Centre of Excellence in Horticulture of Agadir

Inception report

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WAGENINGEN UNIVERSITY & RESEARCH

Netherlands Enterprise Agency

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This study was carried out by Wageningen University & Research and was commissioned by the Dutch Ministry of Foreign Affairs and financed by the Netherlands Enterprise Agency

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This report is the result of the inception phase of a project aiming at a Centre of Excellence in Horticulture (CEH) at the Complex Horticole d'Agadir (CHA) of the Institut Agronomique et Véterinaire Hassan II. The objective of the inception phase is to draft a scientific programme for the CEH and consists of the development of a 5-year scientific programme; the identification of possible Dutch involvement in the execution of the programme; and the identification of design parameters of a greenhouse complex suitable for research, demonstration and training as needed for the proper execution of the programme.

Key words: Horticulture, Agadir, conceptual design greenhouse, research and educational programme

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Introduction

This report is the result of the inception phase of a project aiming at a Centre of Excellence in Horticulture (CEH) at the Complex Horticole d'Agadir (CHA) of the Institut Agronomique et Véterinaire Hassan II. The project is commissioned by the Dutch Ministry of Foreign Affairs and financed by The Netherlands Enterprise Agency. Wageningen University & Research (WUR) has implemented the project in coordination with the Complex Horticole d'Agadir.

The objective of the inception phase is to draft a scientific programme for the CEH and consists of the following components:

1. The development of a 5-year scientific programme in a participatory process, involving all relevant stakeholders

2. The identification of possible Dutch involvement in the execution of the scientific programme, including action plans, planning and budget estimations

3. The identification of design parameters of a greenhouse complex suitable for research, demonstration and training as needed for the proper execution of the scientific programme.

The inception report is considered as a consultancy activity and covers two parts:

- Conceptual design of a demonstration and research greenhouse in the region of Agadir, Morocco
- Scientific and education programme of the Centre of Excellence in Horticulture of Agadir.

Approach

The inception phase has been set up as follows. First, two draft reports were produced about the conceptual design of the greenhouse complex and the scientific and education programme, based on previous visits, workshops and reports. Second, both reports were discussed during a workshop that was held in November 2016 in Agadir, and attended by the staff of CHA and representatives of WUR, by representatives of the private sector (APEFEL: Association of vegetable and fruit producers and exporters in Morocco; and a producing company) and (via videoconference) by the Dutch Agricultural Counsellor (Rabat).

The conceptual design report of the demonstration & research greenhouse was approved without change. On the other hand, the workshop resulted in major amendments of the draft scientific and education programme for the Centre of Excellence in Horticulture. In particular, post-harvest and horti-business have a lower preference from CHA and were dropped from the priority list of research and education themes proposed by WUR, and the final list is as follows: water and ferti-irrigation management, climate management, crop protection and crop management. Initial thesis topics for each theme and each education level were identified in cooperation between WUR and CHA and are reported here. It is recommended to add post-harvest and horti-business to the programme in a later stage.

The inception report will be the basis for the following phase aiming at the participation in the execution of the scientific programme.

Disclaimer: The mentioned budgets for scientific supervising and training are indicative and relate only to the context of this project.

Conceptual design of a demonstration and research greenhouse in the region of Agadir, Morocco

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Contents

1 Introduction

Morocco annually produces nearly 1.27 million tonnes of tomatoes. Nearly one-third of this production is for export. The remaining two-thirds are destined for fresh consumption in the domestic market and for processing. Although there is also, to a lesser extent, cultivation of tomato in other regions of Morocco, the region of Agadir alone contributes about 96% of the total national export of tomato. Horticultural production (protected horticulture in particular) is one of the most important economic activities of the region of Agadir (Sous-Moussa-Draâ). Conditions are particularly favourable to tomato production (experienced producers, favourable climate, and an internal market able to absorb discrepancies between production and exports). The production area of tomato in the region is approximately 5,619 ha, of which 98% under plastic.

Horticulture has been identified as one of the pillars of the future economic development of Morocco and a national strategy has been formulated to stimulate this sector and attain the following objectives:

- To attain a significant improvement in agricultural GDP, exports and private investment
- To increase farm income to fight rural poverty
- To improve the purchasing power and the quality/price ratio for consumers in the domestic market
- To increase the area of protected cultivation to at least 12,400 ha (which is more than double the actual area under protected cultivation), opening the door to a new wave of investments on more sustainable greenhouses.
- To make better use of available water resources, in particular by full implementation of drip irrigation and an increase in the use of substrate cultivation.

However, in spite of its considerable strength, this sector faces constraints that limit its growth. In particular, the region is marked by an increasingly important water deficit. Climate change (low rainfall, increasing drought) is playing a worrisome role in the decline of regional water reserves: the level recorded in dam basins is falling each year. The deficit is also certainly increased by poor management of irrigation, and the deepening of the ground water table is attested to by the need to build ever deeper wells.

In addition, the poor quality and age of the greenhouses cause poor productivity and quality, poor resistance to pathologies (scarce implementation of integrated pest control strategies) and to weather shocks (such as Chergui), which threatens the winter production, which is the most valuable given the ‘export window’ to the EU. In short, there is a need to increase productivity (not only in respect to water, but also to all other inputs, which are relatively expensive), quality and reliability as well as more sustainable ways of production, with due robustness with respect to the expected effects of climate change.

It is therefore necessary to propose a new model of production to promote sustainable development and competitiveness of protected horticulture in this region, thanks to:

1. More efficient use of water resources;
2. Increased productivity, quality and sustainability and
3. Improved know-how of (present and future) managers and growers. These are the founding objectives of the Centre of Excellence in Horticulture Agadir (CEH). The result of a collaborative project between Moroccan and Dutch institutions, the CEH is expected to become the national reference platform for research and innovation in the issues related to protected horticulture in Morocco. It is also expected to become a showcase demonstration for the transfer of sustainable greenhouse technology to producers of the region.

1.1 Objectives

This report proposes a conceptual plan for the greenhouse complex that will be the heart of the Centre of Excellence. The objectives of the Centre of Excellence that were agreed upon beforehand, and to which this conceptual design complies are:

- The greenhouse complex should have the dual purpose of demonstration/testing/training aimed at growers and of research/education for the students of the Centre Horticole d'Agadir
- The technologies and growing methods that will be considered will make a decisive contribution to increased environmental and economic sustainability and to climate-smart horticultural production
- In order to achieve the desired impact, the technologies proposed/demonstrated/researched in the Centre should entail limited, stepwise changes to the existing greenhouse technology.

Accordingly, the first part of this document is devoted to an analysis of the present situation and a study to pinpoint the technologies most likely to increase productivity and sustainability with an affordable investment, in order to propose a conceptual design for the demonstration/training function of the greenhouse complex. In the second part we use the results of the same study to propose a conceptual design for the research/education component of the greenhouse complex.

1.2 A challenging context

Although everybody is aware that there is a need (and room) for improvement, growers often are turned off by the investment required. Although public subsidies are available (the Green Morocco Plan), very little has been explicitly aimed at greenhouses. Indeed, the Moroccan contribution to this particular project and its follow up has not yet been finalised.

Nevertheless, there is a very large potential market for Dutch companies supplying greenhouse producers, if particular attention is given to fine-tuning the product (and the message) to the local conditions. In this respect, the participation of APEFEL (the Association of Vegetable and Fruit Producers) in the CEH is most welcome, since they maintain a well-run 'research station' taken over years ago from a United Nations-financed programme to phase out the use of methyl bromide as soil disinfectant. Whereas most of the activity there is aimed at variety testing under contract from breeding companies, there is also some research/demonstration on technology, particularly substrate growing, rainfall collection and also some climate management. We propose that the CEH should not do variety research and testing, and the training function of the CEH site should be emphasised and operated in close connection to APEFEL (see part 2 of this report). In addition, there is a need to understand why so little of the technologies that have been proven at the APEFEL station has found application in practice, in order to learn and also propose synergies.

2 Current situation of Moroccan greenhouse production

2.1 Greenhouses

Figure 1 *Interior (top) and exterior (bottom) of a Canarian greenhouse, the most common greenhouse in the region of Agadir, a typical size being 1 ha. Air exchange and water discharge is ensured through holes in the roof and by the openings (covered by nets) on the sidewalls. A very limited management of ventilation is done by manually causing splits between adjoining plastic sheets in the roof (top) and lowering/rising the plastic on the sides (below).*

The most common greenhouse by far is the so-called ‘Canarian greenhouse’, which is very similar to (but usually much higher than) the ‘parral’ greenhouse typical of the Almeria region in southern Spain. Such greenhouses were developed for the cultivation of bananas, which was the first crop to be grown in greenhouses in Morocco. The typical size of such a greenhouse is about 1 ha. It consists of vertical supports (usually wood) for a two-layered iron network enclosing the plastic sheets (Figure 1, top). Ventilation (and water discharge) is ensured by openings between adjoining sheets. Additional ventilation comes from manually lowering/lifting the plastic on side walls (Figure 1, bottom). Nearly all greenhouses (and certainly the ones certified Global GAP for export) are fitted with insect nets over the sides.

The main merit of such a greenhouse is that it is cheap: prices range from 40 to 45 k€/Ha (see Table 1 for the costs) and that it shows a fairly good structural behaviour against strong winds. Major shortcomings are the poor ventilation, which results in very high temperatures in spring/summer, high humidity and very low internal concentrations of carbon dioxide; the absence of thermal insulation (for instance thermal screens) and/or heating which, coupled to the unmanaged openings, causes sub-optimal night-time temperatures in late autumn and winter. Considering that this is the period with the highest prices, there is obvious room for improvement. Other weaknesses are poor light transmission, bad insulation that enables pests entering the greenhouse, rain dripping inside and no collection of condensation water in the cover, etc.

Table 1 *Capital costs of a Canarian greenhouse of 1 ha.*[1]

	Amount (kg)	Unit price (€)	Total price (€)	Lifetime (years)	Yearly cost (€)
Plastic film 220 micron	3,000	2.13	6,390	4	1,600
Metallic Structure	30,000	0.90	27,000	10	2,700
Insect Net	2,800	0.80	2,240	5	448
Strings	300	0.60	180	1	180
Hangers (units)	36,000	0.03	1,080	2	540
Work (days)	250	8.00	2,000	10	200
Plastic Mulching	240	1.50	360	1	360
Total			**39,260**		**6,028**

[1]Practical information (confidential)

2.2 Crops

The most common crop in the region of Sous-Moussa-Draâ is tomato, which in most cases is harvested loose. Typical productivity is around 20 kg/m^2, of which 6-7 kg in the winter months, when prices are high, thanks to the export to Europe. Some export-oriented groups, such as Matysha or Azura produce also ‘niche’ tomato types such as cherries, plum or truss.
Some diversification is taking place, also among small producers: melon, green beans and strawberries are taking up surface, as are sweet pepper and courgette to a more limited extent. Diversification should be stimulated, as a means both to increase value and to decrease the vulnerability of dependence from a single crop.

