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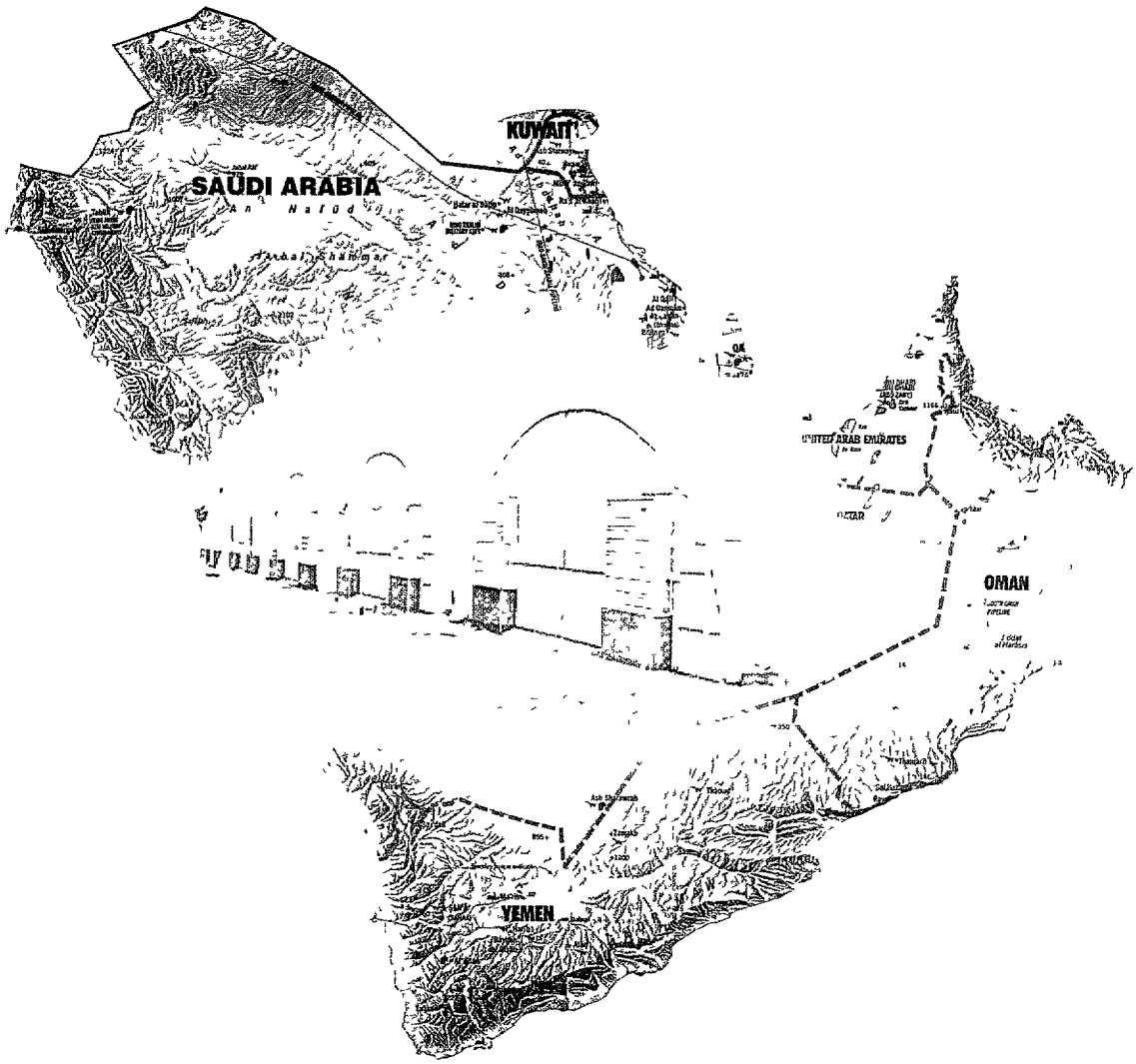
Protected Agriculture in the Arabian Peninsula



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Protected Agriculture in the Arabian Peninsula

Summary Proceedings of an International Workshop
15–18 February 1998, Doha, Qatar

Editors

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Foreword

Protected agriculture represents the most intensive and dynamic form of agricultural production In the Arabian Peninsula, the adverse climatic conditions of harsh weather, scarcity of water and limited land resources necessitate the use of protected agriculture where environment and production-timing can be controlled and yield can be improved

Investment in protected agriculture is high due to the cost of structures, good-quality water, hybrid seeds, specialized fertilizers, and chemical and biological control To achieve and maintain high levels of production, well-trained technicians and managers are required Well-designed greenhouses with sophisticated climate-control facilities can be very expensive, but can provide rich dividends It is important to recognize that an efficient greenhouse industry can have a significant effect on the economy of a country

Protected agriculture—with its associated growing systems—can minimize environmental degradation in a number of ways Compared with field crop production, protected agriculture can

1 significantly reduce the amount of water and fertilizers utilized in growing the product,

2 reduce and possibly eliminate the potential contamination of groundwater by fertilizers and pesticides,

3 provide the possibility of economically producing 'organic' products,

4 eliminate or minimize the use of toxic pesticides through the adoption of an improved integrated plant production and protection program aimed at preventing infestation and use of biological control methods

To review the state-of-the-art of protected agriculture in the region, this workshop, the first of its kind, was organized by the Arabian Peninsula Regional Program (APRP) and financially supported by the Arab Fund for Economic and Social Development (AFESD) and the International Fund for Agricultural Development (IFAD) International experts in different aspects of protected agriculture, together with the regional experts, researchers and specialists from the Arabian Peninsula countries attended this meeting to exchange information and discuss the present and future for protected agriculture in the Arabian Peninsula

The major aspects of protected agriculture addressed in this workshop were

- Greenhouse design, structure and covering materials
- Growing systems in relation to water-use efficiency, fertigation and postharvest technology
- Integrated plant production and protection
- Regional networking for the exchange of experience and information

The recommendations from this meeting form the basis for immediate and long-term strategies for protected-agriculture development in the Arabian Peninsula The issue of communication and exchange of information was highlighted in the workshop and as a result a Regional Network for Protected Agriculture is being developed

The meeting was mainly supported by AFESD and IFAD The Food and Agriculture Organization of the United Nation (FAO) contributed partially by supporting the participation of two scientists and financing the editing of the proceedings The workshop was organized locally by the Ministry of Municipal Affairs and Agriculture of Qatar and ICARDA

It was a step in the right direction for the Arabian Peninsula Regional Program (APRP) of ICARDA and the national, regional and international experts to build a strong, technically sound and efficient protected-agriculture industry in the Arabian Peninsula I trust that the following pages and the associated web-site will prove a valuable tool for all those involved in developing protected agriculture in the region as we move into the 21st century

Prof Dr Adel El-Beltagy
Director General
ICARDA

Editors' Note

These proceedings are only the first part of the output of the International Workshop on Protected Agriculture in the Arabian Peninsula, held in Doha, Qatar, on 15–18 February 1998 In addition to the abstracts of the technical papers and the summaries of the ensuing discussion sessions published here, the full papers will be made available In fact, this publication may be seen as a 'taster' for the outputs of the Doha Workshop

For those wishing to obtain more information on the technical presentations of the Workshop, the Arabian Peninsula Regional Program (APRP) of the International Center for Agricultural Research in the Dry Areas (ICARDA) has made the full papers available on its HomePage For those without Internet/World-Wide Web access, the word-processed files (in Microsoft Word 97) are available from the APRP Office in Dubai At the time of going to press, the APRP HomePage had yet to be established Information on how to access the information can be obtained through the Dubai office

The APRP Dubai Office may be contacted by e-mail at either *<icdub@emirates net ae>* or *<A Moustafa-t@cgiar org>*

We hope that you will find the information on the HomePage both easy to access and relevant to your needs Look out for the discussion forum for matters of relevance to protected agriculture in particular and to APRP in general

The Editors

Acknowledgments

The organizing committee and participants would like to express their sincere gratitude to the Government and people of Qatar for the kind hospitality that they all enjoyed while in Doha, in particular to the Department of Agricultural and Water Research of the Ministry of Municipal Affairs and Agriculture in hosting this meeting, the Minister H E Ali Bin Saeed Al Khayareen, and the Undersecretary, Eng Ali Bin Saad Al Kuwari

Particular thanks to Mr Abdulla Salem Al Sulaiteen, the Chairman of Al Sulaiteen Agricultural Complex for hosting a wonderful cultural evening and dinner at his farm

Thanks also to the owners and management of the following farms that were visited during the meeting

- Al Sulaiteen Agricultural Complex, Aum-Salal Ali
- The Arab Qatari Agricultural Production Company, Al Shahania
- Al Sameria Farm, Al Shahania
- The Horticulture and Greenhouse Research Station, Ottoria

Thanks also to Drs Wilfried Baudoin (FAO) and Khaled Makkouk (ICARDA) for their considerable help with the reporting of the final discussion sessions

Thanks to the Food and Agriculture Organization of the United Nation (FAO) for their contribution to this workshop by supporting the participation of two scientists and financing the editing of the proceedings

