Protected Horticulture in Egypt

A study on the technology of protected cultivation in Egypt

Anne Elings and Esteban Baeza

Report WPR-704

WAGENINGEN
UNIVERSITY & RESEARCH

Netherlands Enterprise Agency

Referaat
De landbouwsector en de bedekte teelt van groenten en fruit onder zijn in Egypte van groot belang voor onder meer de voedselzekerheid, de exportpositie en werkgelegenheid. De Egyptische overheid heeft recent de ontwikkeling van een groot areaal aan kassen (40.000 ha) aangekondigd en heeft hiervoor Nederlandse ondersteuning gevraagd. Dat heeft onder meer in deze studie van WUR Glastuinbouw naar de technologie van bedekte teelt in Egypte geresulteerd. Dit verslag levert een analyse van aandachtspunten voor de bedekte teelt in Egypte, geeft een overzicht van betrokkenen ('stakeholders') en eindigt met een Terms of Reference voor een vervolgactiviteit inclusief actieplan, deliverables en geschat budget.

Abstract
The agricultural sector and greenhouse production of fresh fruits and vegetables in Egypt are important for, amongst others, food security, export position, and employment. The Egyptian Government recently announced the development of a large acreage, 40,000 ha, of protected horticulture and has requested Dutch support this development. This has resulted, amongst others, in this study by WUR Greenhouse Horticulture on the technology of protected cultivation in Egypt. The report presents a gap analysis on technological issues related to greenhouse horticulture in Egypt, gives an overview of stakeholders involved and ends with a Terms of Reference for a follow-up activity, including action plan and deliverables and a budget estimate.

Reportinfo

Report WPR-704
Projectnumber: 3742239400
DOI number: 10.18174/425533

Disclaimer

Address

Wageningen University & Research, BU Greenhouse Horticulture
Violierenweg 1, 2665 MV Bleiswijk
P.O. Box 20, 2665 ZG Bleiswijk
The Netherlands
+31 (0) 317 - 48 56 06
+31 (0) 10 - 522 51 93
glastuinbouw@wur.nl
www.glastuinbouwur.nl/glastuinbouw

Table of contents

Summary

The agricultural sector and greenhouse production of fresh fruits and vegetables in Egypt are important for, amongst others, food security, export position, and employment. The Egyptian Government recently announced the development of a large acreage, 40,000 ha (100,000 feddan), of protected horticulture. The Egyptian Government has requested, through the Dutch Ambassador and the Agricultural Counsellor, Dutch support this development. This has resulted, amongst others, in this Dutch RVO funded study on the technology of protected cultivation in Egypt conducted by WUR Greenhouse Horticulture.

A gap analysis results in the following main observations and recommendations:
- Low technology greenhouses are used by small-scale farmers that serve the local market, whereas medium technology greenhouses are used by large-scale farmers that serve the urban and export markets.
- Medium-tech greenhouses in Egypt have a metal construction and a plastic cover. This fits with the needs of the country. The quality of the plastic and nets that cover the ventilation openings should be of good quality.
- Management of the high day-time temperatures is very important. Especially in summer, it may be economically best to cease cultivation. Management of low night-time temperatures in winter should be considered to ensure a continuous crop growth and development between autumn and spring.
- It is strongly recommended to install a weather boxes outside and inside the greenhouse.
- Shade screens are widely used in Egypt to reduce the radiation intensity in the greenhouse.
- Electricity is required to operate pumps, computers, etc. As the grid is not always reliable, a generator is an absolute necessity.
- The use of solar (and wind, if present) energy could be utilized much more.
- Water is the major limited resource in Egypt. Nile water is of low quality and without cleaning not suitable for greenhouse production systems. Bore hole water is of variable quality, and also limited in availability.
- Desalination of sea water (e.g. the Mediterranean) with solar-generated electrical power should be seriously considered if the Land Reclamation sites are in the vicinity of the seas.
- Cultivation is currently mostly in the soil, as it is less risky in terms of irrigation strategy. However, it also requires more water than cultivation in substrate (pots, slabs, troughs).
- Medium-tech greenhouses in Egypt have a computerized system that requires un-interrupted power supply and that results in the optimum availability of water and nutrients to the crop.
- The limited supply of domestically produced predators and the ban on import of predators seriously hamper the biological crop protection in Egypt. This results in high chemical residue levels and problems for the export industry.

A Terms of Reference for a follow-up activity is formulated, including action plan and deliverables and a budget estimate.

1 Introduction

1.1 Background of the study

The agricultural sector is of crucial importance to the food security in Egypt. The Egyptian agricultural and horticultural sectors contribute approximately 15% to the gross national product and approximately 40% to the employment. Horticulture and agro-logistics in the Nile delta and valley (Lower and Upper Egypt, respectively) are important pillars for the economy and economic growth. Large amounts of high-value products are exported to Europe while Egypt itself imports about 60% of its food. With about 50% of the total agricultural production being lost after harvest, and an expected population growth from 50 to 150 million inhabitants during the coming 20 years, food security is an Egyptian top priority. Food security will be under pressure over the next decades with current production capacities, and water availability will be an increasing problem for agriculture. Efficient use of water is therefore a second top priority of the Egyptian Government and is closely linked with food security.

The Netherlands has a good relation for agriculture with Egypt and the two countries are collaborating closely in development of the agricultural sector. The Egyptian Government recently announced the development of a large acreage, 40,000 ha (100,000 feddan), of protected horticulture. The Egyptian Government has requested, through the Dutch Ambassador and the Agricultural Counsellor, Dutch support this development. 'This has resulted in this Dutch RVO funded study on the technology of protected cultivation in Egypte under number MAT16EG04.' This report is the result of that.

The development of protected cultivation can contribute enormously to the policy priorities to maintain food security at least at the current level, and to utilize scarce water resources in a more sustainable manner.

The Egyptian Countryside Development Company (SAE) has contracted the Association of Netherlands Agro, Food & Technology Center Africa (NAFTC Africa) to 'design a general approach/methodology for the development of 10 rural clusters and the first implementation for the appointed area Mogra', for which NAFTC shall cooperate closely with WUR. This report can be read alongside the outputs of that agreement.

1.2 Status of greenhouse horticulture in Egypt

Greenhouse production of fresh fruits and vegetables in Egypt is important. Some of the advantages are: increased production levels, better quality, less use of scarce resources (e.g., water and nutrients), longer production periods and better timing of production. Large-scale greenhouse horticulture is concentrated along the river Nile, for instance along the Cairo-Alexandria Desert Highway. Also Upper Egypt knows areas with protected horticulture. It is difficult to obtain good estimates of the acreages of protected horticulture in Egypt. Pardosi *et al.* (2004) report the following acreages: 1350 ha of greenhouses and large plastic tunnels, 50,000 hectares of low tunnels and 10 ha of soilless culture. Van der Lans *et al.* (2011) report 30 ha of organic greenhouse horticulture. As most of these data are old and may be incomplete, it is best to consider them indicative.

The larger picture is that Egypt faces a shift from food surplus to food shortage up to 2025 (Siderius *et al.* 2016) without appropriate intervention[1]. Increase in production can be achieved through increase of production area or through increase of production per unit area, or both. Increase of the area with greenhouses would serve both. Another element in the discussion is the desire to earn foreign exchange and to employ young professionals. Greenhouse horticulture does offer employment possibilities, in the production phase itself and in the pre- and post-harvest supply chains.

Some of the major obstacles for advancement of the greenhouse sector are:

a. Limited water resources, and sometimes limited quality. Nour *et al.* (2015) mentions that brackish groundwater resources of salinities in the range of 2,000 – 10,000 ppm are widely available in the western desert and Sinai from a number of aquifers. High levels of solar radiation could be utilized for desalination.
b. Excessive use of pesticides. Minimum residue levels are regularly exceeded, which makes export impossible and poses health risks to workers and consumers.
c. Low availability of qualified greenhouse managers.
d. Eduction, research and extension that can not keep up with international developments.
e. Sub-optimal logistics.

1.3 Expected results

The expected result is to briefly report on:

1. Identification of stakeholders for knowledge, production of material, cultivation, etc.
2. A GAP analysis of the current and desired level of knowledge with regards to protected cultivation, technology, operation etc.
3. A draft of the development possibilities and options that are necessary for up-scaling to the desired acreage of protected cultivation.
4. An action plan, deliverables and budget for a feasibility study with focus on technology for protected cultivation.
5. A terms of reference (ToR) for the feasibility study with focus on technology for protected cultivation

Activities are coordinated with the study on the agro-logistics related to protected horticulture in Egypt. (MAT16EG06).

2 Stakeholders

The major stakeholders involved with protected horticulture in Egypt are firstly the growers or owners themselves. To this group belong as well greenhouse managers, crop specialists, workers and others of the greenhouse staff. Growers / owners can be either large export-oriented entrepreneurs or small to medium-scale horticulturalists (SME's). Growers / owners are organized in associations such as the Horticultural Export Improvement Association (HEIA) and the Agricultural Export Council.

Figure 2.1 *Major stakeholders involved with protected horticulture in Egypt.*

The second group of stakeholders is formed by the greenhouse constructors and the supply industry. Greenhouse constructors are often foreign, ranging from Dutch and other European countries (Spanish, Italian, French) to Indian and Chinese constructors. The Arab Organization for Industrialization (AOI) is intended to supply Egypt-made greenhouses. The greenhouse designs and quality they offer vary. The supply industry comprises breeding companies (e.g., RijkZwaan from The Netherlands), nutrient suppliers, suppliers of local biological crop protection means (e.g., BioEgypt), and any other material that is needed for operating a greenhouse.

The post-harvest value chain comprises carriers, logistic service providers, warehouse / cold store facility owners, industry associations / research / extension / NGO's, government and shippers. Middlemen play an important role in national value chains, including a role as finance suppliers.

The Agricultural Research Institute (ARI) and the Horticultural Research Institute (HRI) are the relevant national research organizations. Education is supplied by the University of Cairo and the American University of Cairo (which also has an affiliated training centre). The extension service falls under the authority of the Ministry of Agriculture and Land Reclamation.

The Ministries of Agriculture and Land Reclamation, Water Resources and Irrigation, and Finance, and the National Parliament are from the side of the Government the most relevant entities. In this groups also falls the Egyptian Countryside Development Company (SAE) (see paragraph 1.1).

3 Gap analysis

A gap analysis compares the actual performance with the potential or desired performance. In this report, the focus is on the technological perspective and to some extent on the enabling environment. An economic analysis is not provided; this can be part of follow-up activities.

The question is what the best greenhouse production system for Egypt look like. 'Best' can be defined in terms of environmental sustainability:
- Water use (efficiency).
- Energy use (efficiency).
- Nutrient use (efficiency).

and in terms of economic sustainability:
- Production.
- Investment costs.
- Running costs.
- Pay-back period.

The design goals that follow from this are:
- A high and predictable production and product quality.
- A high energy efficiency and predominantly use of sustainable energy
- High water and nutrient use efficiencies, with low water and nutrient losses
- Low pesticide use, high food safety
- Economic profitability of the production system

As the control over production factors increases, the production level increases. And as the amount of inputs remain the same, or even reduce, the resource use efficiency increases.