2.3 Productivity

Most producers make a living, in spite of the low productivity. An issue is the relatively high fraction of yield waste (up to 40% unmarketable) and low quality (unfit for export) yield, both good subjects for future research at CEH. Besides technology and climate management, improving such numbers requires improved skills for crop management (such as truss pruning). Indeed, some tests at APEFEL have shown that improving the quality of the greenhouses and/or of the growing system can increase productivity, starting from the admittedly low productivity of 20 kg/m^2.

For instance, Table 2 gives the production costs of a good and successful commercial company, producing truss tomatoes from grafted plants on substrate in a curved multi-tunnel greenhouse. It would seem that a production of 30 kg is enough to have a fairly good profit, in spite of the capital costs that are 250% of what is given in Table 1.

Table 2 *Yearly production costs of a (good) company growing truss tomato on substrate, winter cycle. The cost price per kg (€0.33) has been calculated with a productivity of 30 kg/m^2.*[1]

	Units	Units/ha	€/unit	€/ha	€/kg	%
Grafted plants	N	25,000	1.25	31,250	0.104	31.5
Substrate	Mats	6,150	1.42	8,733	0.029	8.8
Nutrient solution	m3	9,720	1.38	13,414	0.045	13.5
Plant strings	N	25,000	0.09	2,250	0.008	2.3
Bumblebees	Hives	36	80	2,880	0.010	2.9
Crop management	h	8,517	1.20	10,220	0.034	10.3
Harvest	h	3,333	1.20	4,000	0.013	4
IPM				4,525	0.015	4.6
Electricity				3,746	0.012	3.8
Services				3,000	0.010	3
Total variable costs				**84,018**	**0.280**	**84.7**
Capital costs				15,140	0.050	15.3
Total				**99,158**	**0.330**	**100**

[1]Practical information (confidential)

3 Pre-selected boundary conditions (reference greenhouse)

The greenhouse complex will have a plastic cover, in order to limit initial investment and to comply with the requirement of not being too different to existing greenhouses.

We advise single plastic rather than double inflated, after weighing pros and contras.

Pro: double inflated polyethylene covers have an excellent thermal performance in winter, also in passive greenhouses, by limiting radiative and heat losses, preventing problems related to condensation on the cover (i.e. preventing the incidence of fungal and bacterial diseases thriving in the water dripping from the cover onto the crop) and also improve the resistance of the cover against strong winds.

Contra: the lower transmission (some 13% less hemispherical light transmission than a standard single PE cover) causes a decrease in yield, both predicted by simulation models and in practice (around 8-15%; for instance, Papadopoulos and Hao, 1997). In conclusion, the combination of a single cover with an energy-saving screen ensures also a similar decrease in thermal losses and protection against dripping during the night, with a minor effect on light transmission and thus in yield. In addition, the use of single plastic films with anti-dripping properties/coatings and a roof slope higher than 20-25° (Gbiorczyk, 2003), by enabling the sliding of the water towards gutters, may help prevent much of the problems associated with dripping of condensation and even allow for some recovery of water.

There are a number of commercial greenhouse types in the market that can be covered with a single plastic film, ensuring a good light transmission during the winter period, enough natural ventilation capacity and good insulation, all of them essential to improve the performance of the existing passive greenhouses in Morocco. A possible and popular option in many regions of the world is to use the so called multi-tunnel greenhouses with a gothic-shaped roof (to improve light transmission in winter and collection of condensation water). However, experience shows that this greenhouse type has some weaknesses that a Venlo structure, covered with anti-drip-coated plastic, does not have. One of them is that the multi-tunnel type is usually built in spans of 8 m or higher width (9.60-11,20 m), whereas the Venlo type has two spans of about the same width. This has negative implications for the multi-tunnel type:

- The climate of Agadir requires a large ventilation capacity (large ratio of opening-to-ground area). Ventilators are most effective when adjoining the ridge, thus relatively more ridges per surface area allow for smaller flaps to attain a given ventilator area/greenhouse area. As we will see, in this case this ratio must be at least 40%, in view of the need for insect nets. Large flaps can be easily damaged by wind gusts, which is usually compensated by a very conservative ventilation strategy, that is, by not fully using the ventilation capacity available.
- In addition, as the ventilation flow is less than linear with the flap opening angle (De Jong, 1990; Perez Parra et al., 2004) more smaller openings deliver a desired ventilation flow at a smaller opening angle than few larger ones. Besides lowering the risk of damage, this has the big advantage of a smaller shadow area resulting from the (often dusty) insect nets.
- On wide spans, also wider plastic sheets must be implemented between the vent and the gutter and in the vent itself, because they are more likely to suffer from the flapping effect of the wind when the plastic dilates because of temperature. This continuous flapping under wind conditions is one of the main factors causing breaking of the plastic on the contact points between plastic and structure. In the Venlo type greenhouse, the plastic sheets in the roof, between gutter and vents and in the vents themselves, are narrower and suffer from less flapping, enabling a longer life span for the plastic film.

- The straight-pitched roof of the Venlo type (or anyhow a gothic-arched roof) allows for a better sliding and collection of the condensed water than in a traditional tunnel-shape roof.
- An additional advantage is the well-established method for roof-cleaning, something that is highly needed to maintain productivity in the dusty desert environment of Agadir. The lifespan of a Venlo greenhouse is considered to be at least 20 years, double of that of a Canarian type greenhouse, which leads to less waste at the end of the lifecycle.

Therefore we propose a light Venlo structure, covered with single, anti-drip-coated plastic, with double side, continuous ridge vents. With respect to the irrigation system, water use efficiency is only ensured by substrate growing with recollection of drainage, so this is the technology that will be installed in the greenhouse complex. In principle, this should lead to a water saving of about 30% in relation to conventional soil cultivation. The use of a closed system also limits the use of fertilisers (up to 40% of N, Pardossi et al., 2011) and decreases the pollution linked to leaching (especially important for nitrates, easily leaked to the underground aquifers). Therefore, in order to quantify improvement, both of production and of water use efficiency, **we propose that at least one compartment is fitted for 50% soil and 50% substrate growing,** the first one fitted with soil lysimeters (to carefully monitor the amount of water really used by the crop) and **the latter also with recollection of drain.** Rain and condensed water must be collected by connecting all gutters to a rainfall basin to be dimensioned after adequate analysis of rainfall patterns and crop water consumption, all of which contributes to water saving and increasing the sustainability of the greenhouse production.

Another important contribution to sustainability of the use of substrate is to dispose of the need for soil disinfection, usually associated with significant energy consumption and pollution. With respect to other aspects where the present greenhouse park in Agadir conforms to international and Dutch trends, **we propose a gutter height of at least 6 m; ventilation openings fully fitted with concertina insect nets and double doors overall.** It is important to highlight that the use of thorough insect-proof netting in all greenhouse vents, the higher insulation of a Venlo type greenhouse in relation to a Canarian type greenhouse and the use of double doors, all contribute to limiting the incidence of pests and diseases and reduce the need for chemical crop protection. In addition, a much-closed environment enables an easy implementation of biological control.

In view of the chance that additional (Moroccan) funds may become available in the future, **we propose a modular construction, making possible an extension with additional demonstration/research compartment(s).** Considering also the need for sustainability we propose that the CEH draws on renewable energy and heat (as far as needed). Therefore **solar panels should be installed on the roof of the facility compartment and on the rain collection basin,** thereby reducing algae growth. The allocation of the panels between electricity and hot-water must be decided in view of the local/future regulations for electricity sale to the grid and the dimensioning of the heating in the research compartments.

We foresee the need for a climate and ferti-irrigation computer that steers ventilation and all other features that will prove necessary, the amounts of irrigation water and amounts of and type of fertilisation, and by doing so limits the inputs to the best productivity levels and prevents 'overuse' of resources.

3.1 General description of structure, facilities and equipment

We estimate the initial block will be slightly less than 1 ha, divided into: about 0.5 ha for three training/demonstration compartments, about 0.25 for the initial bloc of six research compartments and about 0.15 ha for facilities and storage and rain collection basin. All demonstration compartments will be fitted for high-wire growing, though not necessarily hanging gutters, since this requirement may make the structure heavier and more expensive. **Both the climate computer and all other**

installations will be dimensioned in order to accommodate more compartments to be added in the future. All compartments will be fitted with a pipe-rail system for transport and crop operation, even when not connected to heating.

At the north side of the greenhouse compartments there will be non-transparent rooms (covered with solar panels):

- facilities for the personnel
- a computer room
- water treatment and mixing tanks
- fertilisers and crop protection storage and small production storage.

In commercial farms in the Netherlands such a technical area usually represents 4-5% of the cultivation area. However, here we foresee a relatively larger fraction, in view of the small scale of the compartments and the need to host many more people than just greenhouse personnel (see Figure 3).

4 Options for demonstration greenhouse

In order to determine the technological improvements that have the largest return on investment (and minimal environmental impact), we have applied the ‘Adaptive greenhouse method’, described at more length in the appendix. The method uses proprietary models of Wageningen University & Research to finally determine the yield of tomato in a given greenhouse, under given climatic conditions. Whenever active climatisation means are applied, the model calculates the requirement for external resources.

First, we collected local yield and climate data to validate the model and establish the baseline. Then we analysed results to pinpoint the factors most likely to limit yield. Finally, we applied stepwise improvements to the baseline and determined the resulting yield (round tomato), starting from ‘passive’ climate management means. The results are found in Table 3.

Table 3 *Effect of increasing technology on production of round tomato in Agadir. Real case is a good, exporting grower, the reference (baseline)*

Greenhouse fitting	Yield (kg/m2)	Winter Yield (kg/m2)
Real case	18.6 of which 11.8 export	7.6 of which 5.6 export
Reference (present greenhouse, no pathologies, good agronomic practices but no pruning/pinching)	23.8	7.3
Improved ventilation	34.2	8.5
Improved ventilation + application of a shadow screen instead of whitewash	35.2	8.6
Improved ventilation + no application of whitewash	36.5	8.4
Improved ventilation + energy screen at night+ no whitewash	37.1	9.3

As we can see, the most effective improvement by far is a having a large ventilation capacity (large openings: here 50% of floor area has been assumed) that can be automatically controlled. That is shown by the increase in winter yield, which follows from the ability to control ventilation. This is supported by results of a prototype ‘improved Canarian’ greenhouse (with a hand-managed ventilation flap on the ridge) installed at the research station of APEFEL, where the yield is about 30 kg/m^2·year.

