle that eats many eggs of the white fly. This beetle occurs amply on Bonaire and eats large amounts of white fly eggs. This insect continues performing in circumstances where other combatants pull out. However, this insect is not active in tomatoes because of the large hairs on the leaf as a result of which it is hard to move.

This is the ichneumon wasp, this ichneumon wasp parasites larvae of the white fly by laying an egg in the white fly larvae. The ichneumon wasp larvae use nutrients of the white fly larvae as a result of which they parasite the white fly larvae. I do not know if the ichneumon wasp occurs on Bonaire.

Cucumber with white fly damage at an early stage.

Cucumber leaf with white fly damage at a very advanced stage with the famous sooty mould.

In Dutch greenhouses yellow catch strips are hung up throughout the greenhouse in order to catch the white flies. It also appears to be the case that if a certain pattern is visible on the catch strips, the white flies are attracted to the catch strips even more. After the cultivation the catch strips are also replaced.

Yellow catch strips attract white files. They sit on it and can no longer escape, which prevents the problem.

4.3 Thrips

Thrips are a small, slender insect with fringed wings. Thrips feed on liquids from cells of different types of plants and animals by punching holes in the cells and by sucking up the content.
Thrips are very small (<1 mm in width) and cannot fly very well, although they can occur at considerable heights due to thermality and the wind. In optimal conditions (high temperatures) thrips can reproduce very easily and fast.

Thrisp damage spinach top.

Damage
The two most frequently occurring harmful types of thrips are the tobacco thrips and the Californian thrips. These small elongated insects scrape the epidermis of the leaves and suck up the liquid. This can be noticed by the silver-like stains they leave behind.

Reproduction
The total cycle from egg to adult thrips is 12 days at 30°C. One female thrips can produce well over 100 offspring.

Damage
Thrips damage the crop by sucking the plant cells empty. The emptied cells fill up with air and thus provide a silver shine on which black dots (the excrement) can be seen. In addition, there are various types of damages, depending on the host plant. For instance, thrips damage to very young cucumber fruit may result in deformed (= crooked) cucumbers. In case of bell peppers thrips cause damage to the fruits and in case of spinach we observe malformed (fringed) leaves, mostly visible in the top.

Thrips damage in bell pepper is a considerable problem.

In case of spinach this problem can be solved by regularly topping spinach plants in case of degradation. This way you often remove the majority of the thrips from the plant and you ensure that the plant starts forming offshoots in the axil of the leaves. These leaves are often less affected and the spinach can grow through the thrips pest.

Prevention
Just like with the white fly it is possible to catch thrips with yellow catch strips. To catch thrips it is also possible to do this with blue catch strips. Namely, thrips are even more attracted to this.

Spider mites; often visible on the bottom side of the leaf. In case of a larger outbreak also with typical cobwebs.

4.4 Spider mite

Recognition
Spider mites belong to the arachnids. Bean plants like yardlong beans are very good host plants for spider mites, hence spider mites frequently occur on these plants. Spider mites also occur on other crops, e.g. rocket, tomatoes, cucumber and basil.

Spider mites can basically be found on the bottom side of the leaves. They puncture holes in the cells and then suck them empty. The empty cells obtain a yellow colour. On the top side of the leaves the damage can be recognised as small yellow dots. In case of serious degradation the leaves turn completely yellow and due to the disappearance of the chlorophyll they ultimately die. In case of tomatoes a small number of spider mites can already result in serious damage. Spider mites on tomatoes is reddish brown. Spider mites on beans are light to dark green.

Lifecycle
The development phases of the spider mite in greenhouses are: egg-> larvae-> nymph -> adult spider mite. The development duration from egg to adult spider mite depends on the temperature and is less than two weeks.

This is about one week over 30°C. The eggs are round and are mostly placed on the bottom side of the leaves.

Spider mites on yardlong beans on the bottom side of the leaf.

Damage
Nymphs and adult spider mites produce webbings. In case of large numbers of spider mites the plants can fully be covered by webs with swarming spider mites.

Measures
Unfortunately spider mite is difficult to combat. Removing plants at an early stage of spider mite degradation may help. Spider mite also causes less nuisance if the crop is kept moist regularly by sprinkling (for instance every other day). Plants that are dry and catching a

draft are very vulnerable. Moreover, the prevention of spider mite also depends on the crop. Yardlong beans are, for instance, very hard to grow because they quickly attract spider mites. In case of spinach spider mites do not quickly pose a problem.

4.5 Aphid

Aphid occurs on many different plants. Aphids are 1.5 to 4 mm in size. The black bean aphid occurs on many crops, inter alia also on yardlong beans. Black bean aphids occur in large numbers in the tops of the plants and on young shoots. This type of aphid mostly causes suction damage. The green peach aphid is particularly harmful because it transmits virus diseases to different crops. Aphids secrete honeydew. This creates a sweet, sticky substance on the leaf in which black moulds are developed.

Aphids often live in colonies on the bottom side of the leaf.

Damage

Shrivelled, malformed leaves are the characteristics of aphids. Aphids are often well visible on the bottom side of the leaf. They often occur in colonies (see figure).

Aphids pierce plants looking for the sweet liquids, usually via the bottom side of the leaf. When piercing plants aphids infected with virus diseases can transmit the virus to another plant. In particular the flying generation can spread virus diseases at a large scale.

Aphids working together with ants in the greenhouse on a bell pepper plant.

Measures

The biggest damage is caused by the transmission of viruses. The prevention consists of removing sources of contamination, e.g. the removal of contaminated plants affected by virus diseases. Aphids can be assisted by ants. Ants can protect aphids against hazards as a result of which the population increases quickly. It is therefore also important to combat ants.

4.6 Mealybug

Mealybugs cause damage to plants by sucking plants cells empty as a result of which malformations may occur and the growth is inhibited. Mealybugs occur regularly on yardlong beans, spinach and Chinese cabbage on Bonaire. Mealybugs also occur frequently on papaya and many other types of plants.

Because the plant liquid that the mealybugs suck up contains very little proteins (and many sugars) they need to consume large amounts of liquid in order to obtain sufficient proteins. The surplus plant liquid is secreted in the form of

honeydew. Sooty moulds develop on the honeydew. This degradation of the crop (leaves) hinders the plants in their photosynthesis (generation of nutrients) and hence in the yield.

Lifecycle
In case of mealybugs five development stages can be distinguished, i.e. for females one egg, three nymphalid stages and an adult insect. The males go through the development stages egg, two nymphalid stages, false pupa and adult insect. The mealybugs thank their name to the fact that the body of the females is from the third larvae stage covered with a white mealy, wax-like material in the form of powder, threads, protrusions or sheets.

Damage
Mealybugs frequently occur in nests. They cannot spread over large distances. If there are flowers or fruits present then these are usually skipped.

Mealybugs secrete honeydew on which sooty moulds start growing that together with the white wax-like secretion of the mealybugs contaminate the plant that can breathe less properly. This reduces the photosynthesis of the leaves as a result of which the production decreases.

Prevention
People who perform crop treatments are the most important disseminators. When it is known degradation is present, it is recommended to first harvest and/or perform other crop treatments at other locations and ultimately at the locations with mealybugs. This prevents dissemination. It appeared to be very difficult to combat mealybugs. It works best to first remove the affected plants and to remove these from the location in a sealed trash bag. If young crops are planted alongside old affected crops then a protection with plastic may also be useful. Work with washed clothing every day and first work in the clean area and lastly in the area contaminated with mealybugs in order to thus avoid dissemination as much as possible.

Considerable degradation of yardlong beans with mealybugs.

4.7 Citrus mealybug

The citrus mealybug occurs all over the world and has many host plants. The insect causes damage to cucumber and aubergine. They can often be found at the growth points and in the axils of the plants.

Citrus mealybug

Because the males have a very short life they are not observed in large numbers.

The duration of generation from egg to adult mealybug is 32 days at 26º C. After mating the females can lay 100 to 600 eggs. The period that it takes to lay eggs is about 1 to 2 weeks. This type of bug also occurs on Bonaire and is, as many other bugs and other animals, referred to as “piespies”.

This type of bug probably also occurs on yardlong beans and basil.
Apart from the ordinary mealybug and the citrus mealybug there is also the long-tailed mealybug. The same prevention method as in case of the other bug species is recommended.

4.8 Rats and mice

Rates and mice usually reproduce fast and can inflict damage by nibbling on fruit or eating seeds. They can also inflict damage on other vegetables, in particular in case of overripe fruits that smell very sweetly and that are juicy damage easily occurs.

They create nests in bales of hay or straw. Rats and mice can always enter the greenhouse; mice even enter through the smallest of holes or cracks.