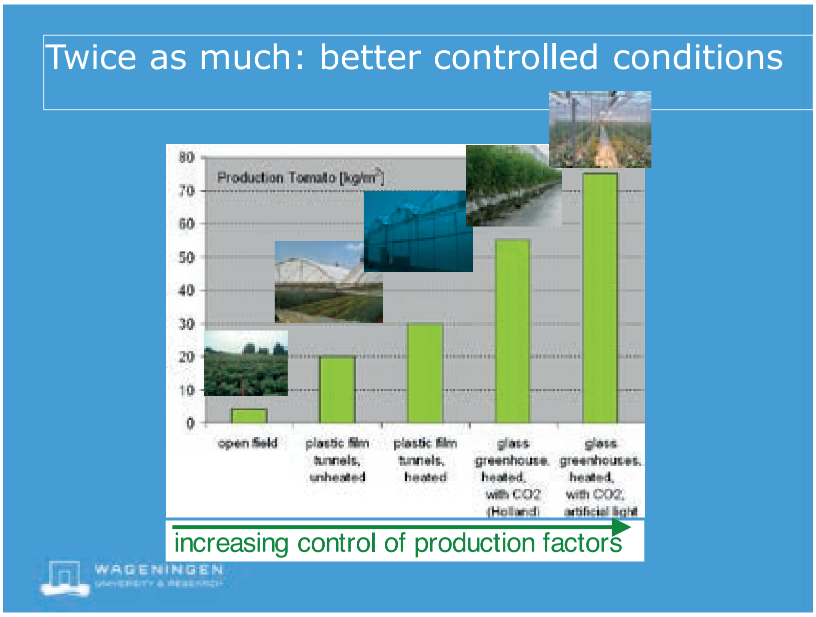


__Figure 3.1__ The concept of increased resource use efficiency.

3.1 Climate

The climate in Egypt is hot and dry. Along the Mediterranean coast the country has a semiarid desert, along the Red Sea coast and some inland regions a xeric shrubland, and an arid desert climate for most inland regions, including the Nile. An arid climate is characterized by (Abdel-Ghany *et al.,* 2012):

- A very hot and long summer season with very high temperatures.
- High solar radiation, up to 30 MJ m^{-2} d^{-1}.
- Dusty and dry weather with very low relative air humidity at noon, but possibly also with very high values in coastal areas during not months.
- Water resources are scarce and brackish.

In figure 3.3 the example of Cairo over 2014-2016 is presented:

- Maximum summer temperatures are on average 30-35°C, but may peak to 45°C. The highest peak temperatures are found in early summer (but differences are small). The minimum winter temperatures are on average 10-15°C, but may fall to 5°C.
- Air humidity is very low, especially during daytime.
- The average cumulative precipitation over 2014-2016 is 16 mm, which is from an agricultural perspective negligible.

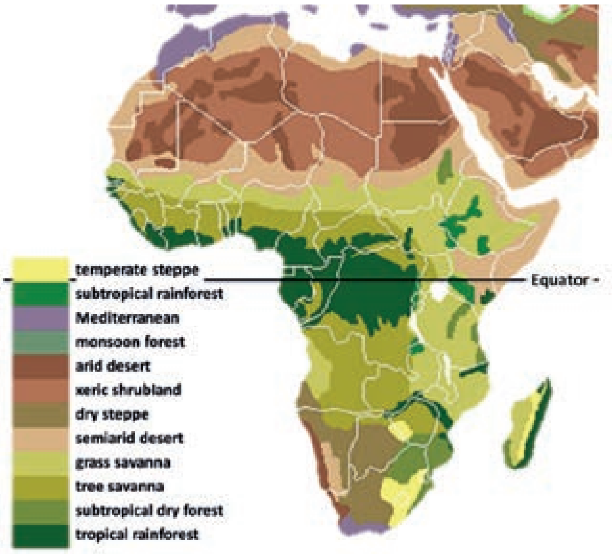


Figure 3.2 *Vegetation zones of Africa. Source: http://upload.wikimedia.org/wikipedia/commons/5/58/Vegetation_Africa.png.*

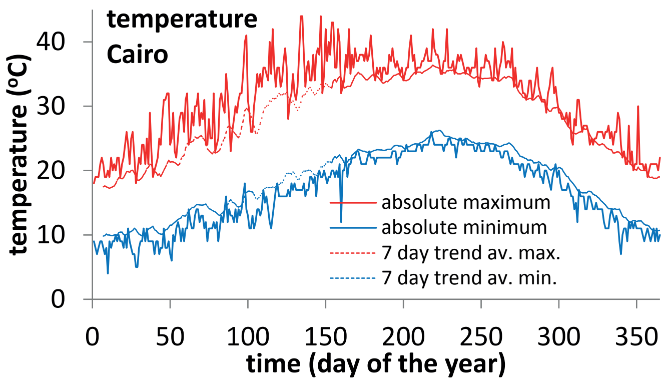


Figure 3.3 *Average maximum and minimum temperatures (their 7-day running averages), and absolute maximum and minimum temperatures at Cairo Airport during 2014-2016. Source: www.wunderground.com.*

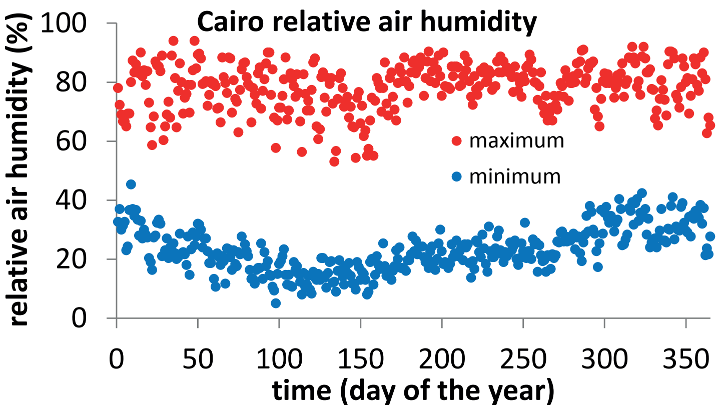


Figure 3.4 *Average maximum and minimum relative air humidity at Cairo Airport during 2014-2016. Source: www.wunderground.com.*

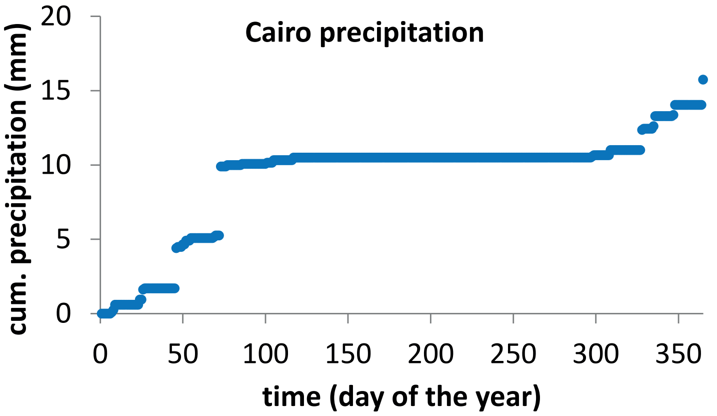


Figure 3.5 *Average cumulative precipitation at Cairo Airport during 2014-2016. Source: www.wunderground.com.*

3.2 Desired greenhouse production system

The desired characteristics of greenhouses in semi-arid and arid areas are:

- Good light transmission of greenhouse construction and covering material.
- Efficient ventilation.
- High volume and good insulation (mainly to pests and sand).
- Wind proof construction.
- A good and efficient combination of cooling systems.
- A high resource use efficiency (so, less inputs, higher production, better quality), in particular with regards to water.
- A conducive enabling environment, with regards to a maintenance industry, rules and legislation that make possible biological crop protection, a supportive system of education, research, and extension.

3.3 Analysis

The technology level of current greenhouses in Egypt range from low to medium. High technology greenhouses as known in Western Europe do not exist[2]. Low technology greenhouses are used by small-scale farmers that serve the local market, whereas medium technology greenhouses are used by large-scale farmers that serve the urban and export markets.

[2] However, BosmanVanZaal has recently constructed for the AOI a greenhouse partly consisting of glass cover, which mostly goes with a high-tech greenhouse. A very interesting development!

Figure 3.6 *Flower production at BioEgypt (2013 picture) and seedling raising (2010).*

3.3.1 Greenhouse construction and cover

Greenhouse constructions can be made of either wood or metal. Wood is less durable and strong than metal, and therefore, more material is required to realize a solid construction. Consequently, light transmission is relatively low. As this reduction can be substantial, depending on the structure, this will also affect crop growth on bright days with high light intensities. Next to that, maintenance costs are considerably higher. Metal is strong and requires low amount of material and therefore have a high light transmission. Depending on availability initial investment costs are relatively high. For any technology level besides the very low one, the use of metal is recommended. The construction should be solid and for example able to withstand high wind speeds if these occur. Medium-tech greenhouses in Egypt have a metal construction.

Greenhouse covers are in Egypt are currently made of net or plastic film. A net provides shade and protects against insects, if entirely closed. A net is not waterproof, but that is not very relevant in Egypt. The ventilation capacity is depending on the mesh size, which determines the permeability for insects and air. Net houses are widely found all over the world, with or without closed sides. They are used for, for instance, seedlings, shade plants, ornamentals, etc. A plastic film protects against rains and insects. It must be combined with ventilation openings to prevent from high temperatures during high irradiation, or a heating installation in situations where temperatures drop (e.g., at night in winter in desert climates). The ventilation openings must be covered with insect nets. Depending on the quality of plastics, the material degrades in time under the influence of UV radiation, high temperatures, chemical or mechanical stresses. There is much dust and sand in the Egyptian air, so it should be possible to clean the greenhouse cover.

Plastic houses are the standard in Egypt. All plastic types have their own characteristics with regards to transmissivity and insulation and can usually be found with a wide range of material properties.

It is not necessary to introduce glass greenhouse cover to Egypt (in the opinion of the author). Glass has a longer lifetime than plastic, but has a higher m^2 price if only initial investment costs are considered. It should be considered under high-tech conditions if yields and profits are high and the grower has access to enough initial investment capital. The current use of net and plastic film can be continued, however, with better selection of the optimal type of plastic film.

3.3.2 Climate system

Protected cultivation in Egypt has to manage the high day-time temperatures in summer, the low night-time temperatures in winter and the continuously low air humidity.

The high day-time temperatures occur for the larger part of the year and are therefore most important to deal with. High summer temperatures are by some growers simply avoided by not cultivating a crop in the period May – August, which reduces the yearly productivity of the greenhouse. In the other parts of the year cooling is realized through ventilation, which can be done in a number of ways:

- *Natural ventilation* relies on natural air movement for cooling the greenhouse crop down to outside temperature. Usually, a greenhouse with natural ventilation has sides with nets, and one or two-sided ventilation openings in the top of the greenhouse. These top openings can be fixed or flexible.
- *Circulation fans* can be placed inside the greenhouse to stimulate air circulation. This creates a more homogeneous climate and increases crop transpiration and cooling, but also requires electricity.
- *Pad & fan* is also applied to cool the air. It requires both energy and water, and causes a temperature and humidity gradient in the greenhouse.

In addition, the following measures exist:

- *Misting or fogging* is applied to cool and humidify the air. It is especially useful to avoid peak temperatures. In itself, it reduces crop transpiration but the total water use may even increase as the misting or fogging itself requires water (of high quality). The difference between misting and fogging is in water drop size and pressure needed and therefore in the quality of the system performance. Besides, application should be in such a way that the crop remains dry, demanding more than 1 m air space above the top of the crop.
- *Hosing* (spreading water with a hose over the soil surface) is a cheap method (if labour costs are low) to maintain air humidity and if water quality is too low for a misting system. Effects on cooling are limited.

Mechanic cooling is medium to high-tech and might not be relevant for all growers. It is a matter of costs and expected extra production (extra income) whether enabling year-round production with mechanic cooling is cost-effective. On the other hand, resource (water!) use efficiency is expected to improve with increasing technology level.

The low night-time temperatures are often not really dealt with in Egypt. This results in a low crop development rate, which is temperature-dependent, and a vegetative crop with only few fruits. This causes a crop with delayed production if temperatures catch up after winter. Heating with for example diesel generators is an option, if economically attractive.

The low air humidity is not necessarily a problem, as long as there is sufficient water to maintain crop transpiration. Consequently, the fertigation system should be good.