Finally our thanks and appreciation for the two main donors, the Arab Fund for Economic and Social Development (AFESD) and the International Fund for Agricultural Development (IFAD) for their highly valued financial support

Introduction

John M Peacock
APRP, ICARDA, Dubai, UAE

The Project

In May 1993, at an Arabian Peninsula Regional Program (APRP) meeting held in Abu Dhabi, UAE, the participants stressed that the APRP must serve and be responsive to the **principal needs** of the seven countries of the Arabian Peninsula

More effort should be made in the research areas of specific interest to the region such as salt tolerance, heat tolerance, drought, disease and pest resistance, weed control, water conservation and management, water-use efficiency, irrigation techniques, irrigated and perennial forages, forage shrubs, **horticulture and protected agriculture**, in addition to on-going cooperative activities such as networking

Out of this meeting, Phase II of the APRP was born—*Strengthening Agricultural Research and Human Resource Development in the Arabian Peninsula*—with the Arab Fund for Economic and Social Development (AFESD) and the International Fund for Agricultural Development (IFAD) as the two main donors

In late September 1996, at the first Regional Steering Committee Meeting of Phase II of the project, the priority areas of research were established, and at the first Regional Technical Meeting held in Aleppo in early March 1997, the four main research themes for Phase II of this project were determined

1 Rangeland, shrubs, irrigated forages and livestock
2. Protected agriculture
3 Abiotic stresses
4 On-farm water use and irrigation management

Countries

The project covers the countries of the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) and Yemen, combining a total area of 246 million hectares

Climate and Soils

The Arabian Peninsula is characterized by an arid and semi-arid climate Rainfall is highly erratic in space and time —annual precipitation generally ranges from

less than 50 mm to 250 mm in the agricultural areas (although some areas of Oman and Yemen receive much more rainfall), there is an accompanying variation in the duration of the growing season, from 0 to 150 days Temperatures are generally high, reaching 50°C at times in some places in summer—the main problem is prolonged hot periods (over 35°C) through the summer, when the relative humidity is also often high

The soils of the region are fragile and subject to erosion by wind and water, as well as degradation through salinization Over 95% of the total land area in the Arabian Peninsula suffers from some form of desertification, of which 44% is severely or very severely degraded, wind and water erosion account for over 60% of the desertification

Population

The region's population was estimated at 43 million in 1995 and—with average annual national growth rates ranging from 2 2 to 4 2%—it is expected to more than double, to 92 million, by the year 2025 The total commodity demands resulting from population growth in the Arabian Peninsula has caused a rapid increase in food imports Food imports are expected to more than double by 2010, if per-capita consumption remains the same and domestic productivity is not increased

Land Uses

Of the total 246 million hectares, 120 million hectares (49% of the total land area) is under permanent (natural) pasture, mostly in Saudi Arabia and Yemen In 1995, the area under arable land and irrigated crops was less than 2% (5 2 million ha) Desert dominates the rest of region In locations where natural vegetation is sufficient it is used for livestock grazing In 1992, the region supported 19 million small ruminants (sheep and goats) and a further 840,000 camels

Water Availability

Given the limitations in rainfall and the lack of available surface water (only the UAE and Yemen have significant surface-water resources), most of the cultivated areas in the Arabian Peninsula depend, to a large extent, on irrigation from groundwater, springs, *aflaj* canals and a series of small dams which harvest run-off water

Because of the increasing demand for water, several countries in the Peninsula have established large projects for water desalination and for recycling of the treated sewage effluent (TSE) for agricultural use Such non-conventional sources

now account for 16% of the total available water resources in the region However, estimates for 1990 of the annual requirements of water for self-sufficiency, including agriculture, of 24 billion cubic meters (bcm), far exceed the total water available, 14 bcm Estimated actual water use in 1990 exceeded the available water by 1 4 bcm (equivalent to 43 m^3 per capita), attributable mainly to the large deficits in Saudi Arabia and Yemen, this deficit is forecast to increase to 8 4 bcm, or 185 m^3 per capita, by the year 2000

The investigation of both traditional and innovative water harvesting and conserving techniques, improved irrigation techniques, and water management and water-use efficiency is, therefore, an important component of the project

Agricultural Production

Almost 70% of the total available water in the region is allocated to agriculture It is estimated that 22% of the total land area is potentially cultivable Cultivation expanded from 1977 to 1993, with the area under arable and permanent crops increasing by 60% (from 3 3 to 5 3 million ha) and the irrigated area increasing by 75% (from 0 8 to 1 4 million ha) However by 1995, the irrigated area was down to 1 1 million hectares, largely due to a 54% reduction in irrigated area in Saudi Arabia

There is considerable heterogeneity in the countries of the Arabian Peninsula with respect to agricultural production The countries with a substantial agricultural sector, in terms of agricultural area, production and proportion of the population involved in agriculture, are Oman, Saudi Arabia and Yemen

The countries with a modest agricultural sector are Bahrain, Kuwait, Qatar and the UAE The cultivated areas in these countries are relatively small and scattered, and support a minimal proportion of the population Per-capita food imports are consequently higher than in the more agriculturally oriented countries, and demand for cereals—particularly wheat and wheat products—is met almost entirely by imports Agricultural production depends mainly on irrigation from groundwater and, to a lesser extent, on rainfall during the winter (November–February) Agricultural production in these countries, as in the countries with more substantial agricultural sectors, is constrained by severe biotic and abiotic stresses including heat, salinity, lack of improved cultivars and cultural practices, as well as lack of trained manpower

Protected Agriculture Workshop

The priority research areas under Protected Agriculture in the APRP are

1 Improved designs of structures including covering material and cooling systems

2 Improving water-use efficiency through efficient growing systems and techniques including fertigation
3 Improved management or integrated disease/pest management systems

A main aim of this workshop was to review the state of the art of protected agriculture in the Arabian Peninsula with particular reference to the research-priority themes Each theme was thoroughly reviewed by the international and regional experts and the various country representatives, providing a synthesis, a series of recommendations and a strategy for the next decade As a result of this productive interaction between the various international, regional and national experts, it was decided that a network for protected agriculture in the Arabian Peninsula needed to be set up to maintain this exchange of information and improve future communication

The strategy presented will be considered by the Steering Committee of the APRP, as a guideline for the next phase of the project research work

Opening Addresses

Opening Address by Mr Ali Bin Saad Al Kuwari

Undersecretary of the Ministry of Municipal Affairs and Agriculture, Qatar

بسم الله الرحمن الرحيم

All praise be to God, the Lord of the worlds, the blessings and peace be upon the noblest of all messengers Peace, grace and blessings of Allah be upon you all

His Excellency, Prof Dr Adel El-Beltagy, respected guests, dear audience

It gives me great pleasure to welcome you all on my behalf and on behalf of the Ministry of Municipal Affairs and Agriculture It also gives me pleasure to convey to you the greetings of His Excellency Mr Ali Bin Sa'eed Al Khayareen, the Minister of Municipal Affairs and Agriculture We wish you a happy stay amongst us

The Ministry of Municipal Affairs and Agriculture has made a practice of cooperating with regional and international organizations in supporting agricultural activity and its various branches locally, regionally and internationally, proceeding from eminent instructions and enlightened policies of His Highness Sheikh Hamad Bin Khalifa Al Thani, Emir of Qatar and His Highness Sheikh Jassem Bin Hamad Al Thani, the Heir Apparent in supporting Gulf, Arabian, regional and international cooperation for the common benefit of all

Today, the International Workshop on Protected Agriculture in the Arabian Peninsula is held as a result of the continued cooperation between the Ministry and the International Center for Agricultural Research in Dry Areas (ICARDA), which has kept on supporting the agricultural sector in different countries of the world

Providing food to the world population has become a major issue, the consequences of which are becoming more serious day by day The effort to increase production has become an important struggle between scientists and various factors of nature Perhaps protected agriculture, with all its technologies, can be one of the best solutions, especially in areas which are suffering from the triangle of natural impediments namely soil, water and weather From this point, benefiting from world experience in supporting local programs is considered inevitable Likewise, regional cooperation—preventing doubling of research work

within the countries of one region—is a matter of policy in accelerating the process of problem-solving, and effort and money—saving both of which serves the interests of all

No doubt, the experiences and information that are put forward and the meaningful scientific discussions held will enrich this meeting and strengthen our mutual cooperation

In conclusion, I would like to assure you of our strong desire to support the activities of this Workshop and that the Ministry will serve fully to achieve success

Lastly, I express our gratitude again to ICARDA and the donors for their generous funding and support in holding this Workshop on time and in selecting Qatar as the venue

I would also like to thank very much all the members of the Joint Organizing Committee who worked hard actively and earnestly in the arrangement of this Workshop

Thanks to all those who contributed at any stage of the preparation and execution of this workshop

Peace and blessings of Allah be upon all

Opening Address by Prof. Dr Adel El-Beltagy

Director General, ICARDA

بسم الله الرحمن الرحيم

Mr Ali Bin Saad Al Kuwari, The Undersecretary of the Ministry of Agriculture, colleagues and friends