A rat trap in which mice, rats and lizards can be caught. A good biological measure.

To avoid rats and mice as much as possible it is recommended not to leave untidy places in the greenhouse. Hence, avoid rubbish like many pots, open bags (potting soil). Namely, rats and mice can easily hide in them.

To catch these animals there are many traps available on the island. This does, in any case, not distribute harmful poison. When catching rats do not leave them dead in the clamp for too long, namely this will quickly attract other animals. Nor is this hygienic. When nets are checked regularly then this will also reduce the nuisance experienced from rats and/or mice. A cat can also act as a predator to catch these animals, as well as iguanas and lizards.

4.9 Lora

The lora (the Papiamento name for the Amazon parrot) is a parrot frequently occurring on Bonaire. In protected cultivation you barely experience any nuisance of them. The problem mostly occurs in case of unprotected cultivation of fruity crops (e.g. pumpkin, papaya and calabash). That is why it is wise not to wait too long with the harvesting. It is better to harvest a little too 'green' (raw) and to let it ripen further at a covered location that cannot be reached by loras.

Lora with calabashes

4.10 Lizards and iguanas

Lizards and iguanas form an important threat to almost all plants but mostly to young plants.

To avoid these animals from eating the plants it can be decided to place one or more rat clamps for these animals. Another alternative is the introduction of cats or dogs at the greenhouse. When the plants get a little older then the threat of lizards is not as considerable. It is good to examine further what plants are very susceptible to this and what plants are less susceptible.

Iguana

Plants that are eaten by iguanas can better not be planted outside the greenhouses. If this cannot be done differently then it is worthwhile to first examine whether large plants are eaten. Iguanas can eat entire leaves with their teeth but lizards do not have actual teeth and therefore only eat young leaves.

Lizard

4.11 Crickets

In case of leafy vegetables in greenhouses with shade mesh we have experienced ample nuisance from cicadas or rather crickets. This was probably the southern field cricket that occurs frequently in warm areas. The cricket eats from roots to parts of the plant that are above ground. The cricket mostly likes a humid and warm environment. It eats grasses, roots but also leaves and seeds. This can particularly pose a problem in case of rocket. Combatting crickets can best be done by using white cloth, repairing holes and removing weeds in a timely fashion.

Southern field cricket

4.12 Caterpillars – Golden twin-spot moth

In the past caterpillars posed problems with rocket and Chinese cabbage. At the time the golden twin-spot moth was probably the culprit. This moth is active at night and lays a lot of eggs in its short life on the bottom side of leaves of the aforementioned crops. We experienced much nuisance particularly during the rainy season.

Preventively insect mesh can help very well against this pest. If degradation nonetheless occurs then it is best to opt for a change of crops in order to avoid worse. Then select a crop that is not or barely susceptible to caterpillars.

4.13 Other pests

Donkeys and goats form a threat for the unprotected cultivation. Closing doors properly is basically enough to avoid these animals.

5. Labour, packaging, cultivation costs and suppliers

Depending on the crop labour is a high or a low cost item. In addition, cultivation costs are also very diverse. Every crop has advantages and disadvantages that may be very divergent. Due to the small-scale market on Bonaire automation is not always an option. Packaging is often a time-consuming activity but can also just add the value to the product that it needs to be profitable. It is in any case important to coordinate with the buyers what they consider to be important in terms of the packaging and the price.

Sales and labour

In this chapter it is described what the used packaging quantity per crop is and what the sales per week were at Krusada and GreenBonaire. Krusada delivered to the supermarkets Van den Tweel, Warehouse, Bon Digro, Bonaire Food Group, More 4 less and some Chinese supermarkets. In addition, deliveries were also made to resorts like Plaza Resort, Divi Divi Resort, Harbour Village, Buddy Dive and Spice. Deliveries were also made to a large number of restaurants. Restaurants that are certainly open to this are At Sea, Capriccio, Between 2 Buns, It rains fishes, El Mundo, Cuba Compagnie, La Cantina, Rum Runners, Rumba Cafe and Sebastians.

Crop	Packaging quantity	Sales / week	Harvest capacity / hour p/p
Spinach	250/500 grams	100-150 kgs	5-10 kgs
Rocket	100/500 grams	30-40 kgs	10 kgs
Basil	50/250 grams	10-20 kgs	5-10 kgs
Mint	50/250 grams	10-20 kgs	2-5 kgs
Chinese cabbage	Per piece (app. 300 grams)	200 pieces	100 pieces
Lettuce	Per piece (from 200 grams)	700 pieces	100 pieces
Yardlong beans	250/500 grams	50 up to max 70 kgs	15 kgs
Cucumber	Unpackaged	700 pieces	250
Tomato	Unpackaged	1000 kgs	60/100 kgs

Packaging

The packaging of vegetables is very important. Fact is that products in attractive packaging are sold better. In addition, suitable packaging is also important to preserve the quality of the product. Much can still be gained when it comes to the packaging of the local product. At Krusada we first opted for being able to deliver a reliable product continuously fresh before also putting this on the packaging.

Sealed packaging is often a good choice. Sealed packaging has a high humidity as a result of which the product does not dry out. If the product has been washed then there is a risk of contamination. Most of the supermarkets prefer receiving unwashed leafy vegetables as this benefits the preservability. Vegetables that arrive from the USA or the Netherlands in sealed packaging e.g. rocket, basil, mint, spinach, etc., are often packaged in mesh packaging as a result of which the chance of contamination is smaller and the decay reduces. These types of investments are, however, not affordable for local farmers and horticulturists; moreover, it is not really necessary for daily fresh products.

Cultivation costs

Cultivation costs are very diverse per crop. In case of spinach, for instance, the costs are highest due to the relevant labour. Shoots and water are in that case not very expensive. The harvesting, however, all takes place manually. Hence this is one of the most considerable cost items for spinach.

In case of rocket the seeds and the WEB water are, for instance, a high cost item. On the other hand, due to the use of the harvester labour is a much lower cost item. Although packaging may again require a lot of labour. For mint and basil harvesting is also the most important cost item.

Van der Tweel supermarket in September 2016 with locally produced spinach, yardlong beans, mixed salad and lettuce.

Suppliers Bonaire

Bon Digro	Garden soil (pflanten erde) to add more organic substances to the soil.
Firgos	Plastic bags (different sizes), plastic trays, bags, attachments.
Bonaire Super Store and City Shop	Scales.
Tung Fung Store	(Biologically degradable) twine for, for instance, spinach and yardlong beans.
Kooyman	Tools, iron wire, water pipes, PVC glue, potting soil, electrics and accessories etc.
Playa Trading	Wood to make tables. PVC foam boards to grow in.
Greenlabel	Seeding soil, potting soil, tyleen couplings, hoses, sprinkler heads, 38-hole trays, hydro pellets.

Suppliers Netherlands / USA

Doehetzelfberegening.nl (NL)	Watering system, tyleen hose, rain bird computer.
Horticoop (NL)	Irrigation hoses, chemical fertilisers.
Rovero (NL)	Greenhouses.
Bodemresetten (NL)	Herbie.
Farmers house (NL)	Dried chicken pellets.
Johnny seeds (USA)	Seeds.
Vreeken zaden (NL)	Seeds.

6. Crop cultivation manuals

A cultivation manual with the most important information about the crops is provided below of a number of crops that were cultivated on Bonaire in the past two years. Following this manual does not guarantee a successful cultivation but it may help. It also describes the most frequently occurring problems that we encountered with these crops.

6.1 Basil cultivation manual

Propagating

Basil can be propagated from shoots and seeds. It is easiest to propagate basil from shoots. The shoots can, when basil seeds are not available, simply be purchased in the supermarket however if there are plants then you can best use these to shoot from. Basil is a plant that loves a warm environment and therefore grows really well on Bonaire.

You can cut basil in small shoots and put them in shoot trays (38 holes) filled with soaked potting soil. It is best to do this in the late afternoon. After that it is best to place them in the shade with little draft / wind. DO NOT water the basil for the first days. When the potting soil gets dry then you can submerge the shoot trays in a large plastic bag filled with a layer of water, however make sure that the shoot plant does not get wet during the first week. This often results in mould as a result of which the shoots will die.

Planting

When the plant has rooted well then the plant can be placed in the open soil. It is best to place a dripper with every plant in order that they receive enough water. Basil grows faster under white (insect) mesh than under black shade mesh.

With the harvest the tops of the plant usually form the best quality.

Duration of cultivation

Depending on the height, when basil gets too high the plant will topple and this is difficult during harvest. The mobility between the crops also decreases. It is estimated at 3 to 4 months. The first harvest is already possible about 10 days after the planting.