Different shading strategies have been analysed. The first three cases (real case, reference and improved ventilation) have all included the use of a traditional whitewash during the high radiation period. Contrary to what one would expect, the use of a movable shadow screen (instead of the permanent shading given by whitewash) is not very beneficial in these conditions, since it does limit ventilation. On the other hand, a good ventilation capacity (possibly coupled to a slightly diffusing cover) makes it possible not to apply whitewash. The second most effective improvement is the use of an energy screen at night (aimed at decreasing energy losses from the greenhouse), which increases night-time temperature in the cold season and has a good effect for the winter yield. **In this respect it is very important to maximise daytime storage of heat in the soil, therefore the soil should not be thermally insulated and any mulching material should not be white, but black.** Enhancing the heat storage capacity of the greenhouse is a very sustainable way of improving night-time temperatures without making use of active heating with conventional fossil fuel sources.

In conclusion, we propose to test and demonstrate the effect of a good ventilation and of an energy screen. In order to do it stepwise (and to evaluate the effect of each technology), we propose the whole greenhouse be fitted with good ventilation, and at least 2 compartments to have an energy screen in addition.

4.1 Specifications for improved ventilation and energy screen

The calculations have been done with a window-to-floor ratio of 50%, considering all vents implemented with an anti-thrips insect proof screen (porosity=25%) which have an effect in decreasing airflow of 44% (Perez-Parra et al., 2004). In practice it is unlikely to have a 50% window-to-floor ratio. However, the effect of the ventilation area is asymptotic (Tuzel et al., in press), which means that a 40% window-to-floor ratio will deliver only slightly lower yields. A 40% window-to-floor ratio can be obtained in practice for a Venlo greenhouse by installing double continuous roof vents on each span. Therefore the tender should be for double-sided continuous ridge flaps with a window-to-floor ratio of 40%. However, a window-to-floor ratio of 35% would also be acceptable if concertina type anti-insect screens are installed (Figure 2), as according to Teitel (2013) a concertina screen with a typical 60° fold allows about 23–32% higher airflow than a flat screen. If possible, and in order to maximise air exchange by natural ventilation, the greenhouses must be oriented with their ridge perpendicular to the prevailing wind direction, which is West in Agadir.

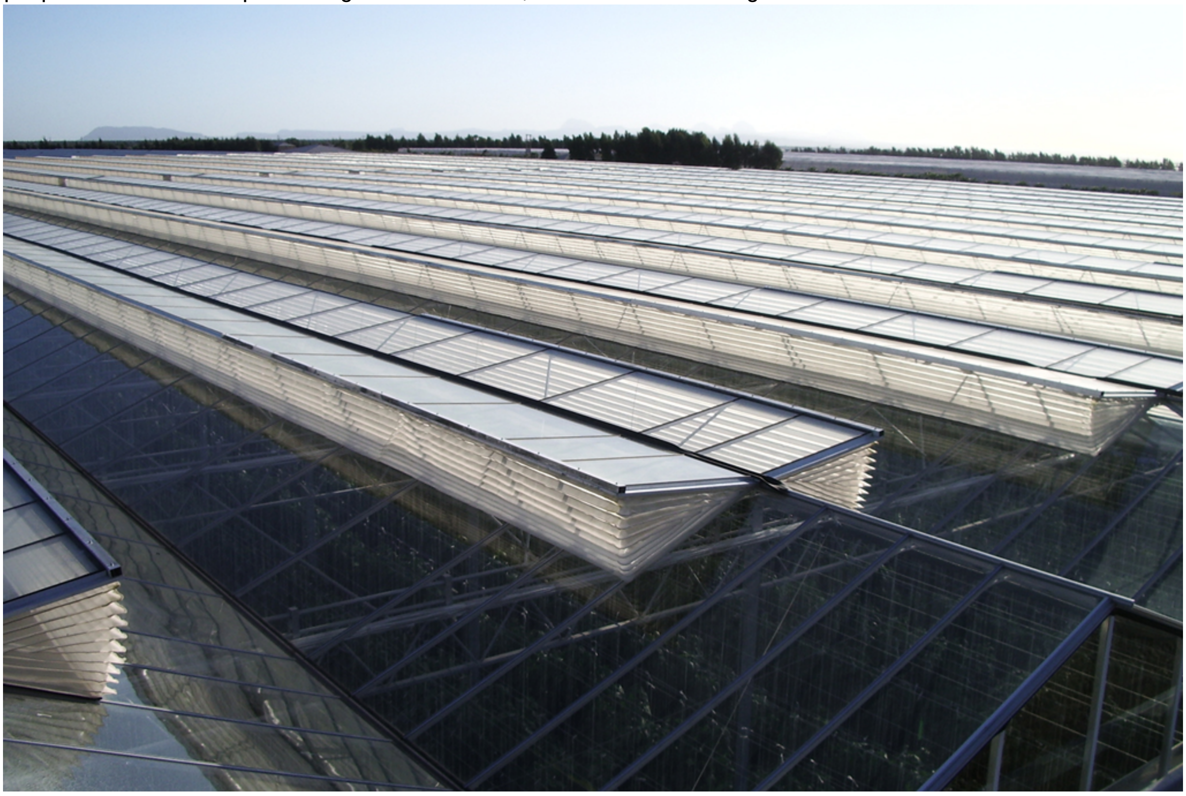

Figure 2 *Detail of a Venlo greenhouse with double continuous roof vents implemented with a concertina type anti-insect screen.*

The energy screen that should be tendered must have a percentage of aluminium material of at least 80% and the remaining fraction should be open. This opening will enhance the water vapour transmission from the lower compartment to the relatively cold roof, where a large part of the water vapour will condense and will be collected in the condensation gutters. This ‘drying’ of the crop compartment, coupled with the prevention of radiative cooling by the aluminium, will help in maintaining crop temperature above dew point and in preventing condensation on the plants, which is the first step required for fungal and bacterial diseases to develop. Altogether, besides increasing mean night-time temperature in winter, this will make management of night-time humidity easier.

Condensation on the crop can be further prevented by increasing air circulation within the greenhouse using interior fans (vertical fans preferably, but also possible with horizontal fans), which will also improve microclimate homogeneity. Although the simulation model cannot simulate the effect of these fans on the night time greenhouse climate, different experimental works carried out in research and commercial greenhouses in The Netherlands have proven that an airflow of at least 10 $m^3/(m^2 \cdot h)$ should be generated by the fans, so this will be the nominal airflow considered in their design.

4.2 Conclusions

In conclusion, we believe that a very good improvement of yield and its quality can already be attained through a good ventilation coupled to application of energy screens in the cold nights. Therefore we propose three relatively large compartments for the demonstration/test/training component, all with the ventilation as described, two also fitted with the energy screen described above. One of the two can be additionally fitted with air circulators and all compartments can in the future be used for other vegetable crops than tomato, such as sweet pepper, eggplant, cucumber, melon or zucchini.

Substrate cultivation with recollection of drain water must be possible in all compartments, although at least one should be for 50% soil cultivation (at least for the first couple of years). In order to lower costs (and increase lightness of the structure), crop gutters resting on well-levelled ground supports may suffice. The levelled and half-hard soil should be covered with dark, non-insulating permeable foil/textile.

The dimension of the three compartments plus the facilities area is about 0.5 ha. Additional compartments besides these ones can be easily added when additional funds become available.

5 Options for the research greenhouse

Obviously some research is also possible in the demonstration/training compartments that we have described above. For instance all matters of crop management (such as pinching, pruning, defoliating, etc.) can easily be dealt with by splitting compartments in two or more crop treatments.

Research on irrigation and nutrition can also be made possible by splitting each of the compartments in two or more fertigation units. Nevertheless, research greenhouses will also be built: 6 equal-size compartments, each about 400 m^2.

With respect to the technology to be installed and investigated in these compartments, the active means of control we have considered are:

- heating;
- carbon dioxide supply and
- artificial light to increase daylight duration.

In view of the water scarcity we did not consider misting and/or fogging, although evaporative cooling might obviously increase spring/summer production and quality. Results are listed in Table 4.

As the table makes clear, carbon dioxide supply and/or lengthening of the day with artificial light are much more likely to increase production than heating. Therefore we would give priority to evaluating cost benefits of such installations in the research compartments rather than to heating. If hot-water solar panels are installed, the use of night-time heating for humidity management should be considered.

Table 4 *Effect of active climate control on production of round tomato in Agadir. The baseline is now the best passive greenhouse (with good ventilation capacity and management and with thermal, aluminium screen)*

Greenhouse fitting	Yield (kg/m^2)	Winter Yield (kg/m^2) (Dec, Jan, Feb)	Resources needed
Best passive greenhouse	37.1	9.3	0
Heating	37.3	9.5	506 MJ/m^2
CO_2 supply (capacity 60 kg/(Ha·h))	44.2	12.2	24.2 kg CO_2/m^2
Artificial light (150 µmol/(m^2·s))	39.5	10.7	106 kWh/m^2
Artificial light on top of CO_2	51.0	13.8	106 kWh/m^2 + 24.2 kg/m^2

5.1 Specifications for CO_2 enrichment

In view of the need for sustainability, carbon dioxide fertilisation should be done with ‘waste CO_2’, originated in other - industrial - processes. A very relevant issue is very often the cost associated with cleaning of the exhaust gases to recover CO_2, and its transportation. Nevertheless, in view of the possible advantage (both in terms of productivity and decreased environmental impact of the process source of CO_2) it is worthwhile quantifying the ‘value’ of CO_2 in horticulture for the region. Therefore, in spite of the fact that we are aware that feasibility of CO_2 fertilisation is probably far in the future, we recommend to fit one research compartment with CO_2 supply. This may also prove necessary, for each research topic that needs to exclude the interference between ventilation, temperature and CO_2 concentration, that is inevitable in the absence of artificial CO_2 supply.

- CO_2 will be supplied in the form of pure CO_2 stored in a CO_2 storage tank located outside the greenhouse and the system may have a limited capacity of 60 kg/(ha·h). We advise this low level, under the assumption that, before demand is created, pure CO_2 will be relatively expensive in the region, and it is therefore important to show the increase of yield possible even with a relatively low consumption of CO_2.