It is my pleasure and delight to be present here with you in this meeting this morning, in this first workshop within the context of the Arabian Peninsula Regional Program of the International Center for Agricultural Research in the Dry Areas The Workshop will be addressing a topic of great importance not only to the Gulf, but also for other areas in the world Protected agriculture is the most dynamic agriculture system worldwide The different components need a lot of manipulation and a lot of understanding, for several avenues of science are involved and in this Workshop we are going to address them The system itself is the art of optimizing production per unit area and per cubic meter of water This optimization is the main issue and it covers water-use efficiency and fertigation During this week, a lot of colleagues and experts from around the world are going to share their experiences with those of our colleagues from the Gulf

The important issues of physical structure, integrated pest management and other management techniques will be addressed in this Workshop The postharvest aspect is also important, because it starts early in the process of the other management systems

I hope that you will have a very fruitful meeting One issue which we are hoping that we could achieve is networking We hope that a network between colleagues who are involved in this process will exist in the Gulf, therefore, exchange of information will be a basic issue

I would like to thank the people of Qatar who are known for their hospitality, which we are all enjoying, and on behalf of all of you we would like to thank His Royal Highness Sheikh Hamad Bin Khalifa al-Thani, Prince of Qatar I am sure that we are in very good hands Also, let me specifically thank His Excellency the Minister Ali Bin Sa'eed Al Khayareen, and our colleagues from the Ministry of Agriculture and thanks to the Government of Qatar for hosting this very important meeting We look forward to hearing your recommendations Thank you

Opening Address by Mr Abdulrahman Al Mahmoud

Director, Department of Agricultural and Water Research (DAWR)

بسم الله الرحمن الرحيم

Your Excellency, Prof Dr Adel El-Beltagy, Director General, ICARDA, dear brothers

The Agricultural and Water Research Department has the honor to welcome all of you on the opening of the International Workshop on Protected Agriculture in Arabian Peninsula which is one of the most important activities of the APRP It is of our pleasure to assure you that, all of our resources are at your disposal to assist your workshop

We hope that the discussion will include all aspects of protected agriculture, looking for the benefits from the gathering of experts and participants Finally, we wish that the APRP will fulfill its goals to serve the agricultural sector in the participating countries with the cooperation of the International Center for Agriculture Research in the Dry Areas (ICARDA)

Best wishes for a successful workshop and I wish you all a pleasant stay in Qatar

Opening Address by Dr Mahmoud B. Solh

Director of International Cooperation, ICARDA

بسم الله الرحمن الرحيم

Your Excellency Engineer Ali Bin Saad Al Kuwari, Undersecretary of the Ministry of Municipal Affairs and Agriculture, Prof Dr Adel El-Beltagy, the Director General of ICARDA, distinguished delegates, colleagues and friends

This important activity is part of the Arabian Peninsula Regional Program, which is supported by the Arab Fund for Economic and Social Development as well as the International Fund for Agricultural Development At the first Steering Committee of the Second Phase of this project—in late September 1996—, the priority areas of research were identified In the First Regional Technical Meeting—which was held at ICARDA's Headquarters in early March 1997—it was agreed to focus on four major themes for agriculture development in the Arabian Peninsula These are rangeland rehabilitation and management, irrigated forages and livestock, protected agriculture, abiotic stresses, and on-farm water use and irrigation management Activities in these themes are conducted in collaboration among the national agriculture research systems in the countries of the Arabian Peninsula—Bahrain, Kuwait, Qatar, Saudi Arabia, Oman, the United Arab Emirates and Yemen—as well as ICARDA

The major goal of our important activity today is to develop a strategy for the improvement of protected agriculture in the Arabian Peninsula for the coming decade We will be focusing on greenhouse design and management, water-use efficiency and fertigation, integrated plant production and protection, networking both within the Arabian Peninsula and with centers of excellence of all over the world, and human-resource development This Workshop is providing us with the opportunity to know the state of the art in protected agriculture in the Arabian Peninsula, as well as in centers of excellence all over the world We all look forward to the deliberations of this Workshop

In closing, I would like to thank Your Excellency and the Government of Qatar for hosting this meeting Appreciation is expressed to the donors for their support and their encouragement

Wishing you fruitful deliberations and a successful meeting

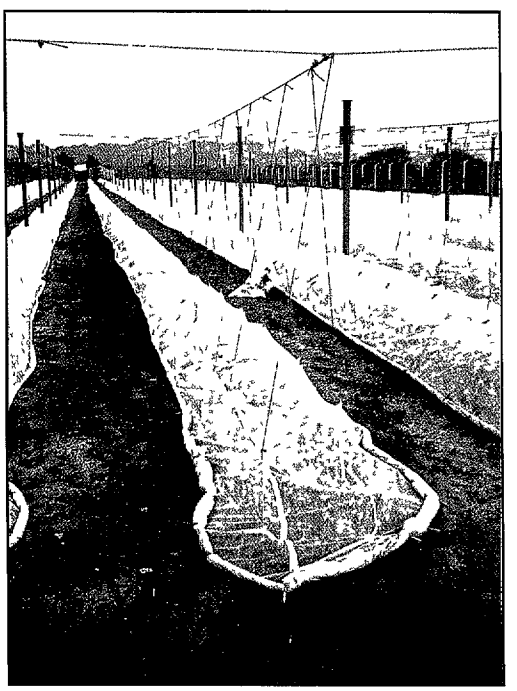
State of the Art of Protected Agriculture in the Arabian Peninsula

Overview of Protected Agriculture in the Arabian Peninsula

Ayman F. Abou-Hadid
Ain Shams University, Cairo, Egypt

This review covers the countries of the Gulf Cooperation Council (Bahrain, Kuwait, Qatar, Saudi Arabia, Oman and the United Arab Emirates) and Yemen—a total area of 246 million hectares

The introduction of greenhouse activities to the Arabian Peninsula (AP) started as early as the 1960s in the Gulf area The protected-agriculture area has increased substantially since then The types of protected agriculture (PA) range from low tunnels to sophisticated glasshouses with heating and cooling capabilities The most common house type is the single-span tunnel plastic-house covered with polyethylene sheets of 200 μm thickness



Low tunnels with insect-proofing net, Mirak Agricultural Services Co , UAE

The cost of plastic houses varies from one country to another, but the average is about US$13 per square meter Climate modification of greenhouses varies according to the needs of each country In general, the special requirements in the Arabian Peninsula countries are related to high temperature and, in many places, high relative humidity, which reduce the potential of using evaporative cooling systems Irrigation systems in greenhouses are mainly localized and are predominantly pressurized systems such as drip or trickle irrigation, low-pressure sprinklers and mist irrigation

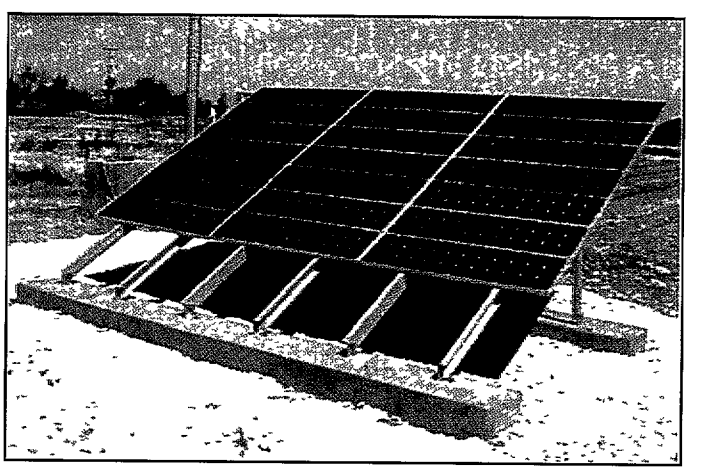
Most of the countries use soil-based cultivation techniques, although some soilless culture and hydroponic systems have been introduced on a commercial basis The main crops grown under PA are vegetables—such

as tomato, pepper, cucumber, cantaloupe, green bean, squash and eggplant—and fruit—such as watermelon and strawberry Some ornamentals are cultivated in many countries but on a limited scale The productivity of the crops varies widely from one country to another, depending on the cultivation technique and the infrastructure used for production. Some crops are produced at levels comparable with PA elsewhere in the world, while others are below the international average yield

The inputs of PA are largely dependant on imported materials such as seeds, fertilizers, pesticides and soil-disinfection chemicals, which pose constraints on the economics of production

The production of high-quality fruits that can compete on the international markets could be improved The most important constraints, needs and problems related to PA in the Arabian Peninsula can be summarized as follows

- The design and construction of structures that can protect plants under the long hot season and relatively short, mild winter
- The availability of scientific and technical personnel, and laborers for production practices
- Solving the problems of natural-resource management such as water desalination and the utilization of wind and solar energy in the production systems
- Problems related to the application of pest- and disease-control measures, and the rational utilization of water and fertilizers
- The use of soil-based versus soilless culture and the limits of technology utilization in the light of cost and returns of the products and their compatibility in local and international markets
- The quality of products to suit the increased quality demands of local markets and the availability of good-quality products from international markets



Utilization of solar power for water management on the Horticultural and Greenhouse Experimental Station, Qatar

- The availability of inputs such as seeds and chemicals and the cost involved
- Improving the research and teaching capability in subjects related to protected agriculture
- Provision of extension and agricultural advice and administration
- Training facilities
- Support services such as cooling, grading, sorting, packing, insurance and transportation
- Laboratories for soil, plant and residue analysis
- Scientific and extension publishing and the accessibility of information to growers and investors