Watering

It is ideal to water these plants with the drip. Sometimes sprinkling from above may help to reduce the pressure of spider mite. However, do not do this too often, it is too expensive and unnecessary. It is also possible to grown basil on hydroponics.

Basil shoots planted in a 38-hole tray.

Location

Full sun, out of the wind, in the greenhouse.

Fertilising

Use the normal fertilisers. Iron deficiency was observed occasionally. This can be seen when the top develops badly and badly developed lateral shoots.

Harvesting
Harvest at least weekly to ensure a good continued growth and to avoid the plant from flowering.

Diseases and pests
Spider mite: visible by spiderwebs and very small animals that are barely visible during the harvest on the bottom side of the leaf. Often spreads fast. Transmitted from, for instance, yardlong beans if this is grown where this occurs frequently. Regular sprinkling helps preventively. Spider mites do not like moisture.

Mealybug degradation

(Californian) thrips: visible through deformation of the growth points in the young leaves. Also occurs in tropical spinach. This is the largest pest for basil. Degradation is also visible through leaf fall at the bottom leaves. A healthy plant is not bothered much and can grow through this. Do not harvest too often.

Mealybug: often with older plants, occurs locally. Easiest to prevent by removing the entire plant locally and the surrounding plants. Often first occurs with only a few plants.

Leaf miner: often comes to basil from yardlong beans or Chinese cabbage. In two years there were no considerable problems with basil. Only occasional damage with older leaves.

Other varieties
- Thai basil: good results. Popular product for At Sea Restaurant and LekLek Restaurant
- Lemon basil: a very fresh lemon flavour. Disadvantage is that it grows less quickly, quickly generates seeds and is not sold very much.
- Yerba di Hole: this is the typical local basil. Disadvantage is that it is very susceptible to spider mite. This variety is occasionally asked by buyers, however the sales are very low (1-2%) compared to normal basil.

Year-round cultivation?	Yes
Seed or shoot?	Shoot
Points for consideration	- Californian thrips (leaf fall) and spider mite. - Regular harvests prevent the plant from flowering. - Flowering may also mean that the plant is cultivated too dry. - Do not store basil too long, it cannot withstand this. Storage also with slightly higher temperatures (15° Celsius), otherwise it quickly turns black.

6.2 Malabar spinach (basella) cultivation manual

Propagating
It is easiest to propagate spinach from shoots, however it is also possible from seeds (this does, however, take longer and is less uniform than propagation from shoots). Flowers and seeds are generated during the short day period in, approximately, the months of November-March when the nights are longer than 12 hours. Malabar spinach is a plant that really loves a warm environment, that appreciates a high humidity and therefore grows really well on Bonaire.

You can cut Malabar spinach in small shoots (app. 10-15 cm long tops) and place them in shoot trays (38 holes) filled with soaking potting soil. You can best do this late afternoon. After that it is best to place the shoot trays in the shade with little air circulation. DO NOT water the spinach for the first week. If the potting soil becomes dry then you can submerge the shoot trays in a large tray filled with a layer of water, however make sure that the stem and the leaves do not get wet during the first week. As a consequence mould is often formed on the stem. Being slightly dry can be good to stimulate the plant to generate roots.

The big advantage of a spinach plant is that it can stay in a small pot for a long time. The plant does become very light in colour (nitrogen deficiency) but if you then place the plant in the open soil it will quickly turn green again.

Planting
Once the plant has rooted properly the plant can be placed in the open soil. It is best to place a dripper with every plant. Spinach grows better under white cloth (insect mesh) than under black cloth.

Duration of cultivation
Depends on the pace of growth. At a certain time the pace of growth will decrease, which can be seen from smaller leaf formation. It is then time to change the crop. This is estimated to take place after approximately six months. We have good experiences with crop rotation with basil.

Watering
It is ideal to water these plants with the drip. Sometimes sprinkling from the top may help to reduce the pressure of spider mite. However, do not do this too often, it is too expensive and unnecessary.

Location
Full sun, out of the wind, where possible. Greenhouse with insect mesh is preferred.

Fertilising
Use the normal fertilisers. Nitrogen is very important. If the plants turn / are yellow then this can often be blamed on a nitrogen deficiency. 1 kg / 100 litres of water can be used as fertiliser with the drip via the water unit.

Harvesting
Spinach can be harvested every day. It is optimal to do this in rows. The side with the most light always grows faster with spinach than the shade side. It may help to occasionally cut away the empty runners with the trimming shears. This requires unnecessarily much energy. The fewer runners a plant has the faster the leaves will grow. Some consumers do not desire too large leaves. Hand size is, on average, a good size.

Diseases and pests
Spider mite: visible through spiderwebs on, or even more on the bottom side of, the leaves. Is transmitted from, for instance, yardlong beans where it occurs frequently. Spinach is not really susceptible, only in case of heavy degradation in other crops may this also occur.

Thrips: visible through deformation of the growth points and later visible on the leaves. Leaves are often dark green and shrivelled. It may help to cut these pieces off.

Scale insect: often in older plants, occurs locally. Easiest to prevent by removing plants locally.

Leaf miner: only suction points visible. No tunnels drilled in the leaves.

Iguanas and lizards: feeding damage to the leaves.

Root-knot nematode - Meloidogyne spp. Bad growth, fast wilting in case of draught and knots in the roots. Prevention: remove affected plants and use Herbie soil decontamination (see chapter 7).

Other varieties
There are not many other varieties. There is a red variety but in reality only the veins are reddish. The vigour of this variety is disappointing.

Year-round cultivation?	Yes
Seeds or shoots	Seeds of LVV, then continued with shoots.
Points for consideration	- One of the easiest crops. - Thrips in the tops, topping offers solutions. - Young plants may be eaten by iguanas or lizards. - Too large leaves not desirable for the consumer.

6.3 MINT CULTIVATION MANUAL

Propagating
It is easiest to propagate mint from shoots. It should also be possible from seeds but this is more laborious and often takes longer.

There are, for that matter, many varieties of mint.
Peppermint is the variety that we have good experience with, this is also for sale in the supermarket as mint.

If we want to propagate mint then use beautiful (thick) pieces of the mint plant. Not wooded but neither very young. Put 10 of these shoots in (plastic) cups with water where you first remove the leaves of the shoots from the bottom 5 to 10 cm. You place this part in the shade. Wait about a day or 5 to a week until the first white root points appear on the shoots. Meanwhile, do make sure that the cups contain sufficient water in order that the plant can absorb water and refresh this when it becomes green. It is very important that the plant does otherwise not get wet. Only the 'bare' stem can get wet. That is why a piece of 5 to 10 cm without leaves is very good.

Mint grows really well in a greenhouse with ample light and sufficient watering.

When the shoots have formed roots they can be placed in 38-hole shoot trays (place this tray in the shade) where the roots can develop further. From about a week, when the plant has formed sufficient roots, the plant can be placed in a larger pot or in the open soil with a dripper. When the plant is in the pot too long then it will become yellower and will simultaneously lose leaves (nitrogen deficiency), This is a natural process that shows that the plant must be repotted.

Planting
When the plant has rooted well, the plant can be placed in the open soil. It is best to place a dripper with every plant. Mint grows better under white cloth (insect mesh) than under black cloth. When mint grows in the shade then it will not have the bright green colour that we prefer seeing. Mint grows best in the full sun with a properly humid soil and will also grow proliferately.

Duration of cultivation
Mint can stay at the same place for a long time. When the growth becomes disappointing this can be a reason to remove the mint. Mint is a real parasitic plant and will always take more soil than you initially envision. Sometimes it may be necessary to push back leaves.

Watering
It is ideal to water these plants with the drip.

Location
Full sun, insect mesh greenhouse, out of the wind where possible.

Fertilising
Use the normal fertilisers. Nitrogen is very important. When plants turn / are yellow then this can often be blamed on nitrogen deficiency. Before a cultivation it is recommended to scatter chicken pellets.

Harvesting
About twice a week. You cut the mint with shears. Make sure not to cut away black old leaves and stems, those are not good for the consumer. It is best to harvest mint when the stems are 10-20 cm long, the latter because the consumer is used to this but also because harvesting will then proceed easy and fast.

Diseases and pests
Spider mite: visible due to spiderwebs on the bottom side of the leaf, not a big problem. Regular sprinkling avoids an outbreak.

White fly: occurs occasionally. If you do nothing then experience teaches that it will pass.

Californian thrips: occurs with the older leaves. Sometimes leaf fall is visible. This is the most difficult pest. When it gets too bad, remove the plants and make sure that it does not occur with new plants. Do in any case plant these in a different greenhouse.

Other varieties

There are certainly other varieties. However, we did not gain experience with this on Bonaire.