- The carbon dioxide is to be distributed evenly over the greenhouse using distribution pipes as manifolds, ending in small plastic punched air ducts by the crop rows.
- These punched air ducts must have the same length as the crop rows.
- Supply of carbon dioxide will be controlled by the central computer.
- The system has to be fitted to local conditions, so a local supplier of CO_2 can provide carbon dioxide on a regular base. Contact should be established with a local supplier by the contractor.

5.2 Additional options for the research greenhouse

Another interesting alternative, will be to install in one of the research compartments an artificial lighting system capable of providing 150 μmol/(m2·s). The light should be provided by LEDs, since high-pressure sodium lamps are incompatible with the use of a plastic film cover due to fire risk. As a certain amount of sensible heat will also be provided by the lamps, the application of artificial light is a (in our eyes more) sensible alternative to installing a heating system.

Another option is a hot-water heating system in one of the research compartment(s), with a power of 40-50 Wm^{-2}, drawing on hot water from the solar panels. Although the simulations do not show an increase in yield that may justify the use of heating for the simulated year, a heating system can provide an extra help to control problems associated with high humidity. In addition, there are other crops for which response to heating could be higher than for tomato, such as pepper, cucumber or melon. In such cases, the heating system should consist of a sun-powered boiler dimensioned to provide the required heating power and the heat distribution system would consist of the typical Dutch system of low metal heating pipes that can be used also to move the trolleys for the different crop tasks such as harvest, leaf pruning, etc.

Another interesting topic for future research can be the feasibility of new materials that are under investigation now: conditions in Agadir (high UV and direct fraction of sun radiation) ensure that the chemical companies working on this topic should be interested in joint research.
A certainly useful application of (a part of) the research section could be to learn and test new crops for the region. As we have mentioned above, sweet pepper, cucumber, eggplant, zucchini and melon require similar specifications as tomato. Other crops, such as strawberries, lettuce, other berries, would require completely different growing systems, such as tables, ebb-and-flow, etc. Therefore, the arrangement and equipment to be fitted must follow a decision on the crop or crops to be studied.

5.3 Conclusions

Technologies that may be promising but deserve further investigation in the conditions of Agadir are:

- CO_2 fertilisation
- additional light through LEDs and
- heating.

As there is a need for crop diversification from tomato, the study/adaptation of growing methods for other crops that the high vegetable crops is a surely worthwhile destination for some of the research/education compartments.

6 Summary and recommendations

An overview of the complex is shown in Figure 3, which also shows how the greenhouse facility can be extended whenever more funds are available. What should be put to tender, in view of the money directly available, are the three demonstration/training compartments, the 6 research compartments, the facility area and the rain collection basin (final dimension to be determined later) for a total of slightly less than 1 ha.

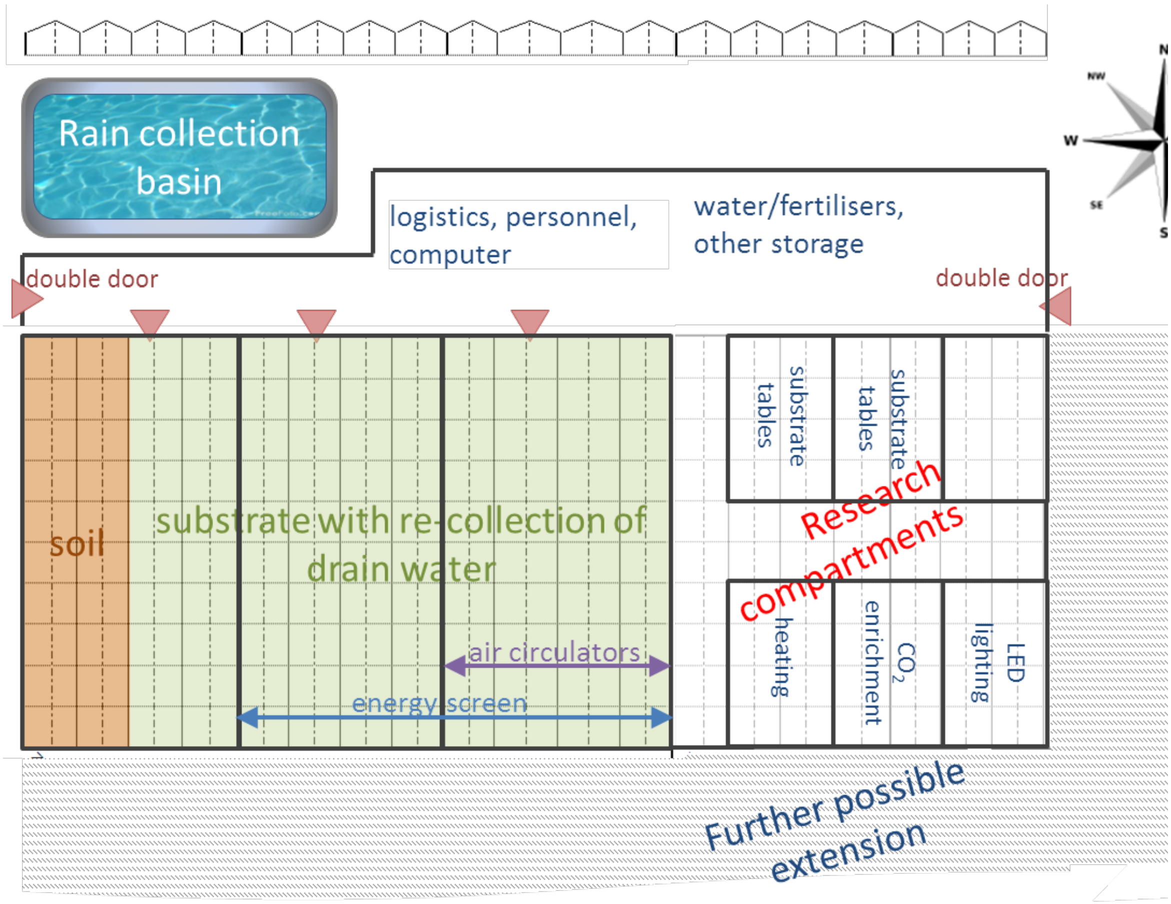

Figure 3. *Overview of the greenhouse facility complex. The final lay-out will be determined in consultation with the contractor, but it must allow for future extension with additional demonstration and research compartments*

6.1 Technical specifications for the CEH complex (tender document)

General

- The greenhouse complex will have a light Venlo structure, the spans oriented N-S
- Gutter height of > 6 m
- Roof slope at least 20-25°
- Covered with single PE, UV resistant, anti-drip-coated plastic
- Double sided, continuous ridge vents/flaps; window to floor ratio at least 40 %; vents fully fitted with concertina insect nets with a typical 60° fold
- External gutters to collect rain water to be transported to the rain water collection basin
- Internal gutters to collect condensation water to be transported to the rain water collection basin
- Floor: levelled with half-hard soil, ground cover dark (black) coloured non-insulating foil/textile
- Fitted with standard pipe-rail (independent of the presence of heating)

- Separation between compartments should be double-layer (to prevent thermal interference between trials)
- Double doors (insect proof) overall
- Climate and ferti-irrigation computer; over-dimensioned (due to possible extension)

Demonstration greenhouse

- total surface about 0.5 ha
- 3 compartments
- fitted for high-wire growing
- 2.5 compartments fitted for closed-loop substrate growing
- 0.5 compartment left for in-soil planting
- Each compartment split into two fertigation units
- Substrate gutters hanging or on supports, with recollection of drain
- 2 compartments fitted with energy screen, 80% aluminium and rest open
- 1 compartment fitted with horizontal/vertical ventilation fans with an airflow of at least 10 $m^3/(m^2 \cdot h)$

Facilities compartment and facilities

- placed at the north of the greenhouse complex
- covered with solar panels
- computer room
- climate and irrigation computer to fully control climate actuators, heating and fertigation, which has spare capacity for additional compartments and fertigation units.
- water storage tanks, fertiliser storage and fertigation mixing and distribution centre, water and drain steriliser
- storage for crop protection chemicals in compliance with European norms
- personnel facilities (toilets/ changing room)
- hot water storage
- yield storage room with loading door to the outside
- roof-washing machine
- at least three mobile working platforms/lifts
- rainwater collection basin, covered with solar panels, connected to gutters (in) and to tanks (out); small pump to pump from basin to tanks

Research greenhouse

- total surface about 0.25 ha
- 6 compartments, each split into two fertigation units, all with substrate and re-collection of drain water
- all compartments outfitted with energy screens
- 3 compartments fitted for high-wire growing
- 3 fitted with substrate tables
- At least one 1 compartment fitted with artificial LED lighting system capable of providing 150 μmol/(m2·s)
- At least one 1 compartment fitted with carbon dioxide feeding system
- At least 1 compartment fitted for a hot-water heating power of 40-50 Wm^{-2}, fed with (stored) hot water from the solar panels

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Appendix 1 The adaptive greenhouse method

Background

Wageningen Plant Research has developed a method ('the adaptive greenhouse') to determine the effect of technology installed in a greenhouse (and its application) on inner climate and, ultimately, on crop production. The method is based on:

- technical models describing the relation of external climate with expected internal greenhouse climate, assuming a given location and/or assuming different greenhouse constructions with defined climate control strategies. We make use of good validated dynamic greenhouse climate models simulating year-round performance as well as specific models for critical days during the year (De Zwart, 1996)
- crop models describing the expected crop performance under a specific actual greenhouse internal climate (Vanthoor, 2011)
- economic models describing the costs for input factors (water, energy, plant material etc.) and necessary investments (greenhouse construction, water system etc.) against expected benefits due to crop yield and quality.