Protected Agriculture in the State of Bahrain

Sheikh Mohamed Abdul Wahab Al-Khalifa and Mohammed T Al-Shaikh
Ministry of Works and Agriculture, Manama, Bahrain

Abstract

Protected agriculture (PA) was introduced into Bahrain in 1976 and by 1996 the total area under protected cultivation was 59 5 ha Interest in PA among farmers, and investors is increasing The greenhouses used are plastic tunnels, the commonest being high (2 5–3 m) single-span tunnels, 36–40 m long Humidity is a serious problem, specially from March onwards Ventilation area is about 10% comprising openings in the tunnels sides, sometimes with electric fans Fan-and-pad cooling has also been used, but is inefficient in the hot and dry Bahrain climate Shading (25–50%) is often used in March, after removal of the plastic covering This reduces inside temperature, but exposes crops to white fly The inefficiency of cooling systems is the major constraint in PA in Bahrain The main PA crops are tomato and cucumber, and both are pruned Drip irrigation works well in PA in Bahrain Ground-mulching with black polyethylene film is commonly practised Soil solarization is used to control soil pests for short-season vegetables, otherwise pest control is chemical Weeds are controlled by weeding, but those outside the greenhouse are essentially ignored Research and extension have covered cultivar selection, drip irrigation, ground-mulching, planting date, shading, plant density, fertigation, pruning and cropping patterns Current constraints to PA development include high cost of inputs, lack of skilled staff, pests and diseases, marketing, and lack of crop diversity The following are needed to help Bahrainian PA progress better designs for land-use efficiency, improved cooling, soilless techniques, integrated and biological pest control, improved water-use efficiency, diversification of crops adapted to the environment

Introduction

Despite limited land and water resources and constraints of climatic conditions, the Government of Bahrain has been encouraging agricultural development in both public and private sectors by providing various facilities, and strengthening research and extension activities This comes within the government's long-range aims of achieving a higher level of self-sufficiency in various agricultural products and in particular high-quality fresh vegetable crops

Protected agriculture was introduced in Bahrain in 1976, and significant changes in the total area of greenhouse vegetable production have occurred The total area under cultivation was 59 46 ha in 1996 An increasing number of farmers are now attracted to this new system of intensified cropping Other investors with capital

and land are also becoming interested We have also been encouraged by the tremendous achievements realized in almost all neighboring countries, where self-sufficiency and even surplus of certain crops for export have been reported

Structure and Covers Used

The structures used for protected vegetable production in the country include low, medium and high walk-in tunnels (usually called plastic houses), erected as single-spans, with frames made of galvanized steel pipes about 22 mm in diameter, aluminum or coated steel pipes The dominant structures are high single-span plastic tunnels, 4–5 m wide, 2 5–3 m high and 36–40 m long (total surface area 140–180 m^2) The cover for tunnels is imported or locally manufactured plastic film of different width and lengths, with a thickness ranging from 38 μm for low tunnels to 250 μm for walk-in tunnels and with ultraviolet-ray inhibitor (UVI) to increase its durability (2–3 years)

Ventilation, Shading and Cooling

Humidity is a major problem in the greenhouse Large quantities of water are transpired through the leaves and evaporate from the soil and the water vapor cannot escape This results in high humidity levels, creating optimal conditions for infection by and proliferation of fungal and bacterial diseases Ventilation is achieved by openings in tunnel sides, but is often insufficient to prevent high humidity, this problem is aggravated towards the end of the season (March onwards) when the outside temperature increases At the present time, ventilation areas are about 10% There are some thoughts of including vents in the roof so that hot air can escape by normal upward convection Electric fans are sometimes used to improve ventilation

We have taken to removing the plastic film cladding from greenhouses in March and covering the frame with shade net cover giving 25 to 50% shading This reduces the temperature inside the house as a result of heat reflection and reduced light intensity Shading has also been useful for the early production of vegetable seedlings from August to September and for extending the season of some vegetables in the open field However, shading does not protect the crop from white fly No doubt, potential crop yield and quality would improve by using white-fly-proof clear fine mesh

The traditional fan-and-pad cooling system was introduced to extend the season of vegetable production through the hot summer Unfortunately, the system loses its efficiency under the extremely high temperatures and high relative humidity prevailing in the country The lack of an efficient and economical cooling system continues to be a major constraint facing the development of protected agriculture

Participants discussing the production of cut-flower roses in open soilless system of sandbags, Ottoria Research Station (Qatar)

Cultivars

Many productive hybrids of various vegetables have been introduced and evaluated under local conditions, with emphasis on salt and disease resistance

Cultural Practices

Drip irrigation performs well under the prevailing water and soil conditions Crop rotation has not received adequate consideration The main vegetable crops produced under protected agriculture are tomato and cucumber Pepper, squash, snake cucumber, eggplant, lettuce, strawberry, bean and cut flowers have been introduced on a small scale

Ground-mulching with black polyethylene film is a common practice It significantly reduces water evaporation, raises soil temperature, eliminates weeds, prevents salt accumulation around the plants, and leads plants to early production

Pruning of tomato and cucumber under plastic is practised Organic and chemical fertilizers and composts have been used Experimental stations apply chemical fertilizers through irrigation systems and as foliar sprays

Vegetables grown under protected agriculture have been subject to severe infections by diseases and insects Common diseases and insects are white fly,

aphids, mites, mildews and blight, but viruses have been reported to be the most serious and difficult Insects and mites are controlled chemically The soils of the country are generally infested with nematodes and soil pathogens Soil solarization is applied successfully to short-season vegetables Control measures against these pests comprise application of chemicals, including Basamide, Vydate and methyl bromide fumigation, as well as the use of resistant cultivars Biological pest control is not practised and, because of the frequent chemical treatments, natural enemies are almost absent in greenhouses although they may be found on field crops

Weeds do not cause a serious problem in protected vegetable production Annual weeds are the most common and their control is almost exclusively cultural, no herbicides have been used other than on a trial basis Weeds outside the greenhouse may be important secondary hosts for pests and viral diseases, but are generally ignored as such

In general, considerable research has been done on the selection of suitable crops and cultivars, drip irrigation, ground-mulching, dates of planting, shading, plant density, fertigation, pruning and cropping patterns Many of the positive results are being transferred to farmers' fields through an organized demonstration program

In summary, various degrees of success have been achieved in this field Further progress, expansion and development of protected vegetable production are generally facing the following constraints

- High initial cost of agricultural inputs
- Lack of skilled technical personnel
- Lack of an efficient and economic cooling system
- Pests and diseases in soil and on plants
- Marketing of the produce
- Need for diversification of crops

Technology to be Developed

- Improvements in structural design of the tunnels with more emphasis in multi-span tunnels for better utilization of limited land resources
- Improved cooling system for out-of-season production
- Introduction of soilless culture techniques and systems
- Development of integrated pest management and biological control
- Better utilization of limited land and water resources
- Introduction of new crops and cultivars and cultural techniques adapted to protected agriculture and the arid desert environment prevailing in the country

Protected Agriculture in the State of Kuwait

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Abstract

Because of the country's harsh climate, scarce water resources and poor-quality land resources, protected agriculture (PA) has a significant role in Kuwait's agricultural development Despite difficulties, PA made spectacular progress during the 1980s (area increased from 3 5 ha in 1979/80 to 425 ha in 1989/90) and was beginning to establish an important niche in the national economy just prior to the Iraqi invasion in 1990 The 1980s boom in PA is still suffering from the extensive damage caused by the Iraqi invasion The postwar revival of greenhouse agriculture has been relatively rapid in the Wafra area, where over 90% of the pre-invasion area under PA had been rehabilitated by 1992/93 The technology used in Kuwait's PA ranges from simple uncooled and unheated plastic tunnels to very sophisticated computer-controlled, cooled and heated, metal-frame glasshouses Approximately 85% of the PA is carried out in uncooled (57%) and cooled (28%) plastic tunnels, with the remaining 15% in cooled greenhouses covered with fiberglass, glass or acrylic material Cucumber and tomato are the two main crops grown in PA, accounting for approximately 90% of the total area The relatively large area under uncooled tunnels results in overproduction during a short period (January to April) and price collapse in the local market, during the remaining period, import levels are high and prices offered are competitive Production expansions were and still are pursued without adequate consideration of efficiency or quality, resulting in technical and economic inefficiencies Inappropriate production technologies are adopted without considering the available soil and water resources The lack of research and testing of technologies for adaptation in Kuwait leaves the farmers reliant on suppliers, who may be biased toward profit rather than efficiency Productivity below international levels is attributed to gaps in technology adoption, unskilled labor force and inefficient management

Protected agriculture is expected to become an important agribusiness industry in Kuwait with greater impact on the national economy than was traditionally perceived For these opportunities to be realized, PA has been identified as a priority area in the 20-year agricultural Master Plan recently developed by the Kuwait Institute for Scientific Research (KISR) This Plan calls for careful evaluation and adoption of modern technologies The Plan also calls for productivity enhancements of at least two- to four-fold by the year 2015 These targets are easily attainable if greenhouse crop production is made efficient, productive and sustainable The main thrust of KISR's PA research in the coming years will, therefore, be to develop, test and demonstrate various water- and

energy-efficient technology packages, and to demonstrate and provide training in high-quality management