It is strongly recommended, almost a necessity to install a weather boxes outside and inside the greenhouse for registering at least temperature, radiation and humidity. Wind speed and wind direction are also useful, just as CO_2 concentration (but these sensors are relatively expensive). Good crop management requires knowledge with regards to the growing environment. This information is necessary if climate conditions are automatically controlled, and can are essential to understand the climate and crop response.

3.3.3 Screens

Shade screens are widely used in Egypt to reduce the radiation intensity in the greenhouse. The reduction depends on the shading factor of the material used. If applied outside on top of the greenhouse (with a construction solid enough to withstand possible strong winds) they are also able to reduce the heat load of the greenhouse. However, they form a barrier for air exchange depending on the material used. So, they can lead to reduced ventilation. There exists a wide variety of screens with specific characteristics in terms of light transmission, light spectrum, heat reflection, emission etc.

Thermal screens can be used to preserve heat in case of low (night) temperatures.

3.3.4 Energy

Greenhouses, except the most simple ones, require electricity for operating pumps, computers, etc. It is available from the grid, however, the Egyptian grid is not always reliable. Therefore, a back-up system such as a generator that requires fossil energy is a necessity. Not providing the plants with water can result in a dying crop within hours, certainly if the plants are grown on substrate that has a low water volume. If plants are grown in the soil then water availability is better because of the water buffer in the soil.

A diesel heat generator can be used to heat during cold winter nights. Better is to combust natural gas that produces CO_2 that can be used in the greenhouse to stimulate growth.

There is still very limited use of solar energy. This energy source could be utilized much more. The author has not seen any use of wind energy.

3.3.5 Water

Low-tech greenhouses obtain their water from irrigation canals that either originate from the Nile, or from bore holes. Mid-tech greenhouses obtain their water from bore holes. The Nile water is of poor quality, certainly downstream from Cairo and is best not used in greenhouses where product quality is important. As water availability in Egypt is very low, rainwater collection in tanks and water re-circulation should be seriously considered, including the necessary disinfection. Another option to improve sustainability of water use is to re-use water in outdoor cultivation systems.

Water availability is one of the major production factors to consider when planning the Land Reclamation projects. The total "National Reclamation project of 4 million feddan" will increase the annual groundwater abstraction by $2 \cdot 10^9$ m^3 (Scholten & Raatjes, 2016).

Water can be obtained from underground sources, and can be of variable quality: at some places it is brackish, making it less suitable for protected cultivation. In any case, bore hole water is an ending resource, although the amounts are difficult to establish. If the land reclamation area is close to the Nile, this is a logical water source. Desalination of sea water (e.g. the Mediterranean) with solar-generated electrical power should be seriously considered if the Land Reclamation sites are in the vicinity of the seas, as desalination costs are falling and as this implies little ecological pressure.

Other options include bioprocessing of waste water from urban areas, which generates clean water, nutrients, gas and electricity.

3.3.6 Substrate

Cultivation in Egypt is mostly in the soil, which is the most simple and cheapest option. The advantage of soil is its relatively large water availability for the plant (although pure sand has a low water holding capacity). A dysfunctional fertigation system is not directly disastrous to the crop. It, however, also introduces the risks of soil-borne diseases. Bacterial wilt, for example, is wide-spread in Africa, and can completely destroy the crop. It also requires uniformity of the soil. Further disadvantages of soil cultivation is its larger water requirement than substrate cultivation and pollution of ground water.

Alternatives are various substrates that are placed in pots, slabs or troughs and that enable a more precise application of water and nutrients. However, they also require a fertigation system, an uninterrupted electricity supply and advanced knowledge with the grower. It is mostly used in combination with a computerized fertigation system.

3.3.7 Fertigation system

The purpose of the fertigation system is to supply water and nutrients in sufficient amounts to the plants.

Medium-tech greenhouses in Egypt have a computerized system that makes use of sensors and a pre-set fertigation regime to apply water and nutrients, resulting in the optimum availability of water and nutrients to the crop. It is usually combined with A and B nutrient tanks, and a pH buffering tank. The system obviously requires a non-interrupted supply of electricity. Because of its capacity to provide optimal amounts of water and nutrients, it contributes to improved production and product quality. A computerized fertigation system can be combined with cultivation in the soil or on substrate.

More low-tech solutions are manual application of water and nutrients. The system is most simple, cheap, but requires the continuous presence of labour and is not very precise in terms of amounts of water and nutrients applied and is only suitable in case of small greenhouses. Gravitational fertigation makes use of a water tank that is placed above field level. The water tank can hold water and nutrients that are mixed in a specific combination, and the water can be applied in specific quantities (the required amount of water and nutrients can be translated to a time period of water flow). The valves of the system are manually operated.

3.3.8 Crop protection

Pests and diseases in Egyptian horticulture are dealt with through sanitation (the greenhouse itself protects the crop to a certain extent to pests) and chemical spraying. International supply chains permit no or only very low levels of chemical residues and permit a limited number of chemical active ingredients, and for reasons of consumer's healthy, national supply chains best adopt the same policy. The export oriented horticultural sector is in desperate need of biological crop protection. Egypt produces a limited range of biological crop protection products, but these are not sufficient. The main hurdle to overcome is the Egyptian government to permit the international trade in biological means and therewith realizing a conducive enabling environment. Concerns for biodiversity can be managed, as in most other countries.

Integrated crop protection (the term Integrated Pest Management, IPM is mostly used) uses a mixture of biological and chemical crop protection. Chemical crop protection is used as a last resort only.

3.3.9 Crops

Given the relatively high investment and operational costs of a greenhouse production system, only high-value crops will result in a viable business case. Vegetable crops such as tomatoes, cucumbers, peppers, peas and other field vegetables are the main greenhouse horticulture crops; and recently, higher value crops such as broccoli and lettuce have been introduced (Nour *et al.* 2015). Also the acreage of flowers can be increased to supply for instance the urban market. Other crop options include green herbs, aubergine, and courgette. An interesting option is the production of high-quality seedlings and grafted plants for domestic use.

3.3.10 Enabling environment

The production of fruits and vegetables in greenhouses requires an enabling environment. There is much room for improvement in Egypt. To mention a number of issues:

- The import of biological crop protection means (for instance, predators) is not permitted. This hampers integrated pest management (IPM) and leads to high levels of chemical residues. If minimum residue levels are exceeded, export to becomes impossible.
- There are extensive national systems for research, education and extension. However, their involvement with commercial greenhouse horticulture and consequently their capacity to link theory with practice could be intensified. This also goes for the international connection of these system.

- Organizational structures to improve the interaction between large-scale farmers and smallholder farmers (SME's) would improve exchange of knowledge and experiences, offer commercial opportunities, and strengthen the sector as a whole.
- There are just a few experienced growth managers. Their presence is crucial for strengthening of the sector.
- A good maintenance industry for greenhouses should be developed.

3.3.11 Summary

- Low technology greenhouses are used by small-scale farmers that serve the local market, whereas medium technology greenhouses are used by large-scale farmers that serve the urban and export markets.
- Medium-tech greenhouses in Egypt have a metal construction and a plastic cover. This fits with the needs of the country. The quality of the plastic and nets that cover the ventilation openings should be of good quality.
- Management of the high day-time temperatures is very important. Especially in summer, it may be economically best to cease cultivation. Management of low night-time temperatures in winter should be considered to ensure a continuous crop growth and development between autumn and spring.
- It is strongly recommended to install a weather boxes outside and inside the greenhouse.
- Shade screens are widely used in Egypt to reduce the radiation intensity in the greenhouse.
- Electricity is required to operate pumps, computers, etc. As the grid is not always reliable, a generator is an absolute necessity.
- The use of solar (and wind, if present) energy could be utilized much more.
- Water is the major limited resource in Egypt. Nile water is of low quality and without cleaning not suitable for greenhouse production systems. Bore hole water is of variable quality, and also limited in availability.
- Desalination of sea water (e.g. the Mediterranean) with solar-generated electrical power should be seriously considered if the Land Reclamation sites are in the vicinity of the seas.
- Cultivation is currently mostly in the soil, as it is less risky in terms of irrigation strategy. However, it also requires more water than cultivation in substrate (pots, slabs, troughs).
- Medium-tech greenhouses in Egypt have a computerized system that requires un-interrupted power supply and that results in the optimum availability of water and nutrients to the crop.
- The limited supply of domestically produced predators and the ban on import of predators seriously hamper the biological crop protection in Egypt. This results in high chemical residue levels and problems for the export industry.

4 Development options

4.1 Transitions

Transitions in protected horticulture can be visualized in a two-dimensional figure (Figure 4.1). The x-axis distinguishes farms on the basis of their technology level, and the y-axis does this on the basis of their market orientation. The y-axis moves from local (municipality) oriented to national market and export market. On the whole, farm types move from no and low-tech farms that produce for the domestic market towards medium-tech farms that produce for the export market, but this cannot be considered as development path for all farms. Technological levels and markets sometimes coexist in the same, bigger companies, depending on the achieved produce quality. In general, export orientated farms tend to have a larger size. A small sized farm will measure no more than 1 ha; while most medium sized farm will measure 1 to 3 ha. A large farm measures more than 10 ha.

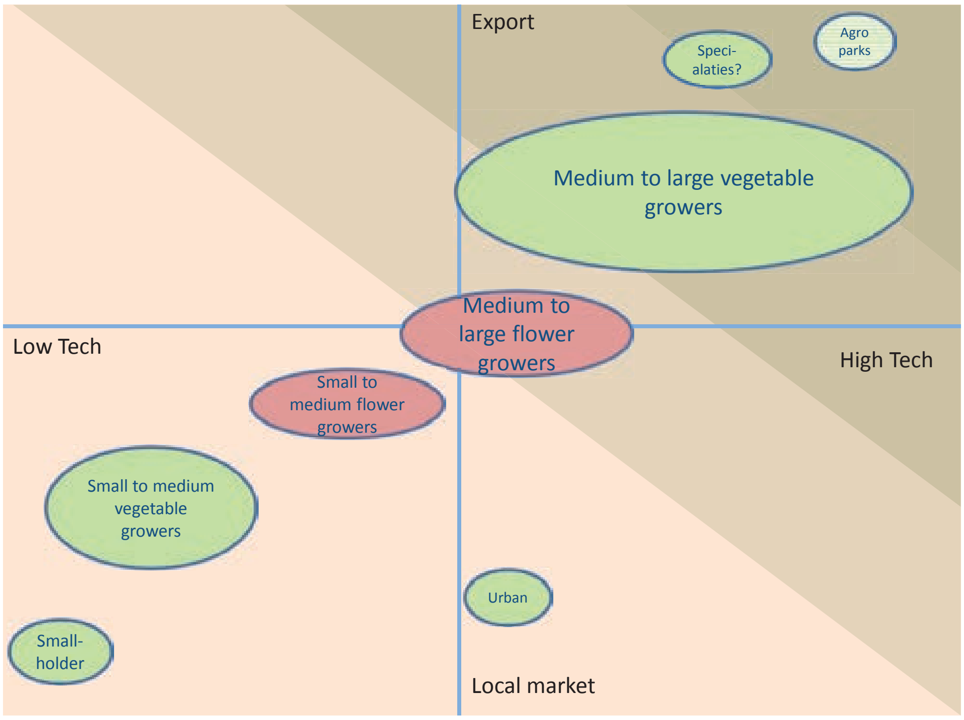


Figure 4.1 *Technology development trends for protected horticulture in Egypt. See text for explanation. The size of the oval represents the approximate size of the segment. The arrow gives the assumed development direction of the farm segment. The darker the background colour, the more market opportunities to be found for Dutch input suppliers. Red ovals: flowers; green ovals: vegetables. Based on Elings et al. 2015; García Victoria et al. 2011.*

1. Smallholders form the majority of farmers in Egypt and are considered, who face severe barriers to enter high quality or export markets, who have not favoured from the benefits of horticulture, and will require new organizational models to remain linked with the markets. If this fails, smallholders may in the long run face a difficult future. Apart from organizational structures, much will depend on factors such as the economic feasibility of their production system, the options to obtain and re-pay loans, the options to maintain the greenhouse structure, and on the availability of inputs.