Year-round cultivation?	Yes, clearly grows better in a greenhouse with ample light.
What shoots / seeds were used?	Shoots from the supermarkets were used for this.
Points for consideration	- It is important to regularly propagate mint. - The Californian thrips is the biggest enemy of mint (often leaf fall), the white fly may also cause problems. - It is important to water sufficiently. - Harvesting regularly prevents rotting parts (contamination) at the bottom of the plant. - Only water in the morning, rotting leaves also occurs more often if watering takes place in the evening.

6.4 Rocket cultivation manual

Sowing

Rocket is sown with a precision sower (see photo) of Earthway. The seed that we use comes from Vreeken Zaden in the Netherlands. Approximately 200 grams of seed are required for 100 m^2. If you purchase a kilo then this will 'only' cost EUR 20.

http://vreeken.nl/242000-rucola

When sowing it is important to follow the following principles.

- Prior to the sowing the soil should be dug properly with a tractor with a digging tray.
- After the digging large lumps and stones should be removed (with a rake).
- It may be recommended to roll the rocket bed as a consequence it is easier to ride over it with the precision sower. At present we do not have this roller.
- It is important that the soil is dry and that the rocket sower is not wet either. Only then can the seeds be sown easily.
- A distance of approximately 20 cm can be used as the guiding principle between the rows. Leave room for a walking path after 4 or 5 rows.
- It is not required to rake after the sowing. The seeds can stay on top of the soil.
- After the sowing it is wise to water well. A good guiding principle is 10 litres / m^2. It is recommended to sprinkle a few times a day. Do make sure not to create puddles as a result of which the seeds could flow away.

Earthway Precision sower

After 1 or 2 days it can already be seen that the seeds are sprouting and the first plants spring up. Then keep the moisture much lower. Only water in the morning with the rain bird sprinkler installation (7-10 min) and the dry leaves a bit more with a garden hose can already be enough.

Harvesting

Three weeks after the sowing it is about time to be able to have a first harvest. This is when the leaves protrude from the soil by about 20 cm. We harvest with the quick cut greens harvester. It is available via http://www.farmersfriendllc.com/products/soln1-8. Potential new blades, a tool kit and the like are also available here. This can easily be shipped via a postal address in Miami. The drilling machine can be purchased from Kooyman. Immediately purchase an additional battery and battery charger in order that the rocket harvester can always be used.

The so-called quick cut greens harvester. Ideal for the harvesting of low leafy vegetables.

It is important to always harvest rocket early in the day. Later in the day the leaves are too weak and the rocket harvester cannot get hold of the leaves. Afterwards keep the rocket harvester properly clean with vegetable fat (available at Caribbean Bakery).

Watering is also very important with rocket. This must happen every morning. If the rocket is entirely weak then do NOT water in the afternoon. This will cause degradation in rocket. Water CANNOT be used from the water purification. Via the rain bird sprinkling installation it can be configured that watering takes place every morning. During the watering moments watering should not take place manually. Then the pressure is not enough for the sprinkling system. Practically watering could take place every morning, it can easily be switched off if it is not necessary when it is still wet from, for instance, the day before or rain (imminent). From, for instance, 8 o'clock, 10-15 minutes when the plants are slightly bigger is usually a good setting. Please do note that it is better not to water on harvesting days and to only water after the harvesting.

Harvesting of rocket can take place once or twice a week. If the leaves are too big then the flavour decreases and the aesthetic value also reduces. That is why regular harvesting is also important for this plant. After a number of months it is good to replace the rocket or to apply crop rotation. This could, for instance, work well with Chinese cabbage.

Diseases and pests

With rocket the following diseases and pests occurred in the past years.

Caterpillars: this caused problems to us just after the rainy season. Prevention is possible by combining cultivation with other vegetables, e.g. chives and sage (no experience). Avoid butterflies in the greenhouse.

Harvesting rocket with the quick cut greens harvester.

Spider mite: spider mite is often a pest that comes from another crop. Rocket itself is not quickly affected by it. Sprinkling, as a result of which the plant gets wet, avoids spider mite degradation to a large degree.

Crickets: crickets can occur very frequently. Crickets eat all sorts of parts of the plant (roots, leaves). Actual damage is, for that matter, hard to see.

Staining: when a full crop receives water in the evening, there is a chance of staining. Always try to avoid this.

Year-round cultivation?	Yes
What seeds were used?	The wild rocket type (available at Vreeken (NL) and Johnny Seeds (USA). There are varieties that shoot and easily start forming flowers. This is highly undesirable. These varieties also wooden faster and flower formation occurs earlier.
Points for consideration	- Avoid too moist cultivation. As a result much will fall after a number of weeks and there is a chance of staining. - Catch butterflies.

	- Regularly resow rocket. Otherwise the old rocket gets too spicy. This is undesirable for the consumer. Advice: change the crop after about 3 harvests of rocket. - Do not water in the evening in connection with staining. - Avoid an outbreak of caterpillars by not cultivating too moistly, by working with combined cultivation or by sprinkling herbal tea. - It is not possible to irrigate with recycled WEB water, water expenses are obviously a considerable part of the costs. - Better not in combination (before or after) with Chinese cabbage and/or mustard due to their shared sensitivity to caterpillars.

6.5 Chinese cabbage cultivation manual

Chinese cabbage is a crop that belongs in the diagram of the cabbages. Chinese cabbage is originally an Asian vegetable. The choice of variety has appeared to be important. Some varieties develop much better than others. Some varieties also sprout much earlier than others (sprouting is undesirable for Chinese cabbage). This will certainly be a problem for some varieties. Experience teaches us that the F1 hybrid Joy Choi Chinese cabbage grows very well on Bonaire and is bothered very little by sprouting. This variety is available via Johnny Seeds USA and is a Sakata variety.

The experience with Chinese cabbage is that it is sown in a 38-hole sowing tray. These sowing trays are available at Greenlabel. Good potting soil is also available at Greenlabel of the brand Holland Potgrond (red-white-blue bag of 45 litres).

From the sowing it takes about 3 weeks before the plant has come up properly and is big enough to be planted in the open soil. However, at a sunny location. Plant on 30*30 cm. The soil must be kept moist during the remainder of the cultivation.

From sowing to harvesting takes about 4 to 5 weeks in case of Chinese cabbage. Often the Chinese cabbage gets quite a bit heavier in the last couple of days, so make sure not to harvest too early. On the other hand, older plants are often more susceptible to more pest pressure. In particular spider mite, caterpillar and leaf miner can be a nuisance and cause considerable crop damage.

6.6 Mustard cultivation manual

In terms of cultivation mustard can be compared to Chinese cabbage. Differences between Chinese cabbage and mustard are:

- Demand for Chinese cabbage is bigger.
- From small seed to harvestable product takes a week longer than with Chinese cabbage.
- The experience is that Chinese cabbage is slightly easier in terms of cultivation, in addition mustard is more susceptible to spider mite than Chinese cabbage.

Mustard can also well be grown in a mix with other lettuce varieties. This can then be harvested younger and more often.

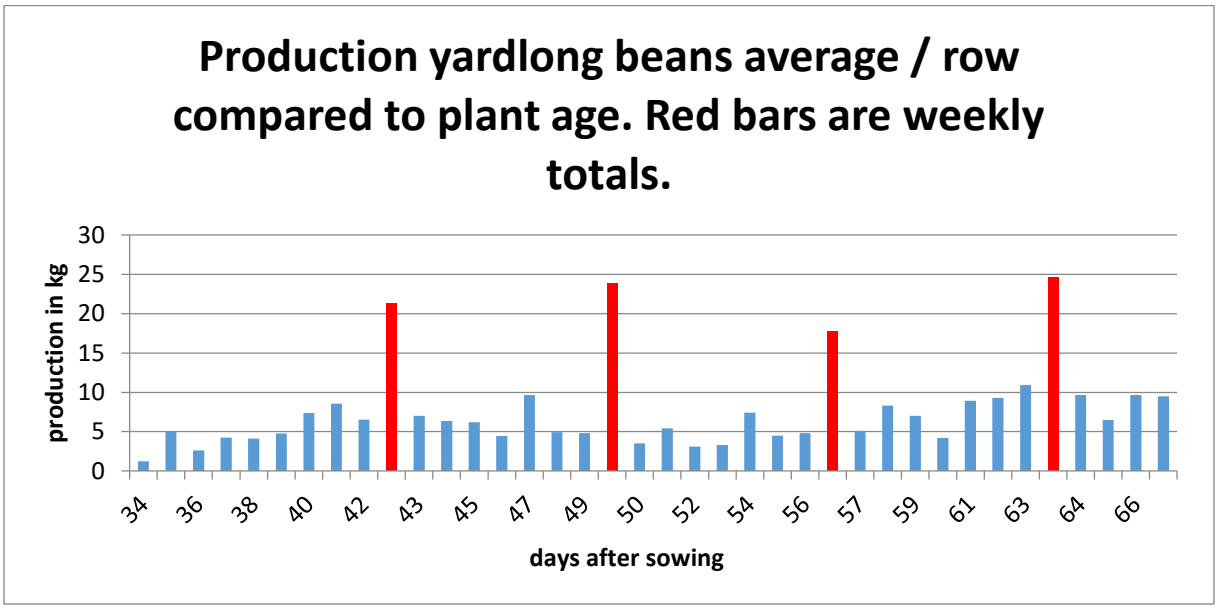
Year-round cultivation?	Yes
What seeds were used?	Chinese cabbage: good experience with Joy Choi F1 hybrid Mustard: multiple varieties
Points for consideration	- Chinese cabbage is a strong crop. - Do not grow after a cultivation of yardlong beans in connection with pressure of spider mite. - Susceptible to spider mite, leaf miner and caterpillar. All are highly undesirable because damage is immediately visible on harvestable parts. - Chinese cabbage and mustard like a sunny greenhouse but also grow well in a shady greenhouse - Well possible in the soil but also on hydropics. - Better not after or before rocket in connection with their sensitivity to caterpillars.