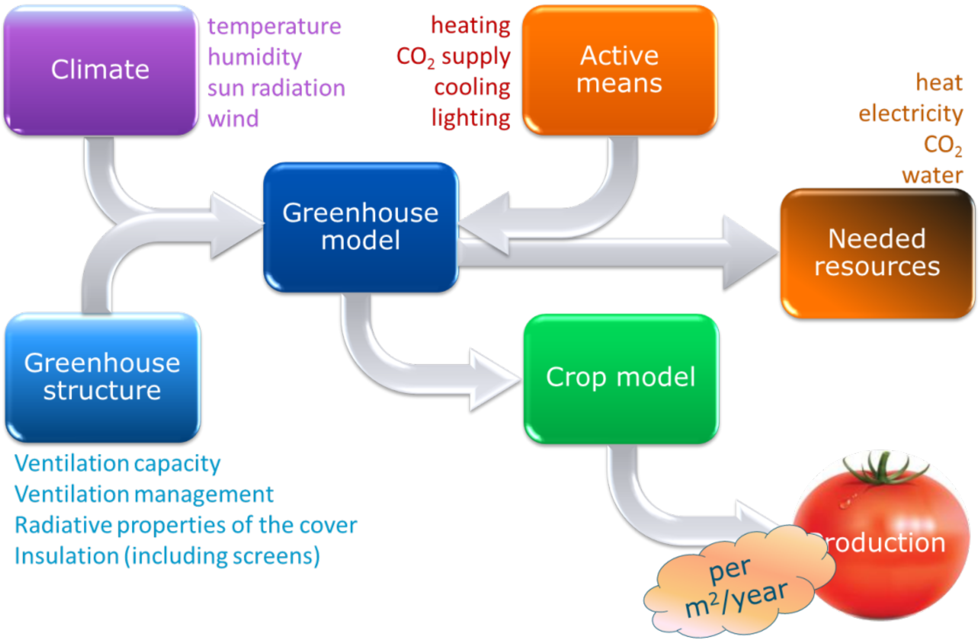

Figure A1. *Schematic depiction of the adaptive greenhouse method. By modulating the parameters that describe the greenhouse structure, it is possible to find the 'best possible' passive greenhouse, in given climate conditions. Thereafter one evaluates the increase in yield that can be attained by active means for climate management. Besides yield, the model delivers the yearly pattern of resource requirement.*

The method has been successfully applied in projects around the world. Indeed, the method has resulted in very different plans for application of technology in places such as Spain, Malaysia, Italy, the Middle East, Turkey, Chile and others. Such a method, applied to local conditions of Agadir can identify the technologies that may be worthwhile to demonstrate and apply.

Description of the work

1. Collect local yield data and corresponding climate information. Generate a realistic climate pattern for Agadir (at least one yearly, hourly values), integrating local data with information available from nearby airport stations.
2. Validate the model by comparing (for the real greenhouse) calculated and collected data of climate (Figure A2) and yield (Figure A3)

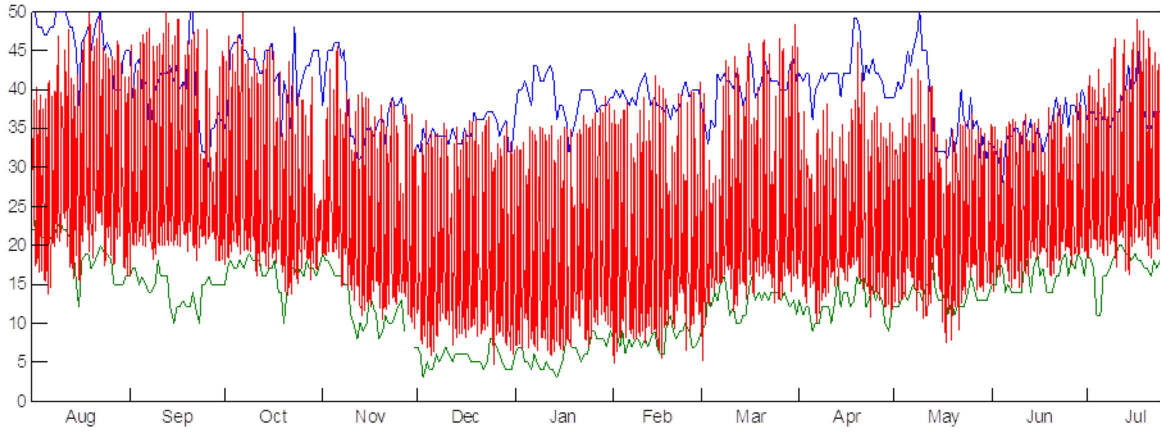

Figure A2. *Simulated hourly mean greenhouse temperatures (red) and minimum and maximum greenhouse temperatures (green and blue) as provided by the local grower.*

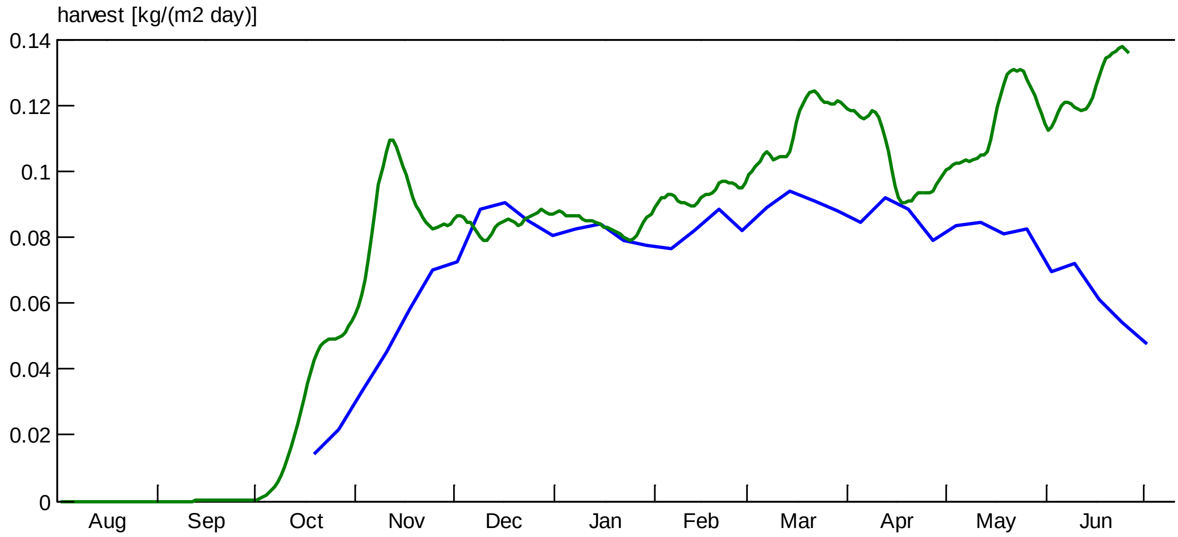

Figure A3. *Simulated greenhouse tomato production (green) and actual tomato production (blue) as provided by as provided by the local grower. He probably pinched the first truss in order to increase winter yield, whereas pathologies may have developed towards the end of the crop. The green line has become the baseline of the following calculations*

3. Calculate the effect of 'passive' improvements of the greenhouse (for instance, Figure A4). This is done by starting with the most effective improvement and adding stepwise all the others.

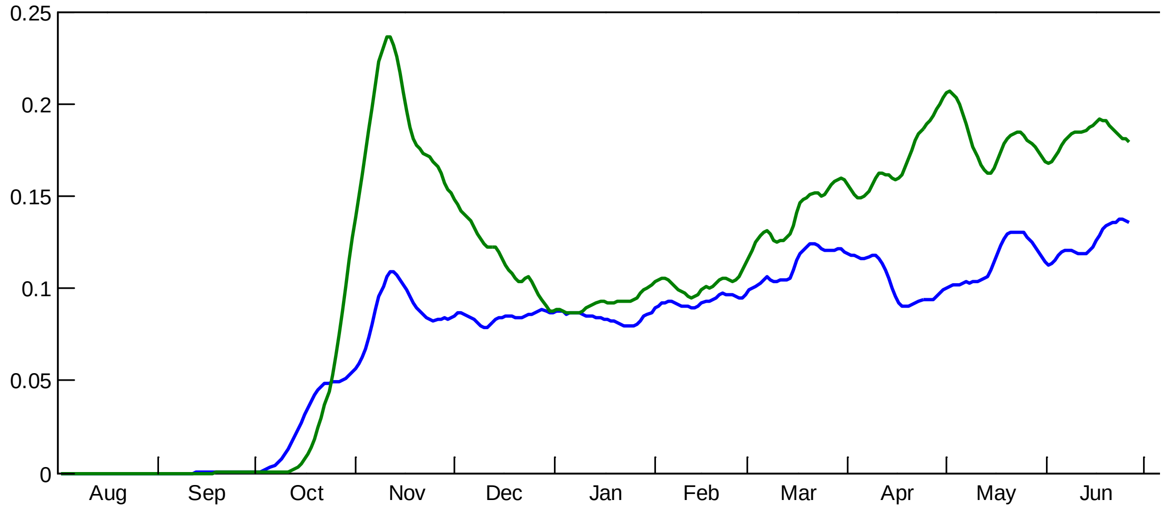

Figure A4. *Simulated greenhouse tomato production in the poorly ventilated greenhouse (blue, the baseline: it was green in Figure A3) and in the regulated ventilation greenhouse (green). Total yields are, respectively 23.8 and 34.2 kg/m*^{2}

4. Calculate similarly the effect of 'active' management means, and the corresponding resource requirement (for instance, Figure A5), starting from the 'best possible' passive greenhouse (the new baseline).

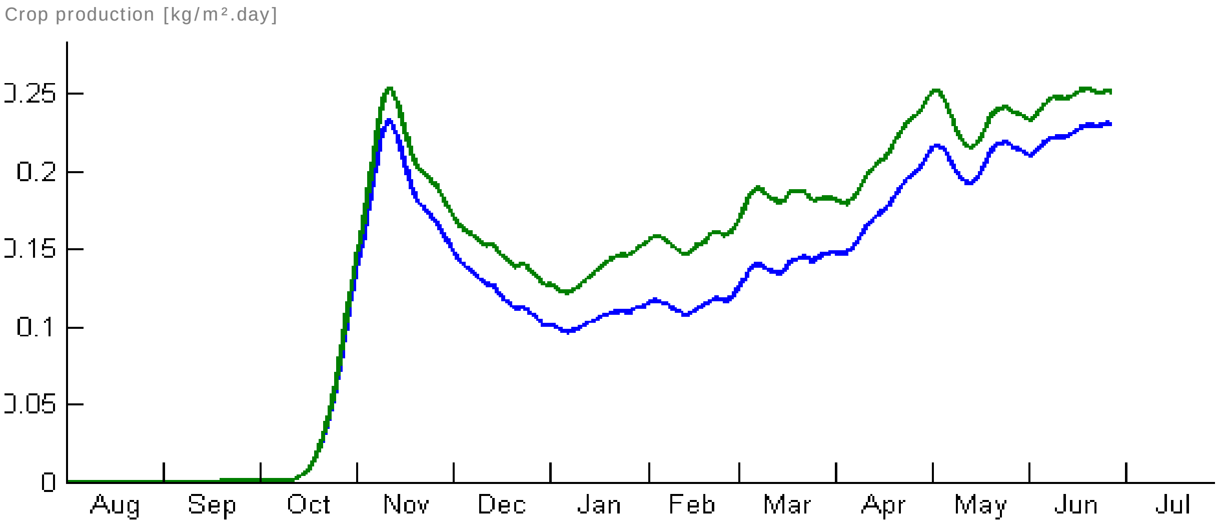

Figure A5. *Simulated greenhouse tomato production in a greenhouse with carbon dioxide supply in addition to good ventilation and energy screen (green) , with respect to the same greenhouse without carbon dioxide. Cumulative yields are respectively: 44.2 and 37.1 kg/m*^{2}

Scientific and education programme of the Centre of Excellence in Horticulture of Agadir

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1 Wageningen Plant Research

2 Wageningen Economic Research

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Wageningen University & Research
Wageningen, March 2017

MEMORANDUM
2017-041

Contents

1 Introduction

The Complex Horticole d'Agadir (CHA) wants (and needs) to be an important agent in the transition of the Moroccan greenhouse horticulture towards a business model that couples increased rural income (higher productivity and value of product) and climate robustness to a reduced environmental impact (higher water use efficiency and less emissions).