Introduction

Like other countries in the Arabian Peninsula, an important aspiration of Kuwait is to achieve at least a modest level of self-sufficiency in food production To fulfill this aspiration, the State of Kuwait has made massive investments during the past 30–40 years to create favorable conditions for crop, poultry and dairy production This has opened up enormous opportunities for agricultural expansion As a result, the agricultural sector witnessed impressive growth during the 1980s Agricultural output doubled and greenhouse production, particularly that of tomato and cucumber, increased spectacularly during the period 1983–88 Although the contribution of agriculture to the national GDP was still small, the agricultural sector was making considerable inroads in providing fresh food commodities, in fulfilling citizens' aspirations, in developing career opportunities, and in diversifying income sources The agricultural boom of the 1980s is still suffering from the damage caused by the Iraqi invasion in 1990 and the slow rehabilitation of protected-agriculture (PA) infrastructure

Different kinds of protected environments are created to alleviate the adverse impacts of hot desert conditions in fresh-vegetable production Besides making cultivation less vulnerable to extreme environmental conditions, PA structures have provided opportunities for extending the growing season and have increased the availability of better-quality fresh vegetables Although past accomplishments have been noteworthy, much remains to be done in Kuwait's PA yields need to be improved substantially, production systems need to be made water- and cost-efficient, product quality needs to be improved and standardized further, and resource utilization needs to be controlled and made sustainable This paper analyzes the status of PA in Kuwait, the problems faced by greenhouse growers and the measures proposed by the Kuwait Institute for Scientific Research (KISR) to overcome some of these problems

Overview of Protected Agriculture in Kuwait

Kuwait's protected agriculture (PA) started in the late 1970s and showed spectacular growth during its initial 10 years This was evident from the fact that the area under PA increased from 3 5 ha in 1979/80 to 424 9 ha in 1989/90 (Fig 1) Protected agriculture accounted for approximately 8% of the total cropped area in 1988/89, and contributed over 37% to the total crop production of the country, suggesting that it was beginning to establish an important niche in the national economy just prior to the Iraqi invasion in 1990 Greenhouse crop production was concentrated almost equally in the Wafra (in the south) and

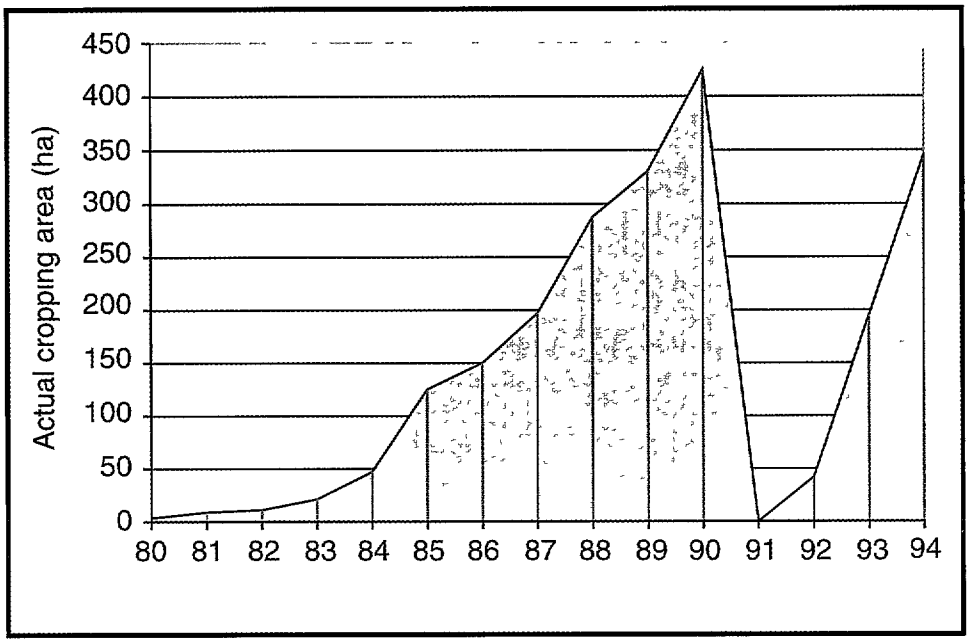


Figure 1. Area under protected agriculture in Kuwait.
Sources KISR (1995), Attar and Shalabı (1993), PAAAFR (1995)

Abdally (ın the north) areas In Wafra, about 66% of the greenhouse area durıng the pre-ınvasıon era was uncooled and about 5% was under fiberglass Abdally had more advanced greenhouses than Wafra The PA ın both locatıons ıs stıll suffering from the extensıve damage caused by the ınvasıon The postwar revıval of greenhouse agrıculture has been relatıvely quıck ın Wafra, where over 90% of the former area under PA was rehabılıtated by 1992/93 and ıs expandıng steadıly The restoratıon of damaged greenhouses ın Abdally, however, has been rather slow (Table 1) The current state of PA ın terms of greenhouse desıgns and management, adoptıon of efficıent water-use and fertıgatıon technology, plant protectıon, along wıth constraınts ıs summarızed below

Table 1. Dıstribution of protected agriculture area in Kuwait.

Location	PA cropped area (ha)			
	1989/90	1991/92	1992/93	1993/94
Wafra	184 6	41 1	179 5	289 2
Abdally	238 7	0 8	14 6	54 7
Sulaıbıya	1 6	0	0 9	1 3
Total	424 9	41 9	195 0	345 2

Source PAAAFR (1995)

Greenhouse Design and Management

A number of reports have dealt with PA in Kuwait (Jensen 1992, Riley 1992, Mansour et al 1992, Basham et al 1993, Attar and Shalabi 1993, KISR 1995) In addition, KISR undertook a survey of commercial greenhouses in the Wafra area in 1993 The PA of vegetables is presently being done in cooled or uncooled plastic tunnels and environmentally controlled greenhouses (KISR 1995) An estimated 85% of the PA is carried out in uncooled (57%) and cooled (28%) plastic tunnels (Table 2) The remaining 15% of production is under cooled greenhouses covered with fiberglass, glass or acrylic material, the most advanced being a few computer-controlled, cooled and heated, metal-framed glasshouses The average size of PA holdings in Wafra is about 2 0 ha (Mathijssen et al 1993)

Table 2. Distribution of protected agriculture area according to the type of covering material.

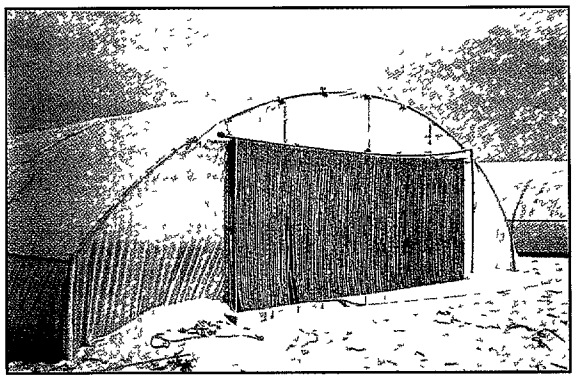
Crop	Covered area (ha)				
	Plastic tunnels	Acrylic	Fiberglass	Glass	Total
Tomato	114 0	0 9	9 5	0	124 4
Cucumber	266 1	0	34 6	2 7	303 4
Eggplant	30 5	0 4	1 8	0	32 7
Pepper	23 9	0	1 1	0 5	25 4
Total fruit-veg	475 1	2 1	47 5	3 2	527 9
Leafy veg	15 1	2 9	1 5	0	19 5
Tuber/root veg	8 1	0 5	0 8	0	9 4
Total	501 7	5 7	50 1	3 2	560 7

Source PAAAFR (1995)

Ultra-violet-resistant polyethylene or fiberglass materials are used to cover the greenhouses, as polyvinyl chloride and polycarbonate materials are not suitable in Kuwait Normally, greenhouse construction and sophistication depend on need and are market driven High investment levels and long pay-back periods are limiting the expansion of cooled and heated rigid-cover greenhouses in the country

Kuwait experiences an extended period of high temperatures from April to October when cooling is required The relative humidity during this period is low enough to allow for adequate evaporative cooling Therefore, it is possible to reduce greenhouse temperatures to 35°C or less during the summer A number of evaporative cooling systems are presently used in Kuwait, but Celdeck and rope 'pads' predominate One serious limiting factor in greenhouse cooling is the poor quality of groundwater, which requires the use of a special design to avoid salt-

encrustation of the cooling pads Cooling pads also get plugged by mobile sand particles and dust storms, and become nonfunctional after 3 to 4 months At the same time, the use of distilled or desalinated water in greenhouse cooling is very expensive New cooling-system designs, which allow the efficient use of brackish water, are needed to improve the profitability of protected agriculture



Kuwait growers using ropes as an economical evaporative surface for the greenhouse cooling system

A clear understanding of relationships among temperature, relative humidity, solar radiation, ventilation and crop growth stage is important for achieving efficient cooling of the greenhouse environment Unfortunately, most commercial greenhouses in Kuwait lack proper instruments for monitoring changes in the environment Winter frost is fairly common, but few greenhouses have heating facilities

The current production and productivity of important PA crops are given in Table 3 Tomato and cucumber account for nearly 90% of the total area The relatively large area under uncooled tunnels results in overproduction during a short period (January to April) when the growing conditions are moderate This leads to a collapse in the price offered for locally produced vegetables during peak production, whereas imports are expensive and prices are high during the rest of the year Furthermore, because of gaps in technology adoption and inefficient management, the productivity of PA in Kuwait is far below the potential (Table 4)

Table 3. Total production and productivity of different crops under protected agriculture in Kuwait.