6.7 YARDLONG BEANS CULTIVATION MANUAL

Yardlong beans is a cultivation that grows very well on Bonaire. Yardlong beans can be grown without too many issues on purified wastewater, as we have also seen with tomato and cucumber. We recorded the course of production of yardlong beans in the period May-July 2015. The rows that were used for this trial were almost 50 metres long and yardlong beans were planted every 20 centimetres, hence 5 plants/m. An area of 1.20 metres was left between the rows. The plants grew in a V system.

A good harvest of yardlong beans.

The following production figures were collected in the period May-July.



Yardlong beans grow at high light levels and high temperatures. In addition, it is important to enrich the soil with organic basic fertilisers. We also think that the production results in a light greenhouse (insect mesh, app. 10% shade) are better than in a 50% shade mesh greenhouse.

Course of cultivation yardlong beans

- Sowing in 38-hole trays. The variety Metro Rouge works well. https://www.vreeken.nl/040300-kousenband-ande-metro-rouge-metro-black-metro-marrone
- Keep well wet the first couple of days in order that the seeds sprout well, then somewhat drier to stimulate root development. Remain alert when watering and make sure that the plant does not dry out. With planting it is easier to use drier plants and to plant in most soil.
- Ideal planting day in open soil is 10 days after sowing. Plant plants every 20 cm, 1 or 2 with every dripper, depending on the available number of plants.
- Hang up twines after about 1 week and help plants to grow upwards.
- The first yardlong beans develop about 35 days after sowing. From day 40 full in production. Harvest on Mondays, Wednesdays and Fridays. It is best to also harvest on Saturdays, otherwise the beans are too big on Mondays.

- We actually observe 2 production waves. One at the beginning of the cultivation and 1 somewhat later from about day 60. See the graph below. Yardlong beans last about 10 weeks from sowing.
- On average we count on approximately 20 kg / week / row.
- Hence, that is about 400-500 grams of yardlong beans metre / week.
- Width between the rows is about 1.20 metres and the plants follow the V system.
- Harvesting approximately 15 kg / hour / person.

Diseases and pests

Yardlong beans are very susceptible to pests. For that reason it is actually not possible to grow on Bonaire. One of the biggest problems is spider mite. When this pest occurs, it appears to be extremely difficult to again get rid of it.

Apart from the spider mite, the black bean aphid and the mealybug also occur regularly in with the cultivation of yardlong beans.

Other pests that occur regularly with yardlong beans are leaf miners and Californian thrips. The latter occurs in the flowers and may result

in deformations of the beans.
Another pest that occurred earlier was the pickleworm – Diaphania nitidalis. The damage of this pest consists of holes in the yardlong beans and excrement of the caterpillar on the outside of the fruit. The caterpillars (± 20 mm) are yellow at an early stage with 4 lines of black dots on the back and later become yellowish green. The butterfly is white with black wing borders. Eggs are laid in or near the flowers. Pupation takes place on or in the soil.
Prevention:
- Provide for a clean planting.
- Do not leave old plants behind in the vicinity of new plants.
- Pick every fruit with the harvest, even if it has already been affected
- Keep the affected fruits outside the greenhouse.

Powdery mildew – Erysiphe sp. Yellow and yellowish brown stains on the leaves that later become necrotic. These stains expand quickly and ultimately the leaves die. White piles of spores are visible as a powder on the top of the leaves. Prevention:
- apply crop rotation (do not rotate with cucumber varieties).
- use healthy seeds.
- clear and destroy affected plants.
- try to use resistant varieties.

Powdery mildew, recognisable by the white stains on top of the leaves.

Yardlong beans are advised against if you grow this alongside other crops in connection with the attraction of the crop to pest insects that may transmit to other crops. If yardlong beans are grown then it is important to realise that pests can be a big problem and hygiene is very important. Early removal of affected plants can make a big difference.

Year-round cultivation?	Yes
What seeds were used?	Metro Rouge from Vreeken Zaden
Points for consideration	- Yardlong beans are a crop that is very susceptible to pests (mostly spider mite, leaf miner, aphid and pickleworm). That is why it is not recommended to cultivate yardlong beans. Certainly not in combination with other crops. - Do not cultivate this crop with other crops and certainly not with Chinese cabbage. - It is important to harvest regularly. - Yardlong bean production occurs in waves. - Yardlong beans are a crop that is reasonably strong on the root and is suitable for cultivation on purified wastewater. - Proper watering is important to render the plant resistant.

6.8 Cherry tomato cultivation manual

To have indeterminate tomato (tomato that produces during a long period of time) grow favourably with a profitable production it is actually too warm on Bonaire. In particular the high night temperature is disadvantageous for the setting and growth of the fruits. It is particularly difficult in the warm months (April – October) to obtain sufficient setting. This means that many fruits abort and that fruits remain smaller.

It is still possible to grow tomatoes. Small (cherry) tomatoes have the biggest chance of success to also set in the warm months and to grow into beautiful fruits. Very large yields are, however, not expected, the flavour, on the other hand, is very good, also due to the more saline soil and high radiation.

Propagating and cultivating

Tomato can best be grown from seeds. Approximately 3 weeks after sowing a tomato plant in a pot of 10 cm is sufficiently big to be planted in the open soil. A plant distance of 40 to 50 cm by 1 metre is then desired.

A different way is to sprout from the existing tomato plant (the thieves). This can save time, however it may be that the vigour lacks behind. From seeds it takes longer before the first harvest can take place. Sprouting tomatoes can best be done in the afternoon with sprouts of about 10 to 15 cm long in 38-hole trays. Place these trays in the shade and out of the wind and do not water for 3 days. Then carefully a little bit of water per day and keep dry in order that the plant is stimulated to create roots. After approximately a week most of the sprouts will, if all goes well, have roots and the tray can be placed in the full sun. Do make sure that the plants do not dry out.

Planting

When the plants from seeds are about 3 to 4 weeks old or have formed good strong roots from sprouts, they can be planted. This is best done in a moist, dug soil. Use proper basic fertilisers like NPK 12-10-18 in advance or use organic fertilisers. A humous-rich soil is desirable for tomatoes.

Crop maintenance

When the plants are approximately 30-40 cm high, it is very important to bind the plants on a stick or to have them grow upwards on a twine. It is wise to tighten the plant thieves (i.e. lateral sprouts) twice a week around the twine and to keep the main stem. If this is done less frequently then the plant will waste energy on the lateral sprouts that would have gone to the tomatoes if they had been tightened.

Harvesting
Approximately 2 months after sowing it is possible to harvest for the first time. This is possible about two times a week. Only harvest red or (semi-) red tomatoes. Semi-red tomatoes should still ripe a bit longer in the heat (from the sun).

Duration of cultivation
Depending whether the plant is still setting and/or it continues growing, the experience on Bonaire is 4-6 months.

Diseases / pests
Tomatoes are a crop that easily attracts diseases and pests. On Bonaire we had a lot of problems with root diseases, e.g. the rot-knot nematode and corky root rot. A remedy against this is the biological Herbie treatment that is described extensively elsewhere in this handbook.

It is important to water and fertilise sufficiently because properly growing plants are less susceptible to diseases. Proper crop rotation also helps to avoid diseases and pests. Apart from root diseases, tomatoes are also susceptible to numerous other diseases. Problems that we experienced with tomatoes were white fly, spider mite and leaf miner. White fly is prevented naturally by the delphastus bug that was described earlier in the chapter.