2. It is difficult to forecast developments of small to medium vegetable or flower growers. One option is that they become better integrated with the market (e.g., price and supply arrangements with supermarkets) and move up in technology level, which would offer opportunities for the Netherlands supply industry. In any case, because of the fact that such farms are already somehow market-integrated, they are in a better position than smallholder farmers. However, risks are still substantial. Financial buffers may be low, and one or more crop failures (which are not unlikely in Africa) may have serious consequences. Also, below-standard performance in terms of production, product quality, marketing may bring such farms quickly in a precarious situation if for example certification requirements are tightened.

3. Medium to large vegetable and flower farms have a high potential to link better with the international market and increase their technology level. Investment capital is available or can be acquired. As the technology level increases, there is an increasing demand for high-quality greenhouse constructions, installation, seeds, crop protection means and other supplies, and knowledge.

4. Speciality farms are attractive customers for the Netherlands supply industry as they are strongly linked with the international market that is very demanding, and as the technology level is relatively high. There are currently only a few speciality farms in Egypt. For example, lettuce is grown on aeroponics (in combination with fish farming). Also organic farming can be classified as speciality farms[3].

5. The urban markets form an integrated part of the domestic market. They can be found for instance in the city of Cairo. The city is rapidly expanding, but some horticultural land remains in production. Urban and metropolitan horticulture (urban = within the city; metropolitan = in the vicinity of the city) currently receive much attention, sometimes with the suggestion that this can contribute to resolving as much as mal- or undernutrition. While it can certainly contribute to a better diet, and can serve purposes such as education and recreation, there is no viable business model if land prices have to be taken into account. Land prices in and nearby cities are very high.

Figure 4.2 *Urban agriculture in Cairo.*

6. Agroparks are currently not existing in Egypt, but are certainly an option for the land reclamation areas. The land reclamation areas offer ample opportunities for an integrated approach to various forms of land use. Agro-activities that fit in a circular economy can be linked in terms of in- and outputs and share resources.

[3] In Europe, spraying with chemicals is not permitted in organic horticulture. It is difficult to believe that in the absence of biological control, an Egyptian greenhouse farmer does not spray. Perhaps spraying is suspended some time before harvest.

5 Feasibility study

A feasibility study to further assess the potential of greenhouse horticulture in the land reclamation areas would be the next step in the process.

1. West West Menya
2. Farafra
3. Moghra Oasis
4. Al Dakhla (Dakhla Oasis)
5. West Marashda (Qena)
6. East Siwa
7. West Kawn Umbo
8. Al Tor (Sinai)
9. Toshka
10. South East Monkhafad

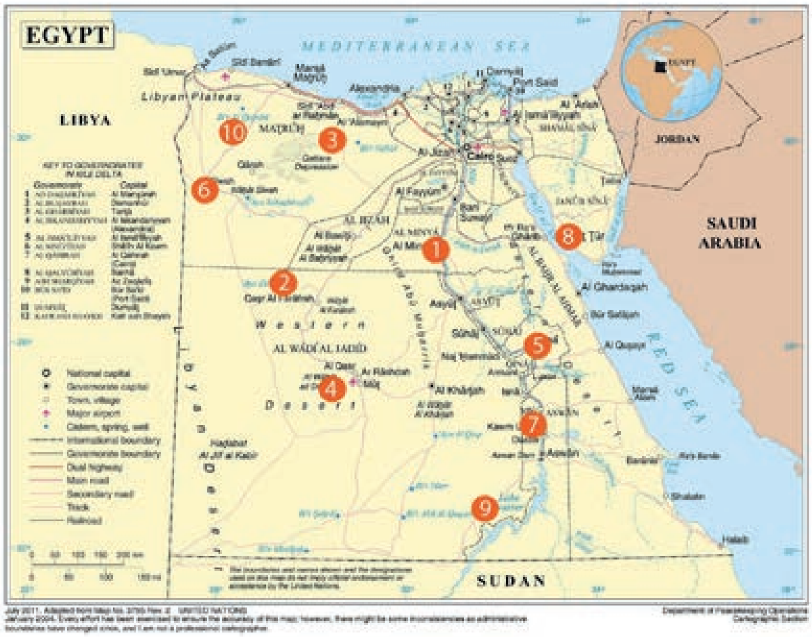


Figure 5.1 *The ten land reclamation areas.*

5.1 Terms of Reference

The Terms of Reference (ToR) for a follow-up activity can be:
1. Translate projected market demand to preliminary estimates of production acreages, levels, and seasons.
2. Establish general eco-physical characteristics for greenhouse horticulture in potential production areas.
3. Establish eco-physical potential of possible production areas.
4. Determine technological options and business cases for the various greenhouse production systems ('adaptive greenhouse approach').
5. Advice on greenhouse production systems for the of possible production areas.
6. Place on the agenda a number of enabling environment issues.
7. Initiate strengthening of capacity building.

Team:
1. Specialist greenhouse production systems.
2. Specialist land and water resources.
3. Greenhouse design specialist
4. Greenhouse economist and expert value chains

Strong collaboration with local experts and stakeholders is necessary. Also, the team must ensure linkages with, or better collaborate with, teams that follow-up on the other fields of interest (see footnote 1).

5.2 Action plan and deliverables

1. Translate projected market demand (to be determined in a different sub-project) to preliminary estimates of production acreages, levels, and seasons. Export and domestic markets demand a certain amount of (fruit) vegetables and possibly flowers of certain quality. These demands can be translated to the greenhouse acreage that is required to produce these amounts at particular moments during the year, taking into account the desired quality. This depends on the level of technology, farmer skills and other factors, so, the activity may result in a number of scenarios.
   Note that this step will be fine-tuned in step 5.
   Deliverable: Estimates of production acreages, levels and seasons derived from projected market demand for various crops.
   Type of activity: Desk study.
   Expertise required: Specialist greenhouse production systems.
   Collaboration: Market demand sub-project, Egyptian sector specialist.

2. Establish general eco-physical characteristics for greenhouse horticulture in potential production areas: water requirements, temperatures during the year, soil characteristics, etc. Although greenhouse horticulture is technically possible in any environment, common sense will restrict the number of suitable locations. For instance, if no water is available, or if temperatures are excessively high, greenhouse horticulture is not an option. Technical solutions to these bottlenecks will be too expensive and need not to be considered. Other locations will only be suitable if specific conditions are met: for example, enough water or desalination units.
   Note that this step will be fine-tuned in step 5.
   Deliverable: General ranges of eco-physical conditions for greenhouse horticulture in potential production areas.
   Type of activity: Desk study; workshop.
   Expertise required: Specialist greenhouse production systems.
   Collaboration: Egyptian sector specialist, Egyptian growers.

3. Establish eco-physical potential of possible production areas. This is one of the more critical phases of the feasibility study, in particular in terms of data availability, quality and interpretation. Much studies have been done, e.g. in the field of water availability, but it is also understood that these data are not at a centralized location, that their reliability is not fully guaranteed, that they may not be complete and consistent, and that they may have to be translated from Arabic to English. Even if access to good data has been ensured, the interpretation is the next phase that requires much knowledge on crops and cultivation systems.
   Deliverables:
   - Definition of required data.
   - Data availability.
   - Data quality.
   - Judgement on suitability for of land reclamation areas for greenhouse production systems.

   Type of activity: Data acquisition mission, desk study.
   Expertise required: Specialist land and water resources.
   Collaboration: Egyptian and other data suppliers, specialist greenhouse production systems.

4. Determine technological options and business cases for the various greenhouse production systems ('adaptive greenhouse approach'[4]). Each greenhouse production system can be characterized by technical greenhouse specifications, investment costs, running costs, crop yields and farm-gate prices. This information leads to business cases that can be used to decide upon the most attractive greenhouse design and associated production system (see Figure 5.2).
   Deliverables: • Technological options for greenhouse designs.
   • Expected crop yields.
   • Business models of the selected greenhouse production systems.
   Type of activity: Desk study, workshop.
   Expertise required: • Greenhouse design specialist, greenhouse economist, specialist greenhouse production systems.
   Collaboration: Value chain study.

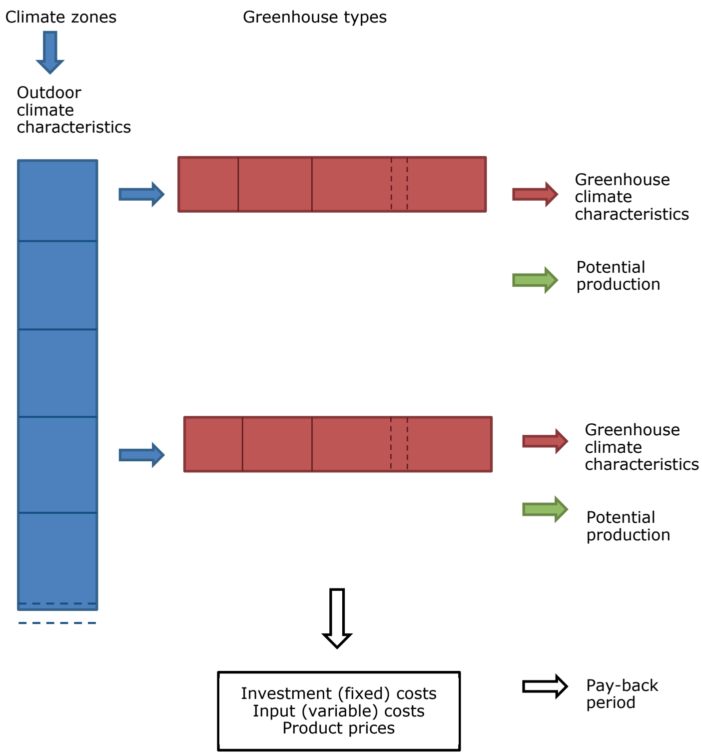


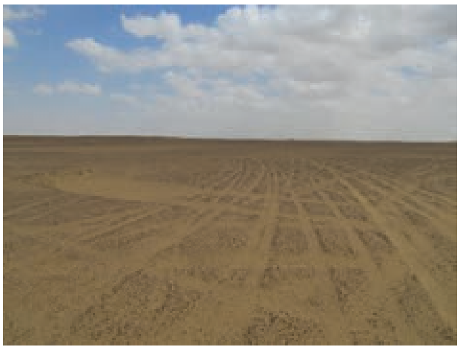
Figure 5.2. *An overview of the 'Toolbox Adaptive Greenhouse Systems for Africa'. From Elings et al. 2015.*

5. Advice on greenhouse production systems for the of possible production areas. On the basis of the technological options and business cases on the one hand, and the characteristics of the land reclamation areas on the other hand, the designs of the greenhouse production systems are matched with the land reclamation areas. Different greenhouse production systems will be suitable for different areas. For instance, nearby the Mediterranean, the possible availability of desalinated sea water enables different possibilities for production systems than a location more inland.
   Deliverables: Options for greenhouse production systems, for different land reclamation areas.
   Type of activity: Desk study.
   Expertise required: Specialist greenhouse production systems.
   Collaboration: Value chain study, Egyptian sector specialist.

[4] 'Greenhouse production system' is meant here.

6. A number of enabling environment issues must be placed on the agenda, apart from technological, eco-physical considerations, and possibilities that value chains offer. This concerns for instance rules and legislation to trade biological crop agents (bca's), the recruitment of good greenhouse managers.
   Deliverables: Specification of shortcomings in enabling environment that hamper development of the greenhouse horticulture industry.
   Type of activity: Mission to interact with stakeholders, workshop.
   Expertise required: Specialist greenhouse production systems.
   Collaboration: experts in value chains, economics, business development, etc.