Crop	Production (tonnes)	Current productivity (t/ha)
Tomato	11,588	50
Cucumber	12,600	125
Eggplant	3,299	55
Pepper	211	50

Source KISR (1995)

Table 4. **Productivity (kg/m²) of tomato and cucumber in different types of greenhouses.**

Crop	Uncooled plastic tunnels		Cooled plastic tunnels		Fiberglass greenhouses	
	Current	Target	Current	Target	Current	Target
Tomato	10	12	12–15	19	16	25
Cucumber	4	n c	6	n c	8	26

Source KISR (1995)

For example, yield levels for tomato in Kuwait are about 10 kg/m² in uncooled plastic tunnels, 12 kg/m² in cooled tunnels and 16 kg/m² in cooled fiberglass greenhouses In contrast, 25 kg/m² was achieved in some countries during the mid-1980s, indicating that there is room for improving productivity levels in Kuwait (Mathijssen et al 1993)

Water Use Efficiency and Fertigation

The production technology in Kuwaiti PA varies tremendously, but soil-based production using the native soil with or without organic-matter addition is still common Drip irrigation systems with desalinated water are used Inorganic fertilizers in the form of soluble compound fertilizers are applied through drip systems at a more or less fixed rate per day

Plant Production and Protection

The infusion of technology into the PA sector over the years has generally been inadequate As a result, production systems have remained generally small and inefficient, with excessive demands for labor and water The yields under PA in Kuwait have been low, diseases and pests have been uncontrolled, and agricultural products have been inferior One of the main shortcomings in the past has been inadequate technical support for incorporation and use of modern production technologies vendors merely promoted their products, resulting in a wide range of unsatisfactory systems and failures Integrated production and protection programs must be introduced to overcome the problems of diseases and pests, and reduce the risk of chemical residues affecting consumer health and the environment

Constraints

Protected agriculture in Kuwait is faced with a number of constraints relating to physical, technological, manpower and economic factors

Physical constraints

Water The groundwater in production areas is brackish with dissolved salt contents up to 9000 ppm Such water is not suitable for PA and must be used cautiously in any agriculture The use of brackish water presents problems in evaporative cooling systems due to encrustation of cooling pads Irrigation with high-salinity water in soil-based greenhouse cropping systems, besides imposing physiological stress on plants, increases soil salinity To overcome this problem, greenhouse growers use desalinated water for greenhouse cooling and irrigation The use of desalinated water for cooling is not economical, requiring more water per plant than is needed for irrigation There is a need to improve the cooling systems to allow the use of brackish water

Soil The native soils used in the Wafra area are generally greatly disturbed and modified during construction The soils are predominately sandy with low cation-exchange capacity, very little organic matter, low water-holding capacity and low available phosphorus The gatch layer when present near or at the surface obstructs natural drainage and causes waterlogging and salinity problems Adoption of hydroponic production systems could eliminate most of the problems associated with soil-based cropping

Harsh weather The extended period of high summer temperatures, low rainfall, high evaporation rates, sand and dust storms presents problems in the operation of greenhouse structures and increases the cost of production

War damage The protected crop-production system and the water-distribution infrastructures suffered extensive damage during the invasion The postwar rehabilitation has been mostly limited to uncooled plastic tunnels as these structures require less investment and can be brought under production fairly quickly Most of the cooled tunnels have been developed by retrofitting these uncooled houses Although some of the rigid-cover (fiberglass or glass) greenhouses constructed during mid-1980s have been brought back into production, there has been very little new construction since liberation Owing to the high investment and longer pay-back period, growers are reluctant to invest in cooled and heated rigid-cover greenhouses This is affecting progress in the PA sector

Technological constraints

Greenhouse design and management As stated earlier, protected crop production is carried out predominately in uncooled plastic tunnels While these structures provide some environmental modifications—chiefly protection from wind and blowing sand, daytime warming due to the greenhouse effect and perhaps lower evapotranspiration rates than open field conditions—, they afford minimum opportunity for controlling the plant environment The shape of these single-span houses (arc in cross-section) leads to poor utilization of covered space and results in considerable waste of ground area between houses They also offer limited

opportunity for using screening materials to restrict the entry of insects Providing efficient drainage and adoption of high-tech production systems in such houses will be more expensive than in multi-span houses The small size of individual units considerably reduces labor efficiency

Crops Profitability in PA is determined to a large extent by choice of crop (cultivars grown) and the level of technology used As stated earlier, cucumber and tomato are the main crops grown in protected environments As in most countries in the region, tomato under PA is less profitable than cucumber Again no PA crops can be grown in summer months without cooling Considering the narrow range of crops presently available to PA, the Master Plan (KISR 1995) recommends exploring new potential crops (cut flowers and potted flowering and foliage plants), besides expansion in the production of certain existing crops

Crop production technology While information from suppliers is useful, it is essential that producers have unrestricted access to unbiased technical information Technical support for PA for both new technology and its adoption remains limited in Kuwait

Marketing Kuwaiti producers face stiff competition from imported produce from other countries in the region and market intelligence is not available to them

Manpower constraints
The technological expertise required for high-tech PA is not available locally Most laborers employed in PA are unskilled and not trained in commercial greenhouse operations The majority of the management personnel also lack experience in crop planning and financial management This results in inefficiencies in operation, besides creating problems in manpower training

Economic constraints
The need for higher investment, high cost of production, low prices, stiff competition from imported commodities and longer pay-back periods than many investors are accustomed to, are some of the economic issues influencing the progress of PA in Kuwait

Opportunities for Modernizing Protected Agriculture

Since the environmental disaster associated with the invasion of Kuwait, the greenhouse sector—especially in the Wafra area—has witnessed an impressive rebuilding and rehabilitation phase Protected agriculture is expected to become an important agribusiness with greater impact on the national economy than was traditionally perceived Therefore, the revived greenhouse sector in Kuwait, if managed properly, will have enormous opportunities for optimizing the production of selected commodities In view of this, PA has been selected as a priority area in the 20-year (1995–2015) Agricultural Master Plan developed by

KISR (1995), in collaboration with the Public Authority for Agricultural Affairs and Fish Resources (PAAAFR) This Plan calls for enhancing productivity of various crops by at least two- to four-fold by the end of the plan period The water-use efficiency in crop production is also expected to improve considerably To achieve this goal, the production system will have to be made both efficient and productive This is possible only through the development and demonstration of water- and energy-efficient technology packages and the infusion of high-quality managerial skills

The first step towards modernizing PA in Kuwait is to evaluate and incorporate all the proven technologies of greenhouse management, fertigation, water application, and pest and disease control into the existing operation For example, providing the uncooled greenhouses with efficient cooling systems would reduce water consumption, extend the harvest period, offer opportunities for crop diversification and automation, and increase productivity, resulting in higher price realization and, ultimately, increased self-sufficiency Applied research on multi-span greenhouses and modifications in cooling systems to allow the use of brackish water will also be required to determine their feasibility in Kuwait

Successful PA production systems have been developed and are being used commercially in Europe, the USA and other areas These advances have enabled growers to raise superior-quality horticultural and floricultural products in record time, throughout the year and with lower input costs Besides being environment-friendly, these systems conserve natural resources Production systems such as deep-flow hydroponics, nutrient film technique, aeroponics and closed insulated pallet system, require careful testing and demonstration on a pilot scale under local conditions Other technologies that need careful evaluation include plug transplant system, crop selection and scheduling, pest control and efficient greenhouse management It will also be necessary to encourage the private sector to shift to technology-intensive, resource-conserving, yield-improving and quality-enhancing production systems

Early production of young strawberry plants raised in cool multi-span houses, Mirak Agricultural Services, UAE

Considering the short- and long-term needs of PA in Kuwait, the main focus of KISR's PA programwill be to develop, test and demonstrate various water- and cost-efficient technology packages and to demonstrate and provide training in high-quality management Therefore, the Aridland Agriculture Department at KISR is proposing to undertake a study to compare water-saving closed production concepts—such as super nutrient film technique, high-density aeroponic system and closed insulated pallet system (CIPS)—with the conventional deep-flow hydroponic system, and to explore new crops for protected agriculture The main emphasis of this study will be to transform the existing greenhouse agriculture into a productive water- and cost-efficient high-tech enterprise

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Protected Agriculture in the Sultanate of Oman