Varieties
Varieties that we had the best experiences with are all cherry tomatoes. The best results were obtained with Sun Gold F1 (Johnny Seeds) and Moscatel F1 (Rijk Zwaan). A reasonable amount of experience was gained with the latter variety.

6.9 CUCUMBER CULTIVATION MANUAL

Initially very good results were obtained with cucumber. Experiences with cucumber were all with cultivation in the open soil, watering twice a day via a drip hose and with purified wastewater.

Sowing
The cucumber was sowed in round pots with a 10 cm diameter. Approximately 10 days after sowing the plants were big enough for planting. (The germ layer had developed fully and the 3rd and the 4th leaves were already clearly visible).

For the cucumber cultivation at GreenBonaire on Bonaire, Dutch partenocarpe (fruit growth without pollination and seed production) hybrid varieties were used. The germination and growth were always very good.
The first cultivation in the open soil was very successful. With a high production per m^2.

After the first cultivation a new cultivation of cucumber was set up. This was, compared to the first cultivation, very disappointing. The start of the cultivation was very good but after a while the top of the plant become yellowish and hard and the growth was not good resulting in pointy fruit. With every attempt to grow cucumbers on the same plot more often ever worse results were obtained.

Planting distance
The planting distance used with cucumbers is 40 cm by 100 cm, let cucumbers grown upwards on twines.

Crop maintenance
Tighten the plants and remove the thieves twice a week.

Duration of cultivation
The duration of cultivation for cucumber on Bonaire is, in case of a regular cultivation, about 8 to 10 weeks from sowing.

Diseases and pests
Cucumber is sensitive to staining on the border area between root and stem. Proper watering in the morning prevents this. Make sure that the water is not too warm if it is sprinkled.

In addition, pests like spider mite (on the bottom side of the leaves), thrips (in the top and in the flowers), aphid and white fly (on the bottom side of the leaves) occur with cucumber.
A cause for the bad cucumber cultivation could be Boron. Boron is found in seawater in a fairly high concentration and is not filtered out of it by WEB. This is, in any case, done under the WHO standard of 0.5 mg B/litre (when it is not harmful to people) but it is much too high for cucumber cultivation. This was also said by an adviser in the area of cucumber from the Wageningen University.

In the spring of 2016 I examined cucumber cultivation on Curacao. The results of this examination are mentioned point by point in appendix 3.

6.10 Hydroponic lettuce cultivation

To date the experience with lettuce is that this only works well on hydroponics. There are also many varieties that sprout quickly due to the high temperatures (they form a stem as a result of which the head loses its desirable form and the flavour of the leaves also become more bitter).

The lettuce on hydroponics is cultivated in trays of 1.22*4.88 metres. Black plastic is placed in these trays. The trays are at the start of the cultivation filled with WEB drinking water and the correct amount of nutrients in the correct concentration (EC of 2.0). The pH is also set at 5 to 5.5 with nitric acid.

After approximately a week the plants are this big. Ready to be planted.

The plants are planted in the cups with hydro pellets. The tray under it is filled with water and fertilisers.

en beautiful white
l in the water. The
s gradually but
t up to the end of

A beautiful head of lettuce, almost ready to harvest.

and remains moving in order to prevent the growth of algae.

After approximately a week the plants are placed in a different tray where they are placed every 25*25 cm. This is where further growth takes place.

The cultivation is as follows:

- Sow seeds on tray in plugs in a pelleted manner.
- Keep in the cooling for 48 hours at 15-20° Celsius. Mist occasionally, this results in better germination.
- Then remove from the cooling. Whilst the seedlings are on the tray, carefully water multiple times a day.
- One week after the sowing, pot plugs in cups with hydro pellets. Place these in the hydro cultivation tray.
- Check and potentially correct pH and EC once a week. pH will slightly increase in case of good growth. EC normally stays the same. In case of rain EC will drop due to rainwater that flows into the trays.
- Water consumption 4 litres / cultivation / plant.
- From sowing to harvesting takes an average of 42 days.

Hygiene on hydroponics
After multiple cultivations in the trays it became apparent that hygiene is extremely important. Some tips that we can give on this:

- Air the water, this reduces growth of bacteria and the water keeps moving and moreover contains more oxygen.
- Refresh the water after cultivation, recycle the water where possible, for instance for crops that receive drip watering.
- Make sure that after cultivation the water tray(s), cups, trays, sowing trays are cleaned with a disinfectant. Then rinse well.

Prevention of pests

- Work in a clean manner, disinfect the trays with chlorine and refresh the water.

Investments tunnel greenhouse of 500 m^2

- Tables $ 10,000
- Greenhouse $ 10,000
- Levelling and cleaning of terrain $ 1,000
- Net $ 1,400 (cover greenhouse is 700 m^2)

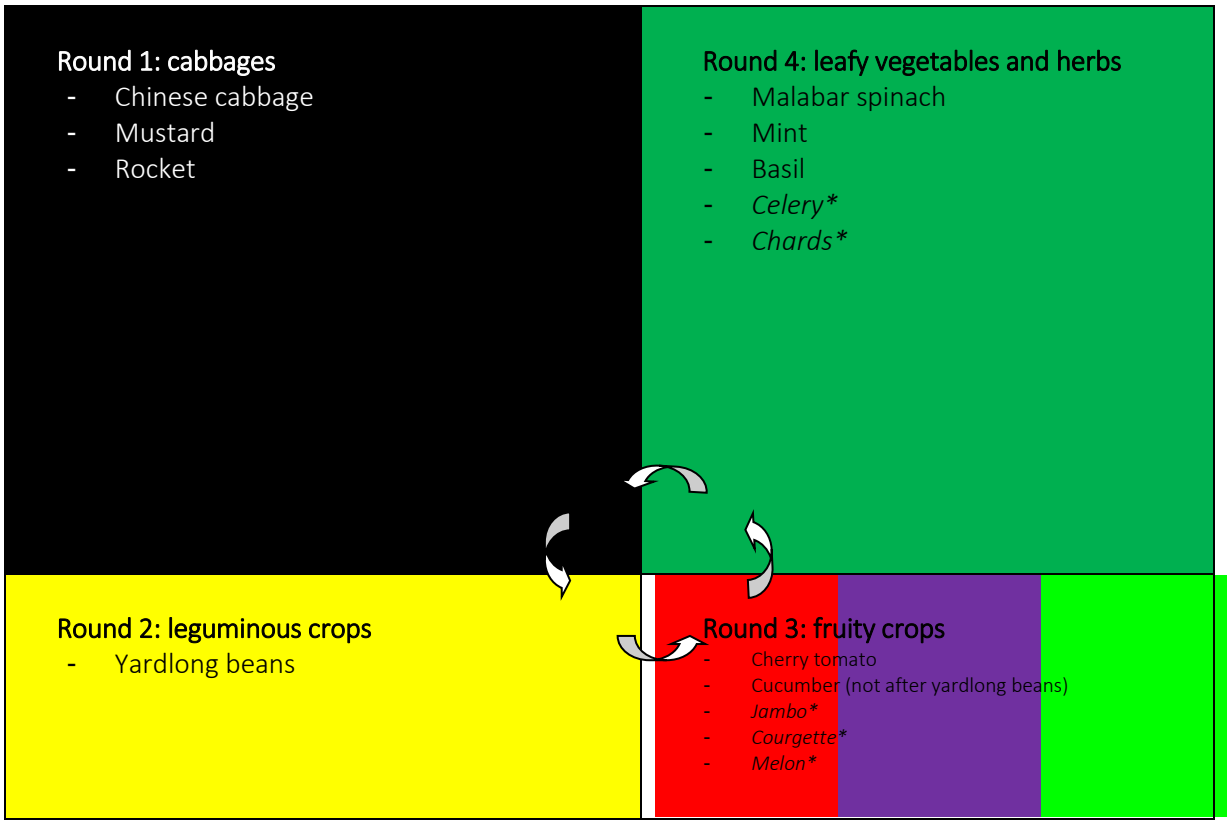
7. SUSTAINABLE SOIL MANAGEMENT

7.1 CROP ROTATION

In the open soil it is important to rotate crops. The latter to reduce the chance of diseases and pests, but also to keep the soil healthy. Some tips on this:

- Cultivating the same crops at the same location for years on end may cause soil fatigue, which stagnates the growth of plants.
- Vegetables have specific needs in terms of fertilisers and the relevant proportion. Proper rotation ensures that the soil is suitable for the type of vegetable that follows next.
- To outline a clear planning of this the vegetables are divided into groups. These groups contain different crops.