In particular, the objective of the Centre of Excellence in Horticulture (CEH) is to contribute to 1) increasing productivity and 2) to developing sustainable production systems, by a combination of research, education and outreach. The challenge is how greenhouse production can be an instrument to improve tomato yield from 14 kg/m^2 to 30 kg/m^2 in a sustainable way. In a workshop held at Agadir on 3 November 2016 with staff of CHA and WUR, the following priorities (transition paths) were identified:

- Water and ferti-irrigation management, with the goal of saving water and decreasing leaching
- Climate management particularly to increase productivity and robustness to climate change
- Crop protection (integrated pest management) with the goal of residue-free product and reduced pollution
- Crop management, with the goal of improving quality and productivity.

The transformation will entail innovation in all relevant aspects (transition paths) through the synergistic actions of research, demonstration/outreach and education, as shown in Fig. 1. Strong emphasis is being laid on the transition to more sustainable production systems and products. This means that sustainability (triple P) in all forms will be incorporated in the programme.

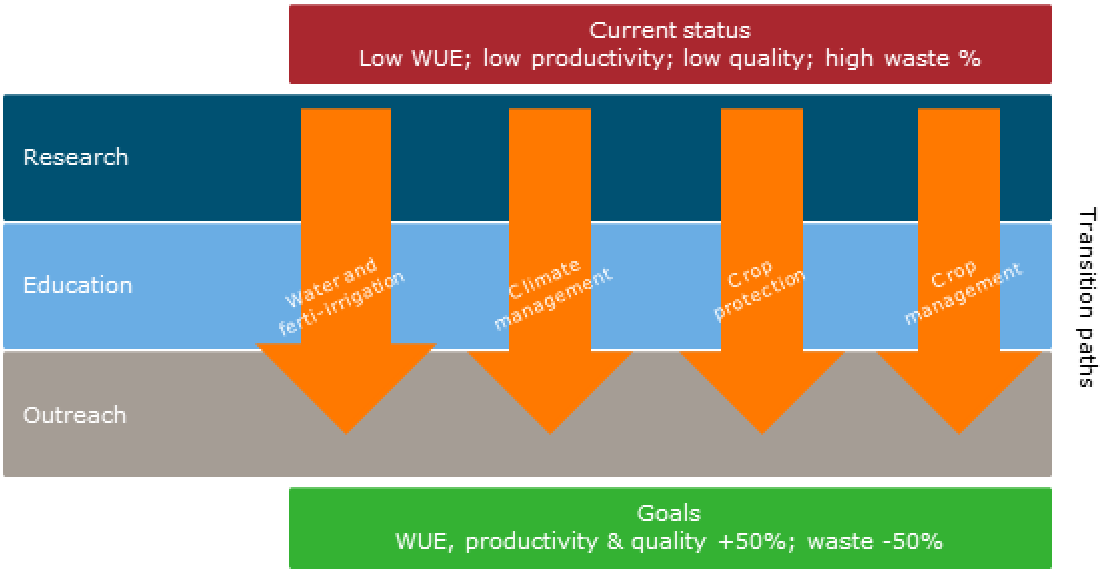


Figure 1. *Schematic representation of the transition process of Moroccan horticultural production, showing both the paths along which transformation takes hold and the topic involved and the means involved.*

The above-mentioned workshop focused on research and dealt little with the education programme. It was agreed that the main means for implementation of the research agenda would be the identification of topics suitable for student theses (BSc, MSc and PhD) and joint (CHA and WUR) involvement in the planning and supervision.
As means for implementation of the education agenda were mentioned:

1. Short courses on the 4 themes/transition paths [and/or seminars on relevant topics within a theme] from WUR staff to CHA staff and/or advanced students

2. Enrichment/modification of the course offer of CHA, with courses (or course elements) providing suitable knowledge (at each level) to enable understanding and implementation of the transition paths.

In the previous document 'Conceptual design of a demonstration and research greenhouse in the region of Agadir, Morocco' (Stanghellini et al., 2016), we have described the facilities that would be necessary for research and (at least partly) demonstration.
In this document we deal with the activities needed to ensure the role of research and education in the transition. In particular, the objectives of this report are:

- To provide an integrated framework for research themes, to be implemented through thesis topics that will advance knowledge about the processes leading to the sustainable and competitive growth of local greenhouse horticulture
- To outline the process that should lead to the identification of possible 'white spots' in the current course offer of CHA (in view of the transition goals of local greenhouse horticulture) and to implementation of required changes/additions, that might rely (at least at the beginning) on seminar-teachers from Wageningen.

CHA's view on this document is necessary before any further steps can be taken.

2 Research programme and thesis topics

2.1 Introduction

One of the objectives of the WUR contribution to the Centre of Excellence is to develop a research programme in cooperation with CHA (and other stakeholders) and to define the WUR interventions in the execution of the research programme. The research programme is thereby linked to the demonstration and research greenhouse, where the research will be conducted. The demonstration and research greenhouse has been designed by WUR and discussed with CHA and different stakeholders and will be realised by a consortium of suppliers. The goal of the research programme will be to investigate the application of innovative techniques and management methods for protected horticulture, with the primary focus on reduction of water use and environmental impact and increase of productivity and food quality. Research and demonstration topics will be:

- Water and ferti-irrigation management: to save water and nutrients and improve input efficiency
- Climate management: to optimise greenhouse climate to improve productivity and product quality
- Crop protection: to reduce application of chemicals and stimulate biological control (IPM)
- Crop management: to improve productivity and product quality.

The research themes will be implemented through the selection of thesis topic, on the three level of education provided by CHA, that is: traineeship reports, MSc and PhD thesis. The long term objectives of the research will be:

- To analyse both directly applicable technologies for growers as well as advanced technologies and management methods
- To support education at CHA, particularly in the form of programmes and topics suitable for thesis on all levels
- To be a knowledge (services) and training centre for growers
- Research results can be published in scientific journals

For each one of the transition paths it is necessary to produce a multi-year framework agenda, both for the demonstration and the research compartments, based on 'where we are' and 'where we want to be in a few years'. Then, each year, specific research and demonstration topics will be selected, taking into account the available facilities, and the need to provide small individual/group programmes, for students doing their internship or thesis work.

Here below we outline initial thesis topics that were selected in cooperation with CHA staff. We have identified topics for each one of the transition paths, for all three levels. We have further identified the topics suitable for a fast application in practice ('demonstration') and the ones whose implementation in practice will be possible on a longer term ('research'). Most traineeship reports will entail 'demonstration', whereas PhD thesis will usually have a longer term potential application. Nevertheless, we have tried to identify a few PhD topics that may yield useful results also in the short term.

The list is the result of first joint (3-11-2016) and then separate 'brainstormings' of CHA and WUR experts and can be modified and enlarged anytime when new insights are generated.

2.2 Irrigation strategies and soilless cultures

Irrigation water for the whole region comes from reservoirs and wells at increasing depth. There is a need to reduce water use, drastically and fast. This means reduced leaching, which has the additional advantage of reducing pollution caused by leaching of fertilisers.

In the long term, the application of closed-loop irrigation (easiest on soilless culture) will become necessary. Besides the accompanying management, automation and disinfection issues, water quality may become the limiting factor. An additional factor in reducing water use may be the introduction of new crop/and varieties requiring less irrigation.

In the shorter term, 'smart' irrigation may reduce water use and emissions. We believe that increasing grower awareness of water use and its consequences will contribute to an overall reduction of water application.

2.3 Climate management

In order to secure (and increase) rural income, there is the need to increase productivity, quality of produce and robustness to weather and to climate change.

As most income is generated by the winter production for export, the short-term goal is to evaluate and demonstrate affordable improvements to the winter climate (energy screens and ventilation management).

The longer-term goal is to evaluate new crops and effect on productivity and quality of more complex climate management means (carbon dioxide supply, heating and artificial light), to enable an economic and environmental evaluation.

Table 1 *Initial thesis topics on the field of irrigation strategies and soilless cultures for the different education levels at CHA*

Irrigation strategies and soilless cultures	Traineeship	MSc	PhD
Demonstration	• Quantify water use (and water saving) in closed system • Quantify nutrient use and nutrient saving in closed systems • Application of root-zone sampling	• Irrigation scheduling and drain properties • Substrate properties and basic irrigation scheduling (in combination with APEFEL)	• Emissions and environmental evaluation
Research	• Irrigation scheduling • Monitoring emissions	• Management of closed systems (Quality of water and water use) • Growing systems for new crops • Irrigation recipes for new crops	• Effect of two mineral nutrition programmes on soilless tomato grown under controlled climate conditions in the greenhouse • Closed systems and bottlenecks to implementation: salinity, water use vs yield and quality

Table 2 *Initial thesis topics on the field of climate management for the different education levels at CHA*

Climate management	Traineeship	MSc	PhD
Demonstration	• Controlled ventilation • Energy screen and night-time temperature • Air circulation and leaf temperature • Roof cleaning	• Energy screen and winter production • Temperature with and without controlled ventilation (in combination with APEFEL)	• Comparative effect of natural ventilation and shade materials on tomato growth and production under greenhouse
Research	• Set-points of ventilation • Air circulation management	• Energy screen and heating • Humidity management with screen and air circulation • New crops	• Combined effect of CO_2 and artificial light on tomato production during the winter period • Effects of temperature, light intensity and some agronomic factors on bumblebees activity and tomato production under greenhouse conditions

2.4 Crop protection

Relevant issues to guarantee farmer income and more sustainable production are: decreasing the incidence of residues, increase resistance to (new) pests, introduction of biological control and prevent emission of chemicals.