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Abstract

Oman is the third largest Arabian Peninsula country, and has generally warm, sunny winters and very hot, dry summers (although there are several diverse climatic regions) Research in protected agriculture began in 1992 with the screening and evaluation of cucumber, tomato and sweet pepper in plastic houses Further research concentrated on cucumber, as the other two vegetables were devastated by arthropod pests Production in single-layer plastic houses was greater than that in double-layer ones Only one type of greenhouse is in use in the country, however single-span, 9 × 40 m, double layer of polyethylene sheets, evaporative cooling and a single door Other constraints to improved production include cost of structural material, cost of inputs (seed, agro-chemicals), supply of good-quality irrigation water, pests and diseases, toxic residues in crops, and shortage of trained personnel The following steps are recommended improving greenhouse structures to improve environmental-control efficiency, making greenhouses pest-proof, research into other potential vegetable crops, integrated pest management research, improved cultural practices (fertigation, water-use efficiency, pruning), soil-sterilization and crop-rotation, determination of safe levels for chemical residues, training of personnel, budget for research, equipment for monitoring greenhouse environments, evaluation of the economics of protected agriculture

Introduction

The Sultanate of Oman, situated at the eastern end of the Arabian Peninsula, facing the Arabian Sea and the Gulf of Oman, is the third largest country in the peninsula after Saudi Arabia and Yemen The Sultanate has 101,346 ha of agricultural land of which 61,530 ha is currently under cultivation (Nadaf et al 1997) The area under cultivation increased by about 28% from 1980 to 1993 (Nadaf et al 1997) Total agricultural production increased by 65% during the same period The total production comprised 66% fodder, 22% fruits, 10% vegetables and 2% cereals

The climate—which essentially consists of warm, sunny winters and very hot, dry summers—varies from region to region, with the coastal areas more humid than the interior and higher-altitude areas, and the southern region in general more temperate throughout the year With the exception of Dhofar province in the south, where monsoon rains occur between June and September, rainfall

throughout most of the country is low and undependable, and water supply is limited Groundwater is therefore the main source for irrigation and domestic use Excessive water-pumping and prolonged lack of rains has reduced the extent of recharge resulting in ocean-water intrusion that progressively increases salinity in both irrigation water and the soil, and thus limits crop productivity

Status of Research on Protected Agriculture in Oman

The arid climate and environmental conditions of Oman necessitate and encourage the introduction of protected agriculture, particularly for vegetable-crops research Research on vegetable crops in plastic houses started at the Agricultural Research Center at Rumais in 1992 Priority was given to cucumber, tomato and sweet pepper, on which screening and evaluation trials were conducted The performance of cucumber was satisfactory and high yields were obtained Both tomato and pepper gave good yields during the first season of experimentation, however, during the second season and thereafter both crops were severely infested by pests such as white fly, aphids and spider mites, which devastated the crops This incidence of pest infestation clearly indicates a structural problem in the greenhouses in use In fact, only one type of greenhouse is in use at the agricultural research centers in Oman That is a single-span plastic house (9 × 40 m) covered with a double layer of polyethylene sheet and having a single door

Further research efforts were concentrated on cucumber These experiments included various planting dates to extend the availability of cucumber through the year Fertigation experiments on cucumber were also conducted during the 1996–98 seasons in both single- and double-layer plastic houses The results revealed significant effects for different levels of nitrogen fertigation and experimental site (i e single- or double-layer plastic house) Both yield and dry-matter accumulation were significantly higher in single-layer plastic houses The data clearly indicated that a simple modification by using one plastic layer instead of two layers was effective in increasing productivity

Constraints

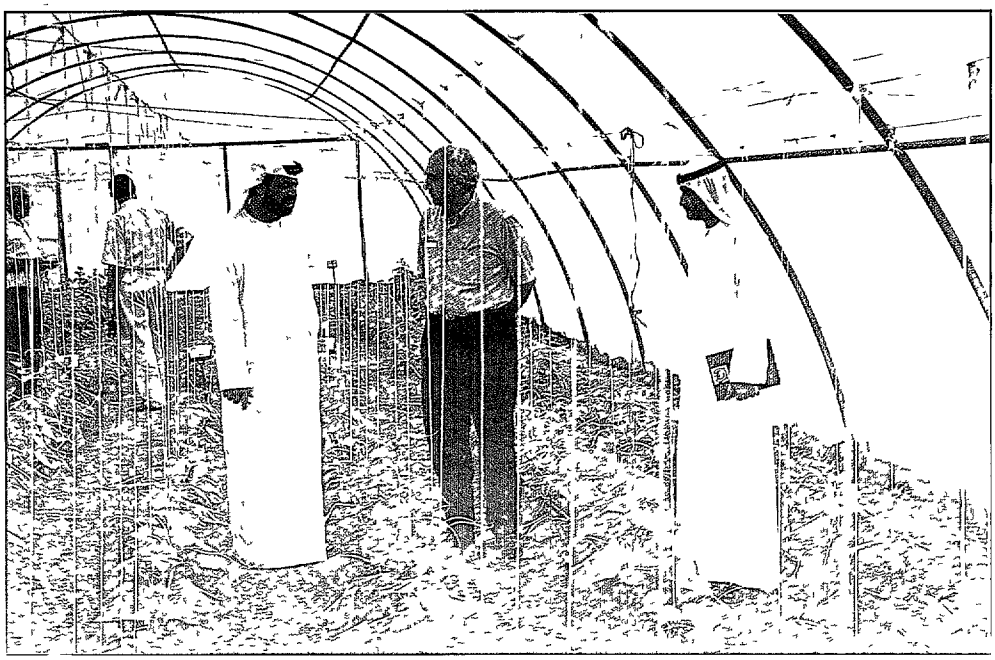
During our research in protected agriculture we observed several constraints that jeopardized our efforts in this field These include the following

- The single-span plastic house (9 × 40 m), used in Oman which is covered with a double layer of polyethylene sheets, with evaporative cooling system and a single door that allows for insect infestation, is not an ideal design for the region
- High cost of structural material
- High cost of inputs such as hybrid seeds, pesticides and other chemicals
- Limited sources of good-quality irrigation water

- Lack of integrated pest management
- Build up of soilborne pathogens and soil degradation due to intensive cultivation
- Excessive residues of toxic chemicals in fruits (cucumber) produced in plastic houses
- Shortage of qualified personnel and trained technicians

These constraints could be alleviated by the following actions and activities

- The structure of the greenhouses in use needs to be improved, environmental control and ventilation have to be developed to reduce running (electricity) costs
- The greenhouses should be constructed in a way that makes them less accessible to various insects, multi-door entrances are recommended



Insect-proof netting on side-wall ventilators of greenhouse (UAE)

- Research should be initiated on several vegetables in the improved greenhouses, in addition to cucumber
- Integrated pest management is strongly advocated and needs to be given priority by relevant scientists

- Improved cultural and husbandry practices, such as fertigation, water-use efficiency and pruning, should be adopted for vegetables grown in plastic houses
- Soils should be sterilized and crops rotated
- Safe levels of toxic residues should be defined
- Personnel involved in protected-agriculture research should be trained
- Sufficient operational budget should be allocated for research
- Control and monitoring equipment is needed for research in greenhouses
- The economics of production under protected agriculture should be thoroughly tested and evaluated

Expected Benefits

Improvement of protected agriculture will lead to the following benefits

- Increased productivity and availability of vegetables to consumers
- Creation of more export opportunities
- Regular income to the farmers
- Improved water-use efficiency

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State of the Art of Protected Agriculture in Qatar

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Abstract

Protected agriculture was introduced to Qatar in 1976 in cooperation with FAO By 1995, the area of greenhouses was about 64 3 hectares

In 1979, a research station was started for protected-agriculture (PA) activities and it was modernized in 1984 The on-going research activities in the Horticultural and Greenhouse Experimental Station in Ottoria is organized under four major research programs (1) development and/or adaptation of new growing systems and techniques with emphasis on soilless culture, (2) greenhouse management—to improve the efficiency of the greenhouse cooling system, to assess various shading systems and materials, to utilize solar power for irrigation and water desalination, and to assess the design and performance of different irrigation systems and materials, (3) crop management—influence of different spacing and plant densities on yield and quality of cucumber, and irrigation, nutrition and pest and disease control, (4) crop and cultivar responses and performance under local conditions Lack of information, high costs and low returns are blamed for the slow growth of PA in Qatar Training of technical PA personnel and development of low-cost, efficient greenhouses are considered the most important needs Farmers also need specific advice in PA

Introduction

The peninsula of the State of Qatar is located on the east coast of the Arabian Peninsula, it has an area of about 11,340 square kilometers and a population of about half a million people The weather is very hot in summer and mild in winter, with an average annual precipitation of 84 mm Groundwater is the only source for irrigation , with the exception of a few farms which are using treated sewage effluent (TSE) for producing fodder crops only Drip, sprinkler and flood irrigation systems are used in those farms Oil and natural gas are the main sources of national income

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Protected Agriculture

Protected agriculture was started in Qatar in 1976 when the Department of Agricultural Affairs, in cooperation with FAO, erected plastic houses in the North Research Station This was followed in 1979 and 1984 by several plastic and fiberglass houses introduced by the Department of Agricultural and Water Research In 1982, the Industrial Development Technical Center started a 3-ha project which became the basis for the Arab Qatari Agricultural Production Company In 1985, the Agricultural Development Department distributed and erected 32 plastic houses in selected private farms

In the third quarter of 1995, some data were collected regarding protected agriculture in the country, as follows