El Moghra



The major issue at El Moghra to deal with will be the is the absence of good quality water. Ground water is saline and must therefore be desalinated before it can be used in greenhouse horticulture. Greenhouse horticulture without good quality water is not recommended. Water desalination is technically possible; whether it is economically feasible must be further investigated. At the moment, jojoba is an important crop, able to grow on saline soils. On the positive side: the land is flat and is reasonably windy (good for ventilation), and after construction of infrastructure within reach of large urban areas and ports. Pressure of pests is low, at the moment.

5.3 Budget

We estimate that the minimum budget for a feasibility study for protected horticulture will be 500 000 Euros.

6 Greenhouse Technology for Cultivation in Arid and Semi-Arid Regions

Presentation held December 2016, Cairo.

Greenhouse Technology for Cultivation in Arid and Semi-Arid Regions

Esteban Baeza

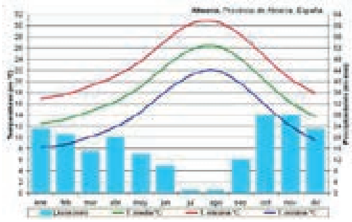
WAGENINGEN UNIVERSITY & RESEARCH

An important part of new greenhouse areas are located in regions of semi-arid and arid climate...

According to Abdel-Ghany et al. (2012), climate of arid regions is characterized by:

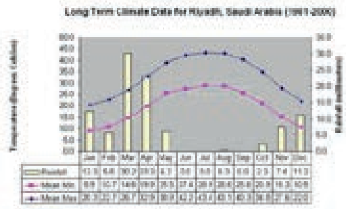
- Very hot an long summer season (the ambient temperature exceeding 45◦C at around noon in summer).
- High solar radiation flux (the daily solar radiation integral reaches to 30 MJm^{-2})
- Dusty and dry weather (relative humidity of the ambient air may drop below 10% at around noon). However, in arid coastal areas, R.H. may also be very high during the hottest months.
- Water resources being scarce and brackish (salty)

WAGENINGEN UNIVERSITY & RESEARCH



Example of semi-arid region...

JULY AND AUSGUST, WHICH ARE THE MONTHS IN WHICH WE DO NOT GROW IN ALMERÍA DUE TO EXCESS HEAT, CORRESPOND IN RIYADH TO APRIL AND OCTOBER...



WHAT GREENHOUSE TECHNOLOGY CAN BE USED TO GROW IN SEMI ARID AND ARID REGIONS????

Example of arid region...

¿WHERE ARE WE REALLY NOW IN MOST SEMI-ARID AND ARID REGIONS?

PASSIVE OR VERY LIMITED CLIMATE CONTROL

GROWERS ADAPT THE CROP TO NON-OPTIMAL CLIMATE CONDITIONS INSTEAD OF PROVIDING OPTIMAL CONDITIONS

GROWING STRATEGIES MORE RELATED TO BIOLOGICAL ASPECTS AND FERTIGATION THAN TO CLIMATE CONTROL

LIMITED YIELDS
GOOD QUALITY IN LIMITED PERIODS
IRREGULAR PRODUCTION
LOW COSTS
THEREFORE....

What characteristics should greenhouses built in semi-arid and arid areas have?

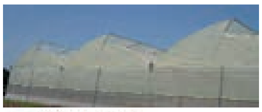
- Good light transmission: greenhouse/covering material
- Efficient ventilation
- High volume and good insulation (mainly to pests and sand)
- Wind proof construction
- A good and efficient combination of cooling systems
- Other possibilities: desalination system, maximum water use efficiency (i.e. closed irrigation system, closed greenhouse?)

WAGENINGEN UNIVERSITY & RESEARCH

What we have in most semi-arid and arid regions...



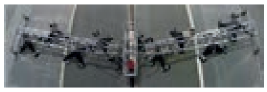





WAGENINGEN

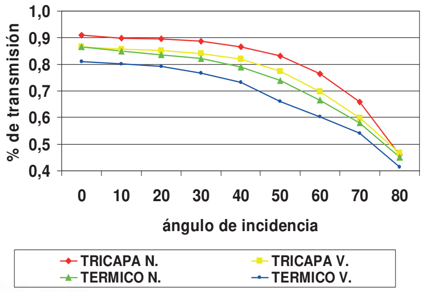
Some companies already offer 16 m wide bay multispan greenhouses (very demanded in countries like Mexico) With higher volume comes higher light transmission and is easier to maintain lower temperatures in the low 3 m crop area, whereas temperatures between 45-60ºC may occur near the roof (Giacomelli et al., 2004). Caution in very windy areas with such high greenhouses!

Covering materials with excellent PAR transmission are available (glass, PE, PVC, Polycarbonate,F-clean, ...). Very important in semi-arid and arid regions is to clean the accumulated dust from the roof: splinkers are an option, but now different cleaning machines have being designed and are in the market.



WAGENINGEN

Important drecrease in transmission por different PE films after one year in the greenhouse...



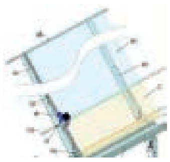
WAGENINGEN

MAXIMUM VENTILATION CAPACITY IS ACHIEVED UNDER SCREENHOUSES...DIFFERENT COLOUR PROVIDE DIFFERENT EFFECTS ON THE CROP...AND ON PEST CONTROL...LARGE AREA IN ISRAEL AND A LOT OF RESEARCH WORK CARRIED LATELY...


THEY COULD BE COMBINED WITH ANOTHER COOLING TECHNIQUE TO GROW DURING THE WHOLE YEAR...OR...

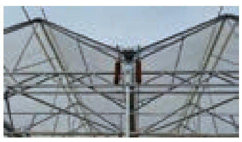
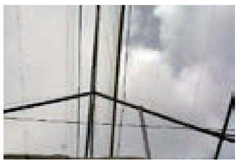
WAGENINGEN

Production strategies for supplying the market

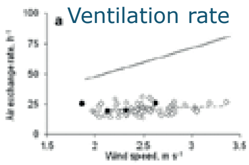


Retractable roof greenhouses or similar concepts:

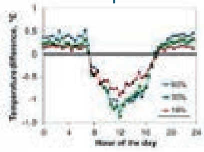
- New prototype of double exchangable cover greenhouse based on rolling mechanism, developed by a spanish company (Gogarsa/NGS) in collaboration with IRTA and IFAPA

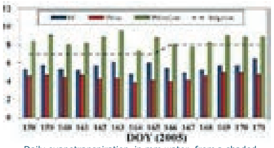
WAGENINGEN



Air exchange rate of pepper plants in an insect proof screenhouse (symbols) and in the open field (solid line). (Tanny et al., 2003).



Diurnal curves of temperature difference between shaded and unshaded apple orchards. Colors indicate different shading levels. (Tanny et al., 2009).



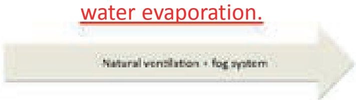
Daily evapotranspiration, in mm water, from a shaded banana plantation. Blue – measurements; Red- model inside; Green – model outside; Dashed line – irrigation. (Tanny et al., 2014).

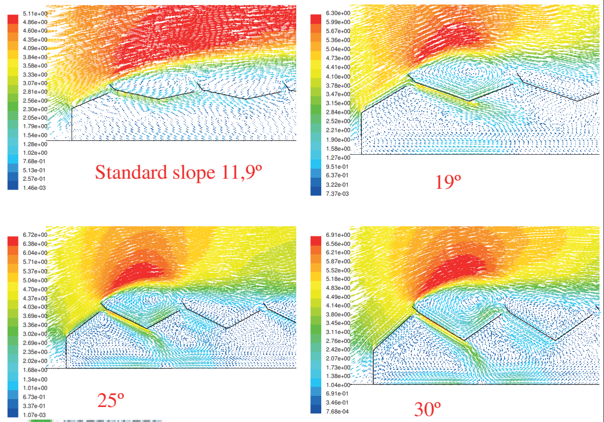
AND NOW...LET'S TALK ABOUT GREENHOUSE COOLING...

STRATEGY A: COMBINATION OF CLASSICAL COOLING TECHNIQUES

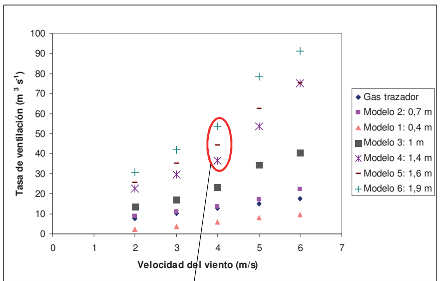
Conventional refrigeration is generally very expensive to install and run in greenhouses, compared to the cost of importing the food produce from cooler regions (food safety is changing the game...) and according to Abdel-Ghany et al. (2012):
Three main categories of cooling techniques commercially used to cool the greenhouse under high radiation conditions: **ventilation, evaporation and heat prevention**. In semi-arid and arid regions, it is not possible to successfully grow along the year without a combination of the previous methods.

Methods combining ventilation and water evaporation.

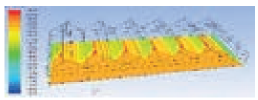


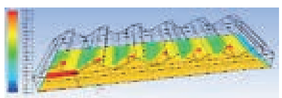


…increasing the size of the roof vetns has clear an important effect on the ventilation rate



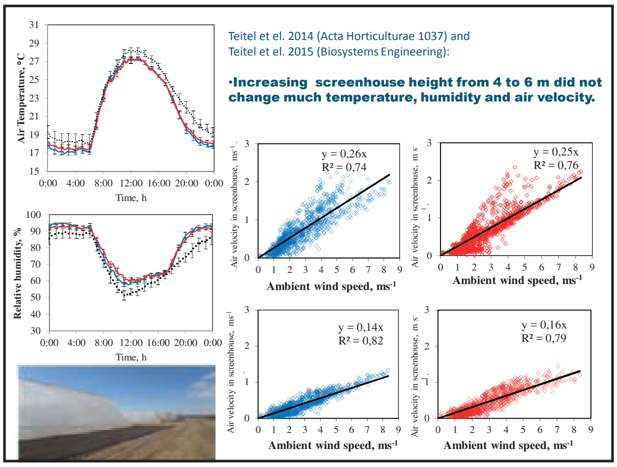
At 4 m s-1, only vents with width higher to 1 m provide acceptable air exchange values (>30 vol. h-1)





FOR WINTER PERIOD, REGARDLESS OF NUMBER OF VENTS OPEN PER SPAN OR ORIENTATION OF THE GREENHOUSE, BUILDING A CONTINUOUS ROOF VENT OF A WIDTH SMALLER THAN 1.7 M AND MAXIMUM OPENING ANGLE HIGHER THAN 60º IMPROVES LIGHT TRANSMISSION WHEN THE VENT IS FULLY OPEN

HOWEVER IT ALSO CAUSE A VENTILATION EFFICIENCY DECREASE
THIS VENTILATION LOSS IS ACCEPTABLE IN WINTER, BUT IT SHOULD BE STUDIED IF THIS VENTILATION EFFICIENCY LOSS IS ACCEPTABLE OR IF IT CAN BE COMPENSATED BY OPENING THE SIDEWALL VENTS IN NOT SO LARGE GREENHOUSES, WHICH ARE THE MAJORITY IN THE MEDITERRANEAN AREA