Short-term goals are the reduction of application of chemicals and limited introduction of biological crop protection (IPM). On the longer term, widespread application of biological control, introducing several natural antagonists and stimulating by natural means the resilience of the greenhouse environment will become necessary. The table with topics is on the following page.

Table 3 *Initial thesis topics on the field of crop protection for the different education levels at CHA*

Crop protection	Traineeship	MSc	PhD
Demonstration	• Scouting-based application of chemicals	• Blue-print application vs scouting	• Advanced blueprint IPM (multiple species per pest) • Banker Systems
Research	• IPM application (single BCA per pest/disease)	• Blueprint IPM (interaction multiple species/synergy)	• Use of beneficial fungi and microbial consortia to enhance the defence barriers of tomato plants against biotic (pests and pathogens) and abiotic (reduced water) stress agents under greenhouse conditions • Potential use of aromatic and medicinal plants extracts in tomato IPM strategies and their effect on controlling moth borer (Tuta absoluta) and whiteflies (Bemisia tabaci) in the greenhouse • Effects of reduced irrigation and mineral nutrition inputs on pests (T. absoluta and B. tabaci) and their natural enemies (predators and parasitoids) on soilless tomato cultivation under greenhouse

2.5 Crop management

Much stands to be gained from a knowledgeable crop management, both in terms of productivity and quality.

The short-term goal is to make growers aware of the value of proven management techniques and methods.

The long-term goal is to develop crop management techniques that are best suited to the particular local conditions and, possibly, to new crops.

Table 4 *Initial thesis topics on the field of crop management for the different education levels at CHA*

Irrigation strategies and soilless cultures	Traineeship	MSc	PhD
Demonstration	• Truss pruning	• Effect of plant density on production of winter crops	• Evaluation of different substrates media on soilless tomato growth and production
Research	• Crop monitoring	• Leaf picking and humidity management • Management of new crops	• Source/sink balance: management of temperature • Improving light use efficiency of winter crops

3 Procedures

In general the experimental part of a thesis project will take 3 months for a trainee, 6 months for a MSc student and one year for a PhD student. This means that there will be a need some time to evaluate conflicting claims and allocate space in the most efficient way possible, also evaluating whether different thesis projects could be combined in the same compartment(s). For this reason we propose that there is a scientific committee that overviews and organises the implementation of the research programme.

It is suggested to include a representative of WUR as agenda member of the scientific committee. Logically this will be a senior expert of Wageningen Plant Research, because of the selected priority topics. The WUR representative will support the scientific committee in setting the selection criteria and in selecting the research or thesis subjects. Moreover the WUR representative will coordinate in searching the most suitable WUR expert for the selected thesis subjects.

3.1 Definition of year activity programme

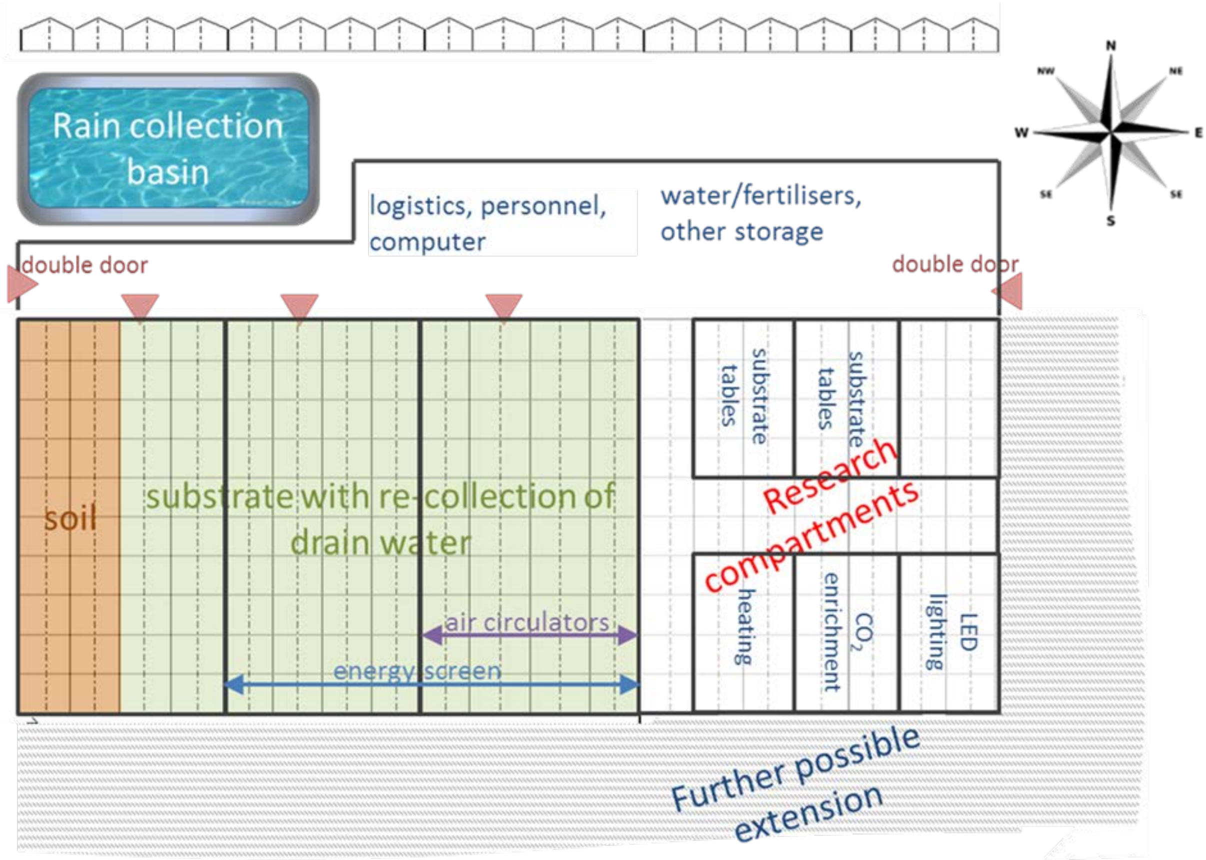
At the beginning of each year, main activity topics are selected (steering committee) in view of the framework agenda and a 'call for research & demonstration projects/thesis proposals' is issued to the staff and students. The proposals must follow an agreed format, outlining:

1. Goal and expected outcome
2. Experimental set-up or set-up desk-study
3. Execution protocol and check-points
4. Method applied for analysis of results
5. Means for publication of results

A prioritisation is made on the basis of the eligibility (does the proposal fit in the agenda); quality of the proposal and available facilities. The same committee should also be in charge of checking compliance to the plan.

3.2 Preliminary planning of research topics and subjects

In this text we assume that facilities will be available as shown below.



The number of compartments and their design determine the possibilities to perform different thesis subjects. It is recommended (and it was agreed in the workshop of 2-3 November 2016) that a number of traineeship will be done at the beginning, to check proper functioning and to train greenhouse personnel. The experimental part of MSc and PhD thesis (that rely on proper functioning) should be delayed until at least six month after completion of the greenhouse facility.

When the final number of compartments and their equipment will be known, and after final agreement on the initial thesis topics as outlined above, it will be possible to make a planning for allocation of the space (to research topics) for the next (for instance) five years, taking into account that lower-level thesis can contribute elements for the higher level thesis.

The head of the greenhouse facility will be charged with the task of implementing the crop plan as results from the research agenda agreed each year.

4 Education programme

Whereas the workshop of 2-3 November 2016 did outline very clearly the expected contribution of WUR to the research agenda of CHA, the expected contribution to the education programme remained undefined. Therefore in the following sections we outline a process that could identify any refreshment/enlargement of curricula that may be needed, and the role of WUR in this process. The implementation path will have to be carried out by CHA staff and it is up to CHA to figure out the extent of WUR participation in it.

To ensure a lasting impact on the local greenhouse horticulture, education will have to take place at three levels: greenhouse owner and/or head operation manager; senior technicians (greenhouse climate; ferti-irrigation; crop management and crop protection) and [skilled] labour.

4.1 Skill/competence profiles and identification of gaps

We propose that a multi-day workshop of relevant CHA staff and WUR experts define the skill/competence profiles after graduation from each level, and makes a consistent selection of course elements (topics) and corresponding learning objectives of each one. That must be compared with the existing offer of courses at CHA in order to identify gaps that need to be filled, possibly by new courses and/or by adaptations/extensions of existing courses.
Small [knowledge] gaps that can be filled by ad hoc seminars and/or trainings by WUR personnel (train the trainers) will be identified as well, and a planning and corresponding budget evaluation will be made.
Therefore the programme for the workshop, which should last at least three days, should be:

- Day 1. Morning: Skill and competence profiles for each level
- Day 1. Afternoon: Identification of required topics and learning objectives
- Day 2. Analysis of existing course offer at CHA and identification of gaps
- Day 3. Morning: Identification of necessary adaptations in existing courses
- Day 3. Afternoon: Identification of required ad hoc trainings and/or seminars.

Within the lifetime and budget of this project (ends 30 June 2018) it is to be expected that up to a couple of courses and/or training/seminars can be adapted and/or set up.

5 Participation of Wageningen University & Research

In this section a general overview is given of the supporting activities, planned capacity and estimated budget to make possible that experts of WUR participate to the activities outlined above and supervise different type of students in their thesis (Trainee, MSc or PhD). At all times this will be in close cooperation with CHA. Effort will be done to select if possible WUR experts who master the French language. The main contribution of WUR experts will be in:

- Participating in the scientific committee
- Discussing and shaping the research plan of each thesis: goal, expected outcome and experimental setup;
- Discussing execution, milestones and preliminary results;
- Discussing draft research report
- Evaluation of final report and of competences attained (if required)
- Participation in the initial workshop to define education agenda
- Ad hoc trainings and seminars
- Advice on modification of the educational offer

A final planning of the activities of WUR within the lifetime of this project will be made in consultation with CHA and can be only made after the workshop.

5.1 Traineeship

For a traineeship the contribution of WUR experts will be a limited number (about 3) of contacts with the student and his/her mentor of CHA. No evaluation of the students competences is foreseen. The discussions with the trainee will be conducted by Skype or other media. No visit to CHA (Morocco) is planned, unless combined with other visits.

Estimated capacity per thesis subject: 1 day within a period of 3-4 months.

Budget for supervising a trainee report is € 976.