Crop rotation cycle



*These crops belong in the crop rotation cycle. A cultivation manual for these crops was, however, not included in this handbook. The latter due to the fact that we have gained very little experience with these crops on Bonaire.

Apart from this cycle there are also specific combinations that can / cannot be combined for all sorts of reasons. More can be found about this on the internet.

7.2 Herbie method

The soil can be decontaminated in a biological manner via the Herbie method. This decontamination method particularly has a positive effect on the prevention of root-knob nematodes (see photo) in the soil and weed seeds.

1. Distribute the Herbie over the soil. About 2.4 kg/m^2.
2. Then sprinkle the Herbie slightly wet.
3. Dig the Herbie in the soil.
4. Do this twice in opposite, different directions.
5. Then again drive over the soil with the tractor in order that the soil is pressed properly.
6. Then wet the soil again.
7. Distribute the plastic over the soil and embed it on the sides for about 20 cm.
8. Wait 3 to 4 weeks in order that the anaerobic bacteria can work well.

Root-knot with Malabar spinach. When the soil is contaminated with this then Herbie is a good possibility to combat this. Also with tomato we experience ample nuisance from root diseases. Grafting is not a remedy due to the high temperatures.

The corky root disease occurs with tomatoes. The roots cork and colour brownish. This is caused by a mould. This is also solved with the method of soil decontamination.

Conclusions and recommendations

Conclusions

To start cultivating on Bonaire, protected cultivation is necessary for a number of vegetables, mostly in connection with iguanas and goats but also birds.

The availability of water is one of the most important conditions. Without the certainty of (affordable) water it is actually not possible to produce vegetables.

The soil composition and fertilisation are some of the factors that we can influence during cultivation in tunnel greenhouses. Good soil management is important for sustainable cultivation.

To cultivate in greenhouses, the cover with netting is favourable. This can be insect mesh as well as shade mesh.

Depending on the type of cultivation: in the open soil or on hydroponics, the necessary investments must be made. In the open soil more cultivations are possible, a larger investment is required in case of hydroponics but the work can be lighter and it is easier to steer with the nutrients proportion, EC and the pH of the water.

The climate on Bonaire is most favourable for leafy vegetables and herbs, e.g. lettuce, Malabar spinach, Chinese cabbage, rocket, mint and basil.

Basically only the cooler months are suitable for tomato cultivation. Cherry tomatoes grow best.

Continuity, delivery reliability and good communication with buyers are important to supermarkets to build a durable commercial relationship.

Crops that still offer ample development: yardlong beans, cherry tomatoes and cucumbers. In particular the latter grows well on Curacao. This may depend on the variety. This requires more research.

Pests that cause most nuisance are spider mites, thrips and aphids. These pests occur in almost all cultivations to a greater or lesser degree. Preventive measures and adequate actions in case of degradation are important to continue the cultivation.

Pests represent a considerable threat for a number of crops. In particular yardlong beans, and that is why it is a difficult cultivation. It is not advised to combine yardlong beans with other crops.

Herbie is a suitable (biological) method to decontaminate the soil. This is effective against nematodes and it kills weed seeds.

Recommendations

It is important to join forces with agricultural entrepreneurs.

There are several cultivations that offer continuous production on the island. People must be stimulated to start with this.

Basically there is still too little knowledge. Proper cooperation with small companies on Curacao and Aruba is certainly worthwhile. These islands have a similar climate. On Curacao people are quite ahead and things can be copied.

Hydroponic cultivation offers more possibilities than presently in use. Moreover, this is an ideal solution for the water shortage. Hygiene is very important for this type of cultivation.

It should be possible to purchase biological crop protection agents more easily. It would be nice if they could be purchased in a central fashion. Cooperation with Curacao in this respect is also an option.

LITERATURE

Books

Dedeene et al, 2015, De groenten & fruit encyclopedie, ISBN: 9789021560809

Johns, Jason, 2014, Hydroponics - A Beginners Guide to Growing Food Without Soil: Grow Delicious Fruits and Vegetables Hydroponically in Your Home, ISBN 13: 9781502525857

Internet

http://www.soortenbank.nl/

http://www.tuinadvies.be/categorie/planten/groenten/bladgroenten

http://www.plantaardig.com/groenteninfo/

APPENDIX 1 – CREATING SOIL ANALYSES

Technique of the sampling

A soil sample of a plot consists of multiple drills at cultivation depth (25 cm). A gouge auger is used for this. Research shows that a number of 40 to 50 drills is required to obtain a representative picture of a plot. These drills are taken all over the area to be sampled. Theoretically the plot should, for instance, be divided into 40 equal blocks. At a random location one drill is taken from every block. This is, however, a time-consuming and consequently expensive method. By walking a W-shaped or a zigzag pattern whilst sampling you arrive at the best compromise. How many drills are performed in the "W" depends on the length / width ratio of the plot. Borders of the plots are not included in the sampling. It is important that the sample does not contain irregularities, e.g. lumps of manure, compost or crop residues. Otherwise it is important that every drill is equally deep and that the auger is filled fully every time.

Time of sampling

- Do not conduct a soil survey just before levelling or a deep soil treatment and instead do this right after these activities.
- Do not conduct a soil survey after a cultivation of leguminous plants. In particular the phosphate analysis may result in a deviating value.
- Once every four years is recommended as a frequency for the sampling. Namely, the fertilisation recommendations based on general cultivated land surveys are valid for four years.

When is it best not to take soil samples?

If animal manure or compost has recently been used then there is a considerable chance of deviating values. It is recommended to wait at least six weeks after manuring before taking samples. The same applies if liming has recently been used (including gypsum) or when artificial manure has been used (e.g. phosphate).

Transport of the samples

After sampling the soil samples must be cooled as soon as possible. With low temperatures conversion processes are strongly inhibited. Think about, for instance, mineralisation of nitrogen from the organic material present in the soil. It is also important that the samples are transported to the laboratory and are processed there as soon as possible. Laboratories have pre-treatment methods as a result of which samples can be retained longer.

Plant Protection Service
Ministry of Economic Affairs

1. Name and address of consignor / Plant protection organisation of country of origin Fundashon Kuraçao Kaminda Lagun 191, Bonaire Tel.: 717-2233 / 717-6514 To whom it concerns	**Import licence for the introduction of harmful organisms, plants, plant products and other objects for trial or scientific purposes and for work on varietal selections (issued under Directive 2008/61/EC)** **Number of Document: 2015/615**
2. Name and address of Importer Relab den Haan Att. R. Timmer Lookwatering 62 2635 EA, Den Hoorn The Netherlands	3. Name of the responsible official body Plant Protection Service Geertjesweg 15 6706 EA Wageningen The Netherlands
4. Address and description of the specific site or sites for quarantine containment As mentioned in box 2	5. Place of origin (documentary evidence attached for material originating in a third country) As mentioned in box 1
6. Declared point of entry for material introduced from a third country Schiphol Airport	7. Phytosanitary certificate number Not applicable
8. Scientific name(s) of the material, including the harmful organisms concerned Soil	9. Quantity of material Max. 30 Kgs.
10. Type of material Soil samples	11. Additional declaration This material is introduced into the Community under Directive 2008/61/EC.
12. Additional information: The material will be subject to quarantine testing procedures according to 2008/61/EC and as mentioned in dispensation TRCPD/2012/0405. No material will be released from quarantine, unless treated under approval of the Plant Protection Service.	14. Stamp of the responsible official body of issue Place of issue: Wageningen Date: 12 October 2015. Name and signature of authorized officer: Nederlandse Voedsel en Warenautoriteit Ministerie van Economische Zaken National Plant Protection Organisation NPPO Netherlands Food and Consumer Product Safety Authority Ministry of Economic Affairs A.J. Boer
13. This import licence, unless previously revoked, shall remain in force till 12 October 2016.	

Example of a permit to bring a soil sample to the Netherlands.

APPENDIX 2 - FARMERS HOUSE

Farmers House Organic Soil Nutrition, NPK 4½-3-2

In the following overview you can find the various nutrients of Farmers House Organic Soil Nutrition and the relevant absorption by the plant.

Nitrogen:
The percentage of nitrogen in this fertiliser is 4½%.
The relevant absorption can be divided into three phases:
- 45% mineral nitrogen; this is immediately available to the plant.
- 37% first-year nitrogen; 55% of this nitrogen becomes available to the plant two months after the scattering.
- 18% residual nitrogen; is released a year after the scattering.

The mineral nitrogen in poultry manure occurs in two forms, namely nitrate and ammoniacal nitrogen. This proportion gradually moves to nitrate nitrogen.
This is caused by the so-called nitrification process.
(NH_4+ + $2O_2$ -> NO_3^- +$2H^+$ +H_2O).