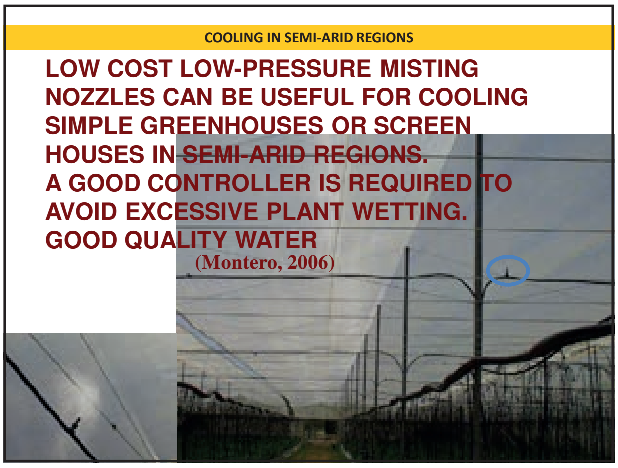
EVAPORATIVE COOLING IS THE MOST EFFICIENT GREENHOUSE COOLING TECHNIQUE IN ARID CLIMATES:

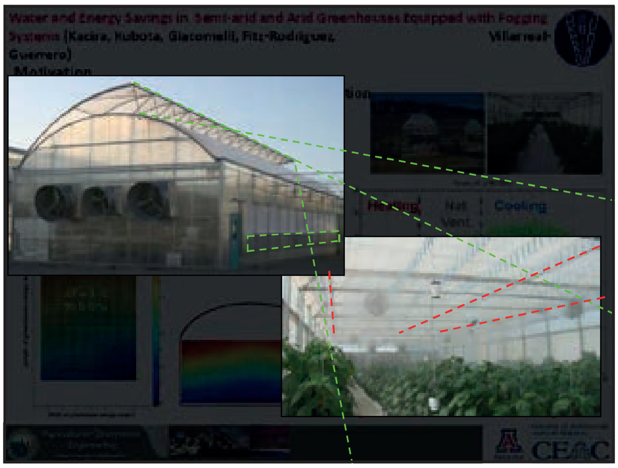
Recent studies (Al Helal et al., 2011) measured as high as 12 ºC ambient temperature decreases and 30% R.H. increases with a new pad and fan system!

However...good quality water (low E.C.) is required and precisely, this is a very scarce resource in semi-arid and arid regions and...

A good control strategy is needed to control both fogging as well as vent opening controls to maintain climate, eliminate canopy wetting as well as for resource savings.

...they do not perform well in arid coastal regions where ambient R.H. is very high during the summer months and/or when the crop is fully developed and transpiring...





Outside and Maintained Greenhouse Inside Climate

Date:	June 18, 2011	June 19, 2011	June 29, 2011	July 03, 2011
Fog range:	0.16-0.26 g m^{-2} s^{-1}	0.27-0.42 g m^{-2} s^{-1}	0.27-0.42 g m^{-2} s^{-1}	0.22-0.34 g m^{-2} s^{-1}
Time period:	11:26-1800h	1005-1605h	556-1530h	955-1800h

		h (kJ kg^{-1})	VPD (kPa)	T (°C)	RH (%)	h (kJ kg^{-1})	VPD (kPa)	T (°C)	RH (%)	h (kJ kg^{-1})	VPD (kPa)	T (°C)	RH (%)	h (kJ kg^{-1})	VPD (kPa)	T (°C)	RH (%)
Inside	Ave	**66.7**	**1.32**	**27.9**	**65.5**	**55.9**	**0.97**	**24.1**	**68.3**	**62.7**	**1.2**	**26.7**	**65.6**	**67.0**	**1.1**	**27.3**	**70.0**
	StDev	5.5	0.4	1.8	7.2	2.8	0.35	1.5	8.4	6.5	0.4	1.6	11.0	4.3	0.3	1.8	6.3
Outside	Ave	**46.6**	**6.2**	**38.3**	**7.9**	**44.8**	**5.5**	**36.3**	**9.0**	**55.8**	**4.6**	**35.7**	**23.1**	**59.5**	**5.1**	**37.5**	**22.2**
	StDev	0.58	0.3	0.8	1.0	1.2	0.3	0.9	0.3	2.2	1.3	3.8	7.2	1.4	0.8	1.9	5.2
Difference		**20.1**	**-4.9**	**-10.4**	**57.6**	**11.1**	**-4.5**	**-12.2**	**59.3**	**6.9**	**-3.4**	**-9**	**42.5**	**7.5**	**-4**	**-10.2**	**47.8**

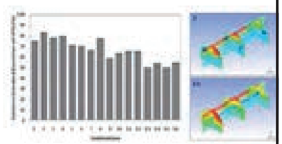
10 ºC Tair & 4.5 kPa VPD difference between GH inside-outside
with energy & water savings about 20-25% with variable rate vent and fogging control compared to fixed vent & fogging control strategy

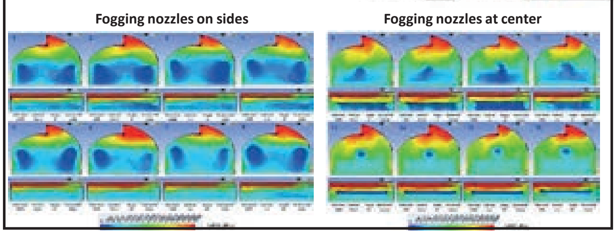
THE UNIVERSITY OF ARIZONA

Greenhouse climate uniformity under natural ventilation with high pressure fogging using Computational Fluid Dynamics (CFD) simulation (Tamimi and Kacira)

- Developed a 3D CFD model that analyze greenhouse internal aerodynamics and climate uniformity.
- The overall model included five sub-units:

(1) Porous media model: Simulate crop canopy,
(2) Solar load model: Simulate solar radiation
(3) Species transport/ discrete phase model: Simulate evaporation of droplets,
(4) Evapotranspiration model: Simulate crop cooling effect



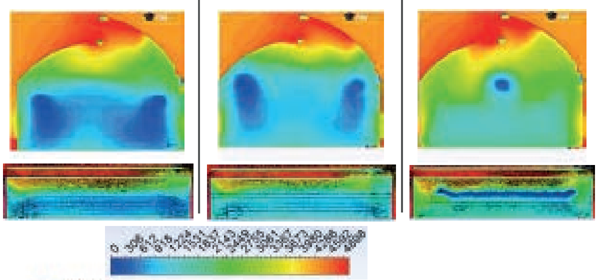


MK1

Side Vent	Height	Angle	Nozzle
100%	0.5m	0°	sides

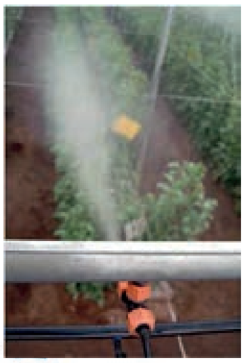
Side Vent	Height	Angle	Nozzle
100%	1m	45°	sides

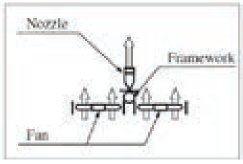
Side Vent	Height	Angle	Nozzle
100%	1 m	45°	center



WAGENINGEN

AIR-WATER FOG SYSTEMS ARE LESS SENSITIVE TO WATER QUALITY…BUT SPEND MUCH ENERGY ON THE COMPRESSOR (MONTERO ET AL., 1990)





Toida et al., 2006

The pad material should have high surface, good wetting properties and high cooling efficiency. A suggested pad thickness is 200 mm. It is very important that there are no leaks in the pad where the air can pass through without making contact with the pad

The pad area should be about 1 m2 per 20-30 m^2 greenhouse area. The maximum fan-to-pad distance should be 40 m.

- Fans should be placed on the lee side of the greenhouse. If they are on the windward side, an increase of 10 % in the ventilation rate will be needed. The distance between the fans should not exceed 7,5-10 m, and the fans should not discharge towards the pads of an adjacent greenhouse less than 15 m away.
- Main problem is their use with brackish water…in that case

WAGENINGEN

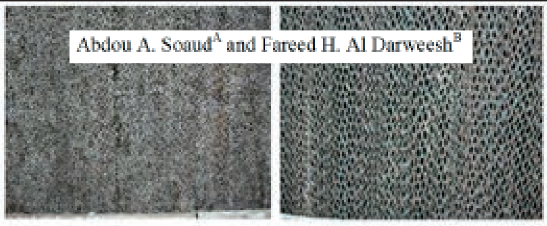


Figure 1. The effect of acidified water in removing scaling and salt deposits from cooling pads.

Initial   After 24 hrs.

Figure 2. The effect of acidified water in removing scale and salt deposits from the cooling pad (dissolved salt in the reservoir of the cooling system).

The acid water was maintained by utilizing sulfur by-product from gas production plant using sulfur burning equipment, the average pH of the acid water generated by this technique was 6.5.

Shading / whitewashing objectives:

- **Improves the efficiency in the conversion of intercepted radiation in dry matter:** ↓

Photo-respiration ↓

Evapotranspiration

- **Improves fruit quality**

Shading reduces potential yield

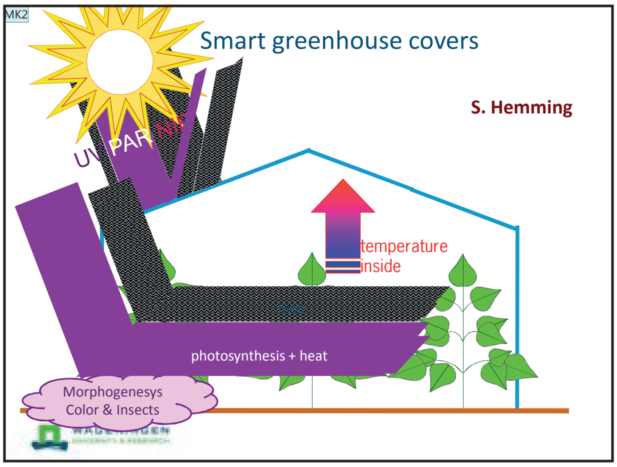
(De Pascale, 2009) 0,6 kg m^{-2} $month^{-1}$ tomato lost for each 10% of light

WAGENINGEN

HEAT PREVENTION: SHADING

Shading reduces irradiance and, consequently, air temperature but also limits productivity (at least, when light quality is not improved). Whitening is the most popular shading technique: cheap, simple to apply but it is not very uniform, adjusting the shading level is difficult and it decreases radiation regardless of the temperature and radiation level…therefore, mobile shading is preferable…

…mobile external shading is more efficient than mobile internal shading for cooling the greenhouse as it interfers less with natural ventilation but…it is very expensive and not usable under windy conditions

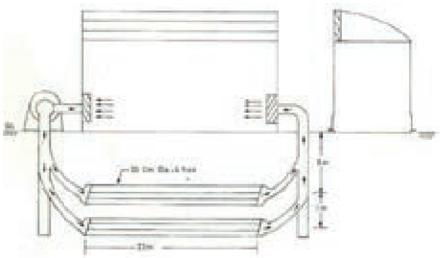


A word of caution about NIR-selective covers:

- Evolution has already endowed leaves with a high (~50%) NIR-reflectance
  - ➔Don't expect wonders from NIR-filtering covers
- NIR-absorption will warm up the cover → a fraction of the withheld energy will end up in the greenhouse at longer wavelengths
- NIR-reflection will lead to multiple reflection between crop and cover → a fraction of crop reflection will not escape the greenhouse
  - ➔Difference in efficacy between absorption and partial reflection may be small
- The contribution of NIR to heating the greenhouse may be welcome often enough
  - ➔A permanent NIR filter may backfire

Stanghellini, C.

STRATEGY B: COMPOSITE SYSTEMS



EAHES: such systems are not suitable to cool the greenhouses in very harsh climates like in the Arabian Peninsula year round. They can only lower the inside air temperature by **3–5 ºC** as compared to the control greenhouses. Another major disadvantage of using EAHES is the cost of digging the soil and laying the pipes to 2–4 m depth.