5.2 MSc student

The participation of WUR will include more contacts and discussions with the student and his/her mentor of CHA (about 5-6 contacts). The thesis will be evaluated and an evaluation of the competences attained will be performed. The discussions with the MSc student will be conducted by skype or other media. No visit to CHA is planned, unless combined with other visits.

Estimated capacity per thesis subject: 3 days within a period of 6-7 months.

Budget for supervising a MSc student is € 2,928 per thesis.

5.3 PhD student

For PhD students the supervision of a WUR expert will be more extensive. The discussion with the PhD student will be performed both in Morocco as well as in the Netherlands (by Skype or other media). Two visits are planned to CHA to discuss the thesis subject with the student and his/her mentor from CHA. One visit will focus on the research and experimental plan, the other visit will take place during the experimental phase of the research. The thesis will be remotely evaluated.

Estimated capacity per thesis subject: 6.5 days within a period of 1-1.5 year (experimental phase) + 1 day thesis evaluation.

Budget for supervising a PhD student per thesis:

- personnel costs: € 7,320
- travel and stay: € 2,400
- total costs: € 9,720/thesis.

It is most likely that a combination of BSc, MSc and PhD students will be supervised. Moreover not all research subjects will necessarily be supervised by WUR experts.

5.4 Scientific committee

The estimated capacity required for the WUR representative is 4 days per year. This includes 1 day visit to CHA in Morocco, that ideally is combined with some supervision activity. Budget for participation in the scientific committee (2017/2018):

- personnel costs: € 3,904
- travel and stay: € 1,200
- total costs: € 5,104/year.

5.5 Participation to the initial workshop for the education agenda

We propose that at least four WUR experts (one per research theme) participate in this workshop (at CHA), which should last at least three days:

- personnel costs: € 13,664
- travel and stay: € 6,400
- total costs: € 20,064.

5.6 Training or seminars

Small knowledge gaps can be filled in by a 1 day training of seminar for CHA staff to be held at CHA.

Budget for training/seminar (including preparation):

- personnel costs: € 2,928
- travel and stay: € 1,200
- total costs: €4,128 /training/seminar.

5.7 Advice in the modification of existing educational offer

Whenever it is observed that there is a need for modification of the topics addressed by an existing course, one WUR expert can advise the relevant CHA staff about t new and relevant knowledge about a specific topic. A rough estimation is 3 days per course and supervision through skype or other media.

Budget: € 2,928/course.

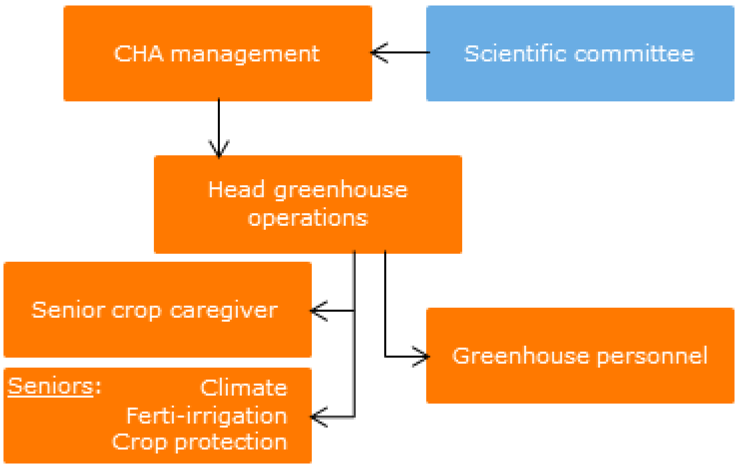
5.8 Conclusion

The final allocation of remaining budget of this project and/or budget by other sponsors will be done in agreement with CHA and local stakeholders and will be done after the workshop. Priority will be given to items that have the highest chance of achieving a fast impact with respect to the goals of the CEH. That means that, ideally, we should aim for 'demonstration' with fast implementation, coupled to high quality of (long term) research and education as an investment in the future.

6 Profiles of the greenhouse staff

The greenhouse staff facilitates the execution of the research projects by producing, managing and maintaining healthy crops as required by the scientific/experimental plan agreed each year. Not to endanger the results of the research, the prevention of diseases has the highest priority. The use of agrochemicals (when needed) must be in compliance with the strictest safety norms. The greenhouse staff facilitates also the execution of demonstration activities, and contribute to its impact, by showing and discussing the innovative technologies and methods with local stakeholders.

Climate control and management of the ferti-irrigation will be automated, the staff must select and implement the desired set-points, and operate a routine check on proper functioning of operating systems and sensors on which the automation relies. As regards the ferti-irrigation, the staff will prepare the concentrated solutions from which the system draws, and will periodically extract samples from the root zone for analysis in specialised laboratories. All norms on storage of chemicals, (fertilisers and crop protection products) must be observed, and the necessary maintenance and periodic cleaning of all greenhouses and adjoining buildings be performed, as well as the update of the programme management and the re-calibration of the sensors used.



A typical organigram is shown here. The head of greenhouse operations falls directly under the CHA management, which is advised by the Scientific committee. The head of greenhouse operation relies on senior/skilled personnel for the most advanced tasks. All of them also perform (whenever possible) standard work in the greenhouse, together with the greenhouse personnel.

A profile of the head greenhouse operations and senior crop care giver is described below.

6.1 Head greenhouse operation

The head of the greenhouse facility is the chief point of reference both of the CHA management and of the greenhouse personnel, whom he/she motivates with his/her natural charisma to give the best of themselves. It has the capacity for abstraction necessary to foresee the consequences of decisions and to identify possible improvements. For that he/she is often present in the greenhouses, has a lot of interaction with workers and periodically writes management reports. His/her final task is to ensure that the facility is optimally used for research and demonstration and is seen as an asset and an example to local growers.

The greenhouse boss agrees with the CHA management the annual plan of the facility and the corresponding budget. He/she is responsible, in particular, for the preparation, planning, performance and administration of all activities, in operation, maintenance and repairs of buildings and facilities. He/she monitors and ensures compliance with the legal and safety regulations, and the CHA policy. He/she is also ultimately responsible for the production, the climate, the culture and fertigation and performs, whenever necessary, technical tasks and management of the crop in the greenhouse. For this reason he/she has a very good knowledge of the techniques that are used in protected crops, such as climate control systems, ferti-irrigation systems, data acquisition systems and measuring sensors. He/she reports to CHA management.

He/she should have in-depth knowledge of planning growing horticultural crops in greenhouses, management and technical concepts of farming, paired with an understanding of the needs of the (internal) customers in Research. Ideally he/she has been involved and experience in planning within a large horticultural farm, a research farm or in food production & processing business. In addition he/she must be able (and feel confident) to challenge the status quo and drive continuous improvement and operational excellence.

Tasks and responsibilities:

- Plan the year around R&D projects in greenhouses, and ensures their implementation
- Instructs the (senior) crop caregivers and monitors and promotes the progress of activities.
- Replaces where necessary the senior crop caregivers
- Assesses the results and makes suggestions for improving the work process.
- Will set priorities.
- Shall intervene in/eliminate of occurring imperfections and problems.
- Will take measures to prevent problems or to improve work processes.
- Provides detailed proposals for improvement of work processes on the (medium) long term.
- Contributes to technical standards and expertise development.
- Conducts guard and consignment (weekend) services.
- Consults with and instruct suppliers in construction and maintenance of installations.

Requirements:

- Completed secondary degree with additional training courses and work experience in the area of cultivation techniques.
- Good knowledge and understanding of the practical implementation of the (test site) research, the research methods and common practice in agriculture and horticulture;
- Has a network in the greenhouse sector;
- Has experience in managing a team and coordinating the work;
- Has experience with professionally coaching of colleagues;
- Very good knowledge of the law and regulations applicable to agricultural and horticultural farms and the safety requirements for the implementation of the various activities;
- Has extensive experience in efficient planning, organising and coordinating of complex technical issues.

Minimal skills and competences:

- Irrigation and plant nutrition
- Climate control
- Crop growth and development
- Crop protection and Integrated pest management.
- Senior crop caregiver

Tasks and responsibilities:

- Is responsible for taking care of plants and the design and execution of various cultivation operations, according to research protocols and fitting within legislation, regulations and internal guidelines.
- Cultivation care of the crop in the greenhouses

- Preparation of the greenhouse facilities
- Implementation of seeding, propagating, growing and harvesting operations;
- Preparation and application of nutrient solutions;
- Control of optimal cultivation and storage conditions such as fertilising, watering, climate settings;
- Scouting crops and applying if necessary chemical and/or biological control to against pests and diseases.
- Carrying out routine observations of plants commissioned and in consultation with the scientist/student
- Composing an implementation plan for the activities requested by the scientist/student and give advice to them
- Interpretation of simple results from experiments.
- Coaching of interns
- Maintenance of assigned facilities such as equipment, greenhouses and other areas.
- Participation in advisory group research.

Requirements:

- Completed vocational education level, with relevant work experience and additional training in the area of cultivation techniques;
- Extensive knowledge and understanding of the practical implementation of research and the research methods in the field;
- Experience in coordinating, planning and organisation of activities;
- Extensive experience with modern operating computer systems;
- Extensive experience in the efficient planning, organising and coordinating of complex technical matters;
- Experience in management of college employees;
- Extensive knowledge of safety regulations.

Minimal skills and competences:

- Basic operational knowledge and experience with regards to the following fields:
- Climate control and energy
- Water management and plant nutrition
- Integrated pest management
- Cultivation of crops
- The other senior specialists are similarly responsible for the proper functioning of the greenhouse facility, each one with respect to its assigned task (climate control; ferti-irrigation; crop protection).

6.2 Senior crop caregiver

Tasks and responsibilities:

- Is responsible for taking care of plants and the design and execution of various cultivation operations, according to research protocols and fitting within legislation, regulations and internal guidelines.
- Cultivation care of the crop in the greenhouses
    - Preparation of the greenhouse facilities
    - Implementation of seeding, propagating, growing and harvesting operations;
    - Preparation and application of nutrient solutions;
    - Control of optimal cultivation and storage conditions such as fertilising, watering, climate settings;
    - Scouting crops and applying if necessary chemical and/or biological control to against pests and diseases.
- Carrying out routine observations of plants commissioned and in consultation with the scientist/student

- Composing an implementation plan for the activities requested by the scientist/student and give advice to them
- Interpretation of simple results from experiments.
- Coaching of interns
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Wageningen Economic Research
MEMORANDUM
2017-041

The mission of Wageningen University and Research is “To explore the potential of nature to improve the quality of life”. Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 5,000 employees and 10,000 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

To explore the potential of nature to improve the quality of life

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