First-year nitrogen and residual nitrogen are present in the fertiliser as protein nitrogen and cannot immediately be absorbed by the plant. Due to mineralisation it is converted into ammoniacal compounds and nitrates. This can be explained on the basis of the digestibility of the raw cell substance. This is divided into three main groups:
- cellulose (good digestibility)
- pectin (good digestibility)
- lignin (bad digestibility)

The digestibility of a product can be deduced from the C/N ratio. A low C/N ratio (10) has good digestibility, a high C/N ratio (80) a bad digestibility.
The C/N ratio of Farmers House Organic Soil Nutrition is generally between 6 and 10.

Phosphate:
The percentage of phosphate in this fertiliser is 3%.
Research shows that phosphoric acid in organic soil nutrition for plants equals phosphates as they occur in the different types of artificial manure.

Potash:
The percentage of potash in this fertiliser is 2%.
The potash occurs in the organic soil nutrition in the form of a readily soluble potassium bicarbonate (KHCO3).
Hence organic soil nutrition is a good supplier of potash for the plant.

Apart from the aforementioned nutrients, calcium and organic substances can also be found in this fertiliser.
The 9.6% calcium in this fertiliser ensures that on balance a pH neutral effect is obtained.
The percentage of organic substances of Farmers House Organic Soil Nutrition is 68%. The organic substances stimulate a good soil structure and make sure that water and nutrients are absorbed. Without a regular supply of organic substances soil life will not be possible. The consequence of too little or no soil life is that the cycle of nutrients is disrupted.

By making use of organic soil nutrition the crop is provided regularly with the necessary nutrients.

APPENDIX 3 – CUCUMBER CULTIVATION CURACAO AT SOLTUNA

Cultivation

- Cucumbers are sown in small pots filled with potting soil. After 7 to 10 days the plants are planted in the open soil.
- The open soil must in advance be dug well and can be supplemented with basic fertilisers (100 gr/m2, see header "fertilisation"). It is important that the entire greenhouse is dug as a result of which the soil becomes very airy. During the visit this had been done insufficiently, a number of plants had become weak. Potential causes were: insufficient oxygen, insufficient distribution of artificial fertilisers. Roots of cucumber do not arrive deep but take root breadth-wise.
- To protect the plants preventively against pests, 10 days after the cucumber has caught on sprinkle with Protector (or Admire) against aphid, white fly and thrips.
- The duration of cultivation is on average 15-17 weeks. Sowing, 10 days later planting, 5 weeks later harvesting.
- Production per cultivation round 10 kg/m^2.
- From the first harvest, harvesting takes place for 10-12 weeks.
- Crop maintenance takes place three time a week (remove thieves, tops, attachment vines).
- According to Elly: at most 50% shade netting. More shade is too dark.

Fertilisation and soil treatment

- Basic fertilisation
  Before the cultivation, best before the digging of the soil, Curacao uses basic fertilisers. They are dug through the soil before the cultivation. This is done with an NPK fertiliser 10-10-10, 15-15-15 of 20-20-20. About 100 grams/m^2 per cultivation or 200 grams/m^2 per annum.
- During the cultivation liquid fertilisers provide the following. On a 250-litre tray the following mix is created: Ureum 1 kg, Multi K 3 kg, MAP 8kg.
- Start of the fertilisation with 12-36-12 NPK, with EC 2,5 - 3,0 and pH 7 to 8, reduction through acidification does not take place.
- Watering takes place in the morning (Soltuna) and usually late in the afternoon (Bakufal).
- It is warned to include trace minerals. This is not common in soil cultivation but originates from substrate cultivation.
- The fertiliser that we use, Pavane, already includes, for instance, Borax. I would not include this as the soil already contains too much boron.

Varieties

- On Curacao 2 varieties of the Japanese breeder Takii are cultivated with good experiences. They are mixed, flowering types, they have ample crop work. About three times a week the plant is topped for lateral sprouts and attachment vines. Vines are kept at 75 cm, 1.5 metres and 2 metres that the cucumbers later grow on. These vines should actually also be topped again in order to have the crop grow in a controlled manner.

- Dutch varieties are, according to Elly, less suitable. Potentially and probably the selection takes place in the breeding process, where this already takes place on stone wool substrate. Plants are less strong on roots than older varieties and are mostly selected on production in ideal conditions.
- Varieties that are used frequently in greenhouses:
    - Long types: Southern Delight and Summer top
    - Short types: Pontia and Paraiso

Crop rotation

- On Curacao, after a cucumber cultivation they rotate with a relatively long cultivation of bell peppers and yardlong beans before planting cucumbers again.
- How many weeks there should at least be between cucumbers and new cucumbers is not known to us (yet). Rotation is important with vegetables from different plant families.

Water

- The water that is used on Curacao originates form the water purification or from sources. The water is extracted from the sea and drinking water is mostly prepared through reversed osmosis.
- Apart from a high boron percentage, sodium and chloride are higher than in our analyses. Cucumber cultivation on Curacao demonstrated that cucumber still grows with high boron concentrations, in any case the varieties that are used there.
- Elly mentioned that they also had water issues on Curacao and that the EC was then much too high. This was discovered later. It is very important to properly measure the water quality.

	pH	EC	Anionen (millimol per liter)					Kationen (millimol per liter)						Spoorelementen (micromol per liter)					
	water	mS/cm	NO_3 nitraat	Cl chloride	S zwavel	HCO_3 bicarbonaat	P fosfor	NH_4 ammonium	K kalium	Na natrium	Ca calcium	Mg magnesium	Si silicium	Fe ijzer	Mn mangaan	Zn zink	B borium	Cu koper	Mo molybdeen
ANALYSE	7.2	0.7	1.0	2.9	<0.2	1.9	0.21	<0.1	0.6	3.4	0.8	<0.2	<0.10	<0.2	<0.2	0.8	68	<0.2	<0.2

Analysis Bonaire 27 May 2015

Analysis Bonaire 18 December 2015

De analyseresultaten (in de dik omlijnde kaders) hebben enkel betrekking op het geanalyseerde monster.

	pH	EC	Anionen (millimol per liter)					Kationen (millimol per liter)						Spoorelementen (micromol per liter)					
	water	mS/cm	NO_3 nitraat	Cl chloride	S zwavel	HCO_3 bicarbonaat	P fosfor	NH_4 ammonium	K kalium	Na natrium	Ca calcium	Mg magnesium	Si silicium	Fe ijzer	Mn mangaan	Zn zink	B borium	Cu koper	Mo molybdeen
ANALYSE	7.1	0.7	0.4	2.7	0.2	2.6	0.27	<0.1	0.6	3.0	0.8	0.2	<0.10	0.3	0.5	0.6	72	<0.2	<0.2

Conclusions

The water quality on Curacao is comparable to that on Bonaire.

With the temperatures on Bonaire and Curacao it should be possible to grow cucumbers year-round.

This will, however, not be possible without crop rotation; to make this possible rotation needs to take place with rows / greenhouses together with, for instance, yardlong beans and bell peppers. For the latter perhaps a different plant from a different plant family.

The question is, when did it go wrong with cucumbers of GreenBonaire the second and third time? Could this be related to a surplus or deficit of certain elements? The symptoms of yellow tops seem to

point to an iron deficiency, this was added at the time (100 grams/A-tray) but is much less than used later (2 kg on A-tray). Comparable yellow tops with basil have since disappeared quickly after a large supplementation of iron.

At the time we also had a cultivation of Moscatel cherry tomatoes that also showed yellow tops on the same plot. Perhaps this could also be attributed to an iron deficiency?

More information about the soil and the crop is required to exclude things and to draw hard conclusions.

Recommendations for potential research

Research regarding year-round cultivation of cucumber is, having regard to the water quality on Curacao (which appears to be comparable to that on Bonaire) and the good experiences with regard to year-round cucumber cultivation already gained on Curacao, worthwhile.

It is good to consider what varieties are selected. A typical Dutch cucumber (seedless), fully flowering females, high production. Or can it also be a little less tasty variety with more chance of success for the year-round production?

- The research should offer room for comparison of varieties. This is the easiest way towards improvement. A variety that is grown frequently on Curacao should in any case be used by way of control and compare it to a Dutch cucumber. Hence, in any case these varieties for control purposes. Long types: Southern Delight and Summer top. Short types: Pontia and Paraiso.
- The research should offer room for crop rotation. Experience has already been gained with yardlong beans. There is barely any experience with bell peppers.
- I would want to examine the following factors in the research: production per variety, product quality, plant preservability, dropouts.
- It is good to conduct a soil and water analysis in the Netherlands once a month or every 2 months. In case of badly growing plants, leaf samples should be taken.
- It would be nice if we register the temperature, how is this related to the production?