USE OF RENEWABLE ENERGIES

WHAT ADVANTAGE DOES A GREENHOUS GROWER GET FROM USING THEM?

ADDITIONAL INCOME (BONUS SYSTEM) BY SELLING ELECTRICITY **(REGULATION FRAMEWORK IS A CHAOS IN SPAIN…NOT INTERESTING NOWADAYS)**

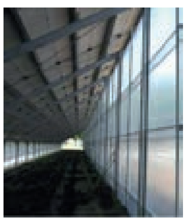
DECREASE COSTS BY SELF CONSUMPTION (ACCUMULATION??)

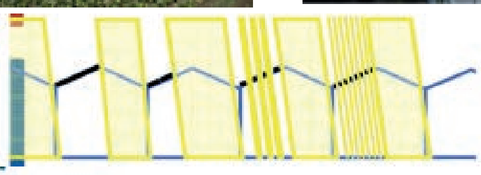
SUPPLY THERMAL ENERGY (IMPROVING YIELD, SUBSTITUTES FUEL ENERGY AT…LOWER PRICE??)

PHOTOVOLTAIC SOLAR THERMAL BIOMASS

GEOTHERMAL WIND

PHOTOVOLTAIC PANELS AND PLANTS COMPETE FOR THE LIGHT…IS THERE A POSSIBLE SOLUTION??





Photovoltaics Integration into Greenhouse Systems

Energy Producing Greenhouses; Elkas and Technokas, Wageningen UR

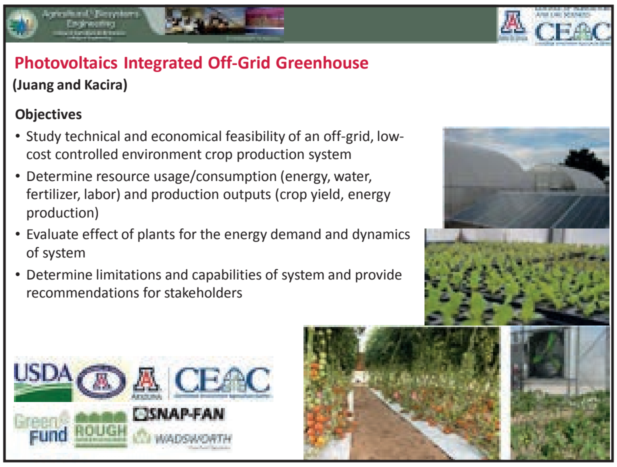
Yano et al., 2009 Minuto et al, 2009 Società agricola M&T Green Power, http://www.hortidaily.com

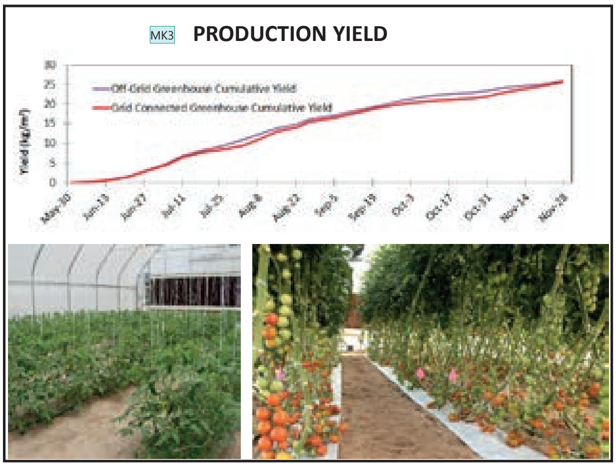
Energy demand, efficiency, system component
Al-Ibrahim et al., 2006; Campiotti et al., 2008,
Vox et al., 2010; Carbone et al., 2011, Marucci et al., 2012

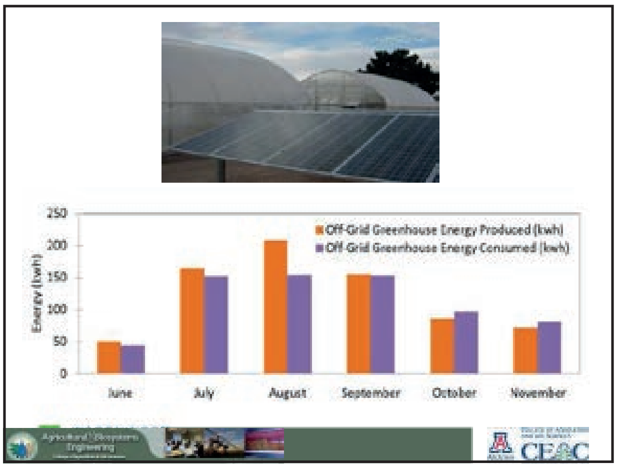
Juang and Kacira, 2013

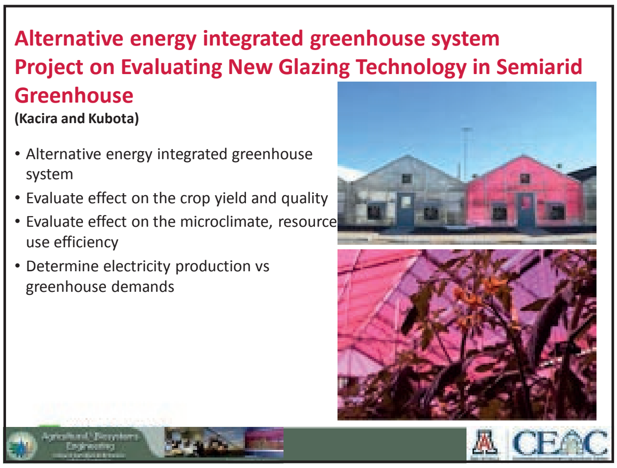
Partial shading, crop growth
Minuto et al., 2009; Dupraz et al., 2011; Carlini et al., 2012; Perez Alanso et al, 2012, Urena-Sanchez et al., 2012; Marrou et al., 2013;

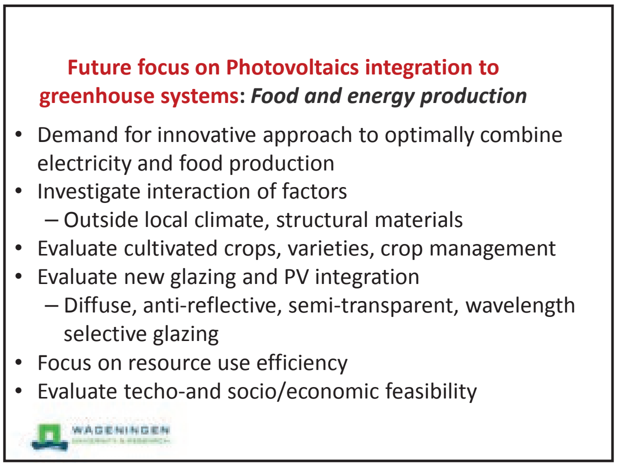
www.PVP.co.at

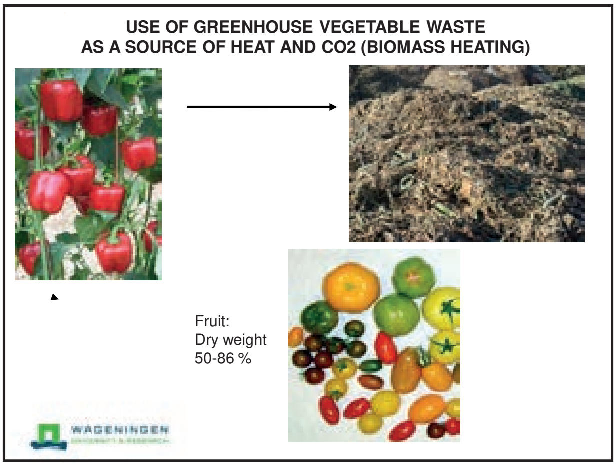

Photovoltaics Integrated Off-Grid Greenhouse
(Juang and Kacira)
Objectives
• Study technical and economical feasibility of an off-grid, low-cost controlled environment crop production system
• Determine resource usage/consumption (energy, water, fertilizer, labor) and production outputs (crop yield, energy production)
• Evaluate effect of plants for the energy demand and dynamics of system
• Determine limitations and capabilities of system and provide recommendations for stakeholders
USDA
CEAC
SNAP-FAN
Green Fund
ROUGH
WADSWORTH

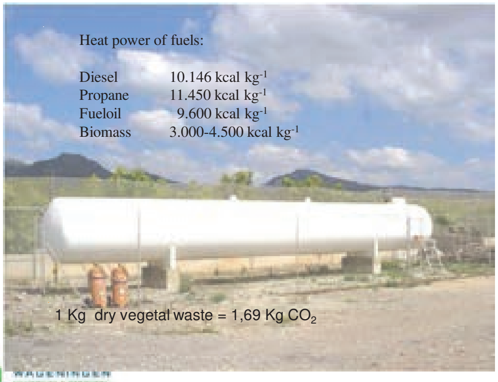

MK3
PRODUCTION YIELD
Off-Grid Greenhouse Cumulative Yield
Grid Connected Greenhouse Cumulative Yield
Yield (kg/m²)
30
25
20
15
10
5
0
May-30
Jun-13
Jun-27
Jul-11
Jul-25
Aug-8
Aug-22
Sep-5
Sep-19
Oct-3
Oct-17
Oct-31
Nov-14
Nov-28


Off-Grid Greenhouse Energy Produced (kwh)
Off-Grid Greenhouse Energy Consumed (kwh)
Energy (kwh)
250
200
150
100
50
0
June
July
August
September
October
November
Agricultural & Biosystems Engineering
CEAC


Alternative energy integrated greenhouse system
Project on Evaluating New Glazing Technology in Semiarid Greenhouse
(Kacira and Kubota)
• Alternative energy integrated greenhouse system
• Evaluate effect on the crop yield and quality
• Evaluate effect on the microclimate, resource use efficiency
• Determine electricity production vs greenhouse demands
Agricultural & Biosystems Engineering
CEAC


Future focus on Photovoltaics integration to greenhouse systems: Food and energy production
• Demand for innovative approach to optimally combine electricity and food production
• Investigate interaction of factors
– Outside local climate, structural materials
• Evaluate cultivated crops, varieties, crop management
• Evaluate new glazing and PV integration
– Diffuse, anti-reflective, semi-transparent, wavelength selective glazing
• Focus on resource use efficiency
• Evaluate techo-and socio/economic feasibility
WAGENINGEN UNIVERSITY & RESEARCH


USE OF GREENHOUSE VEGETABLE WASTE
AS A SOURCE OF HEAT AND CO2 (BIOMASS HEATING)
Fruit:
Dry weight
50-86 %
WAGENINGEN UNIVERSITY & RESEARCH



Heat power of fuels:

Diesel	10.146 kcal kg^{-1}
Propane	11.450 kcal kg^{-1}
Fueloil	9.600 kcal kg^{-1}
Biomass	3.000-4.500 kcal kg^{-1}

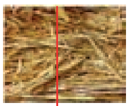
1 Kg dry vegetal waste = 1,69 Kg CO_2

WAGENINGEN

Types of biomass-vegetal waste

CROP RESIDUES

HERBACEOUS:



- WOODY

AGROINDUSTRIAL WASTES

- NUTS

- ALMAZARAS

GREENHOUSE VEGETAL WASTE

WAGENINGEN

Processing of the biomass

Non processed biomass

Densifying

Pellets and briquettes

Low density

Logistic problems:

- Storage
- Transport
- Conservation

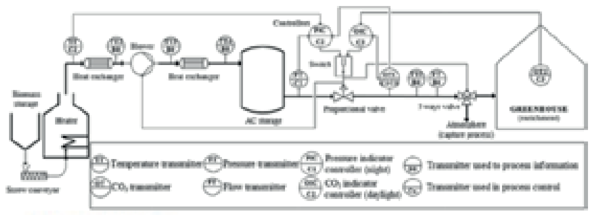
Multiple advantages:

- Clean
- Homogeneity
- Easy to store and move

WAGENINGEN

Development of a biomass-based system for nocturnal temperature and diurnal CO_2 concentration control in greenhouses

J.A. Sánchez-Molina, J.V. Reinoso, F.G. Acién, F. Rodríguez, J.C. López



WAGENINGEN

COMPLEX CONCEPTS FOR ENERGY AND WATER SAVING

WAGENINGEN

Closed and semi-closed greenhouses

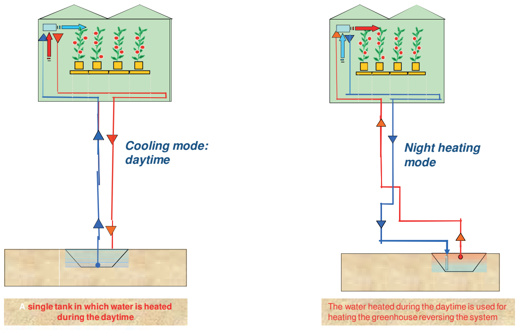
The extra sensible heat is normally evacuated through ventilation (natural or forced)…but

- Maintain high CO_2 concentrations → Higher production (especially in high radiation season)
- Reduce emissions (CO_2, pesticides)
- Reduce water use (depending on the system, water can be collected and re-used)
- Reduce risk of pests and diseases
- Reduce energy use (if heat is stored and re-used)

This is the main reason why from the 70's different experimental systems were tested to close the greenhouses

WAGENINGEN

OPERATION MODE IN COLD SEASON



Source: A. Grisey (CITFL, Balandran, France). Adapted.

SOLAR THERMAL ENERGY

HOT WATER CAN BE USED TO HEAT/COOL THE GREENHOUSE BUT ALSO FOR DESALINATION AND DISINFECTION (IF PROPER TECHNOLOGY IS USED TO ACHIEVE HIGH ENOUGH TEMPERATURE)

VERY HIGH INVESTMENT

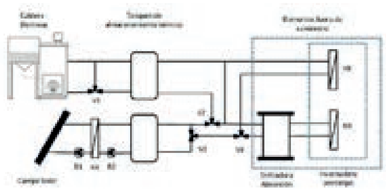
HIGH SPACE REQUIREMENTS

INTERESTING OPTION FOR GREENHOUSE COOLING IN ARID AREAS?

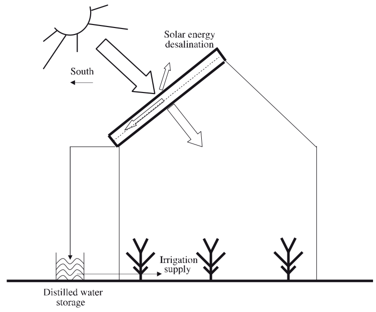
BIOGREEN PROJECT

Some recent attempts on the use of Solar Cooling, combining production of hot water from solar energy, cooled by absorption chillers…

THERMAL SOLAR COLLECTORS AND ABSORPTION SYSTEM APPLIED TO GREENHOUSE COOLING
ILEANA BLANCO, EVELIA SCHETTINI , GIACOMO SCARASCIA MUGNOZZA, GIOVANNI PUGLISI, CARLO ALBERTO CAMPIOTTI, GERMINA GIAGNACOVO , GIULIANO VOX



Biogreen project
New prototype of air cooled absorption chiller

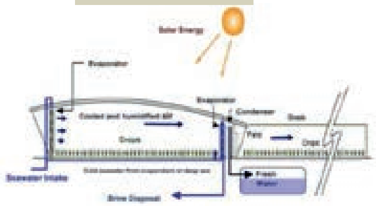


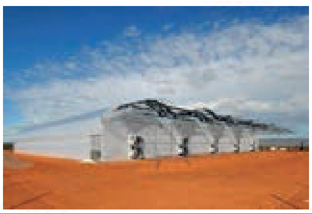
CHAIBI, 2003

Principle of a water desalination system integrated in a greenhouse roof

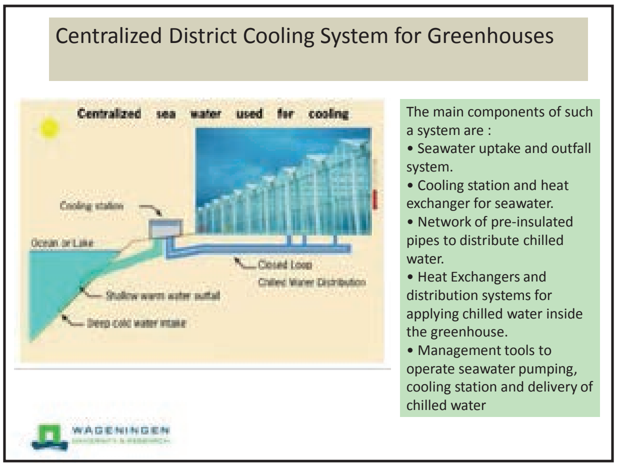
---

SEAWATER GREENHOUSE



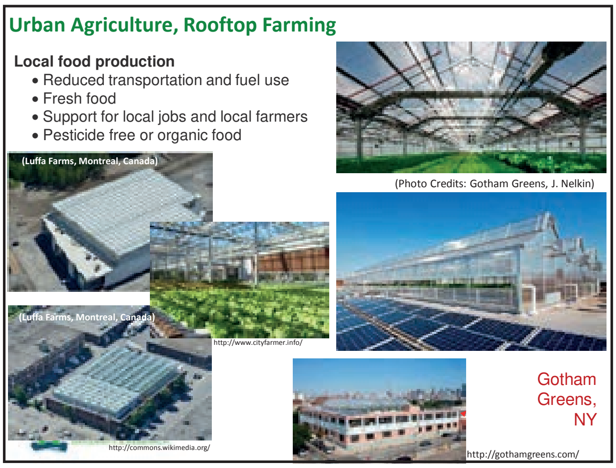


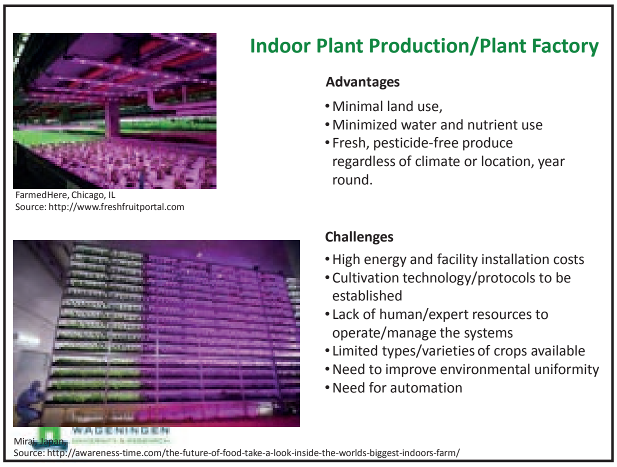
SAHARA PROJECT


Centralized District Cooling System for Greenhouses
Centralized sea water used for cooling
Cooling station
Ocean or Lake
Closed Loop
Chilled Water Distribution
Shallow warm water outfall
Deep cold water intake
The main components of such a system are :
• Seawater uptake and outfall system.
• Cooling station and heat exchanger for seawater.
• Network of pre-insulated pipes to distribute chilled water.
• Heat Exchangers and distribution systems for applying chilled water inside the greenhouse.
• Management tools to operate seawater pumping, cooling station and delivery of chilled water
WAGENINGEN


Converting food waste into useful products
30-40% of America's food is wasted
In the United States, 31 percent—or 133 billion pounds—of the 430 billion pounds of the available food supply at the retail and consumer levels in 2010 went uneaten. (Buzby et al. 2014, USDA Study)
Annual food waste by region (kg/person)
Organic fertilizer
Agriculture
Harvester
Refinery
CEAC


CEAC
Use Resources Wisely: Waste Management and Organic Liquid Fertilizer Use in CEA System (Jensen, Kacira, Giacomelli)
WISErg
CEAC


Urban Agriculture, Rooftop Farming
Local food production
• Reduced transportation and fuel use
• Fresh food
• Support for local jobs and local farmers
• Pesticide free or organic food
(Luffa Farms, Montreal, Canada)
(Photo Credits: Gotham Greens, J. Nelkin)
(Luffa Farms, Montreal, Canada)
http://www.cityfarmer.info/
http://commons.wikimedia.org/
Gotham Greens, NY
http://gothamgreens.com/


Indoor Plant Production/Plant Factory
FarmedHere, Chicago, IL
Source: http://www.freshfruitportal.com
Advantages
• Minimal land use,
• Minimized water and nutrient use
• Fresh, pesticide-free produce regardless of climate or location, year round.
Challenges
• High energy and facility installation costs
• Cultivation technology/protocols to be established
• Lack of human/expert resources to operate/manage the systems
• Limited types/varieties of crops available
• Need to improve environmental uniformity
• Need for automation
Source: http://awareness-time.com/the-future-of-food-take-a-look-inside-the-worlds-biggest-indoors-farm/
WAGENINGEN


Making Egypt a leading greenhouse horticultural producer...is possible!!
esteban.baezaromero@wur.nl
WAGENINGEN
60

Literature

Elings, A., S. Hemming, S. Bakker, E. van Os and J. Campen, 2015.
The African Greenhouse. A toolbox. Wageningen UR Greenhouse Horticulture Report GTB-1360, http://edepot.wur.nl/351439.

García Victoria, N., O. van der Valk, and A. Elings, 2011.
Mexican protected horticulture. Production and market of Mexican protected horticulture described and analyzed. Wageningen UR Greenhouse Horticulture, Wageningen, Report GTB-1126, http://edepot.wur.nl/196070.

Lans, C.J.M. van der, R.J.M. Meijer and M. Blom, 2011.
A view of organic greenhouse horticulture worldwide. Acta Horticulturae 915: 15-21.

Nour, M.H., A. Ghanem, M. Buchholz and A. Nassar, 2015.
Greenhouse based desalination for brackish water management using bittern evaporative cooling technique. Water Science and Technology: Water Supply 15(4): 709-717.

Pardossi, A., F. Tognoni and L. Incrocci, 2004.
Mediterranean greenhouse technology. Chronica Horticulturae 44(2): 28-34.

Scholten, H. and P. Raatjes, 2016.
Renewable energy & water nexus in the new land development project, Egypt. Final Report. EnergyWatch & RMA.

Siderius, C., P.E.V. van Walsum, C.W.J. Roest, A.A.M.F.R. Smit, P.J.G.J. Hellegers, P. Kabat and E.C. Van Ierland, 2016.
The role of rainfed agriculture in securing food production in the Nile Basin. Environmental Science & Policy 61: 14–23.

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

Wageningen University & Research,
BU Greenhouse Horticulture
P.O. Box 20
2665 ZG Bleiswijk
Violierenweg 1
2665 MV Bleiswijk
The Netherlands
T +31 (0)317 48 56 06
F +31 (0)10 522 51 93
www.wur.nl/glastuinbouw

Greenhouse Horticulture Report WPR-704

Wageningen University & Research, BU Greenhouse Horticulture initiates and stimulates innovations for a sustainable protected horticulture and a better quality of life. This is achieved by partnering with primary producers, the supply sector, plant breeding companies, the scientific community and governments in applied research.

The mission of Wageningen University & Research is 'To explore the potential of nature to improve the quality of life'. Within WUR, nine specialised research institutes of the DLO Foundation have joined forces with WUR to help answer the most important questions in the domain of healthy food and living environment. With approximately 30 locations, 6,000 members of staff and 9,000 students, WUR is one of the leading organisations in its domain worldwide. The integral approach to problems and the cooperation between the various disciplines are at the heart of the unique Wageningen Approach.