- The total area covered by greenhouses was about 64 3 ha—about 1 7% of total area of registered farms
- The covering materials used were PE (polyethylene), fiberglass and glass
- Galvanized pipes were the main structure components used in PE houses, while galvanized posts were used in other types of greenhouses
- Aluminum strips were used to cover the cropping area of the green-whole
- Drip irrigation was used in all greenhouses except for a few where sprinkler or flood systems were used Hydroponics were used in some areas
- Cooling system The pad-and-fan system was the only means used for cooling greenhouses in Qatar Both glasshouses and fiberglass houses were fully equipped with cooling systems, while only 4% of plastic tunnels were cooled
- Growing system Direct planting in soil, 54 7 ha (85 6%), sand bags, 9 1 ha (14 2%), water culture, 0 1 ha (0 2%)
- Crops The most common crop grown in the greenhouses was cucumber followed by tomato Cut flowers and other vegetables were also cultivated

Research Facilities

Research in protected agriculture is conducted in the Horticultural & Greenhouse Experimental Station in Ottoria, under the Department of Agricultural and Water Research, Ministry of Municipal Affairs and Agriculture The research station is located in the middle of Qatar , some 35 km east of Doha

The Horticultural & Greenhouse Experimental Station in Ottoria was established in 1979 with 12 plastic houses (2160 m^2) In 1984, a modern fiberglass house with computer control was erected The total area of this well-equipped unit was 1102 m^2 and consisted of 6 compartments The unit was furnished with control room, central computer, laboratory, stand-by generators and nutrient film technique

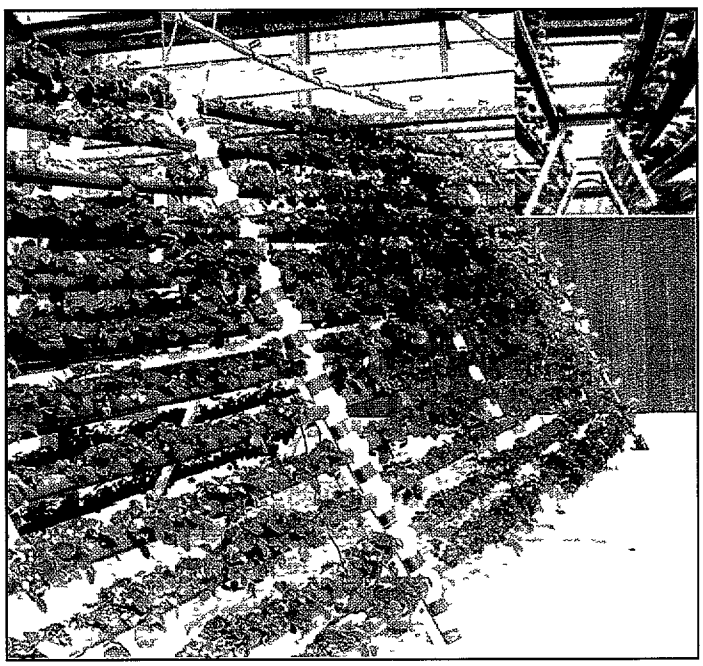
(NFT) controlling equipment The station in Ottoria was recently expanded to include an additional 12 plastic houses with cooling systems

Research Activities

The ongoing research activities at the Horticultural & Greenhouse Experimental Station are organized within four major research programs

1 Development and/or adaptation of new growing systems and techniques with emphasis on soilless culture

- Development of the tube culture technique for the production of cucumber, tomato, pepper and sweet melon
- Continuous production technique for cucumber in nutrient solution culture
- Adaptation and development of a high-density cropping system for strawberry (pyramid culture)
- Influence of solution concentration and temperature on yield and quality of crops
- Comparison between yield and quality of crops grown in different systems (tube culture, sandbags, sand beds and soil beds)
- Economic considerations of different systems in relation to capital cost, running cost and output per unit area, labor and water



Pyramid culture system for the production of strawberries, Ottoria (Qatar)

2 Greenhouse management

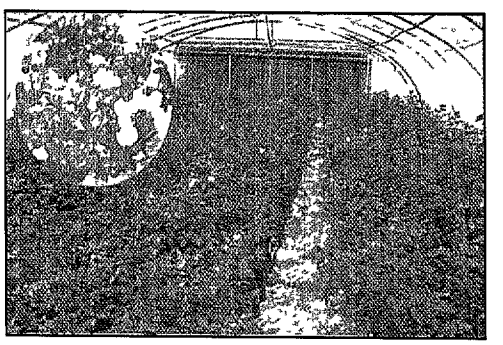
- Improvement of the efficiency of the greenhouse cooling system
- Assessment of various shading systems and materials
- Utilization of solar power for irrigation and water desalination
- Assessment of design and performance of different irrigation systems and materials

3 Crop management

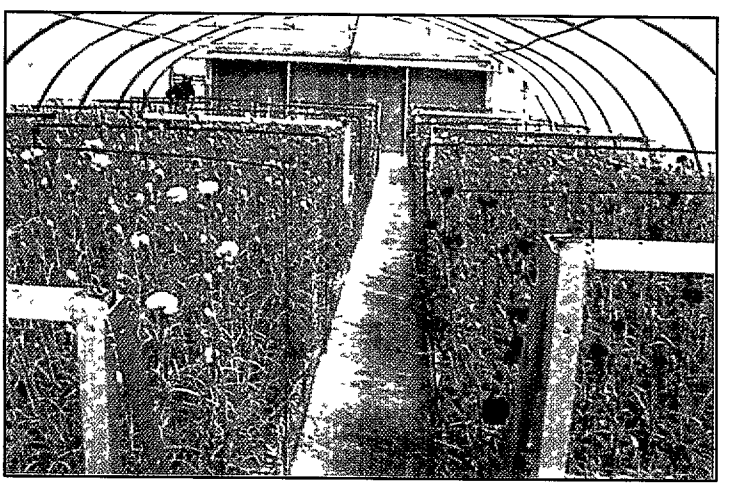
- Influence of different plant spacing and density on yield and quality of cucumber
- Irrigation, nutrition and pest and disease control programs

4 Response and performance of crops and cultivars under local conditions

- Production and quality of cut flowers (rose, carnation, and bird of paradise) in different growing systems



Research with cut-flower Bird of Paradise, Roses and Carnations in different soilless culture techniques at Ottoria Research Station, Qatar



- Assessment of banana production in cooled fiberglass houses
- Performance test for new cultivars of cucumber, tomato, pepper, eggplant, lettuce, melon, squash and strawberry under local conditions

Expected results and findings

The expected outputs of the research programs can be summarized as follows

1 Develop an adaptable soilless production system that can offer the following
   - major saving in production cost by increasing the output per unit of area, labor and water
   - produce an early and high-quality yield
   - overcome problems associated with soil and sand cropping systems
   - better working environment

2 Determine the optimum plant density and spacing

3 Identify the most suitable and productive cultivars under local conditions

4 Establish standard programs for irrigation, fertilization, and pest and disease control

5 Identify the most suitable shading systems and material for the greenhouses

6 Improve the efficiency of the cooling system

7 Assess and demonstrate modern irrigation systems, new material and equipment

8 Provide growers with a wider choice of high-value crops

Problems and Needs

Although protected-agriculture activities were started in Qatar a long time ago, the expansion of this industry only occurred in the last few years The lack of knowledge, high cost and low return from the agricultural activities, beside other factors, are the main reasons for the slow growth of this important industry

There are many needs, but training of qualified and active personnel is the most important Development of low-cost and high-efficiency types of greenhouses suitable to this area is also very important The small-holder farmers require support to find the right way to maximize their income and to improve efficiency

Protected Agriculture in the Kingdom of Saudi Arabia

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Abstract

The adverse climatic conditions and scarcity of irrigation water within Saudi Arabia have encouraged the development of protected agriculture as the main agricultural emphasis A range of different greenhouses is in use, from semicircular-tunnel plastic houses without cooling to triangular or semicircular glass and fiberglass houses with fully automated (computerized) operation Current constraints include lack of experienced technical personnel, soil and water salinity, and the cost of desalination, marketing problems and low produce prices, pests and diseases Fertigation is practised using sprinklers and drip irrigation, a limited amount of soilless culture is conducted Pests and diseases have generally been controlled by extensive pesticide application, resulting in increased costs, the emergence of pesticide-resistant pathogens, and pollution (crop and environment residues) Integrated production and protection needs to be introduced

Introduction

As a result of the diverse climate conditions and the scarcity of irrigation water in some regions of the Kingdom of Saudi Arabia, the Ministry of Agriculture and Water has much experience in protected agriculture (PA) Because of the constraints, agricultural emphasis was on PA which can control the crop-growing climate and, using modern agricultural and irrigation techniques, produce fresh products throughout the year Development of the PA industry in the Kingdom could not have been achieved without the support and encouragement given by the Ministry of Agriculture and Water and the Agriculture Bank This support was in the form of distribution of land, extension and technical services, loans and subsidies for all the inputs for protected agriculture

Types of Greenhouse in Use

Glass and Fiberglass Houses

These greenhouses are triangular or semicircular in cross-section Each unit covers one hectare, partitioned according to need and crop They have automated computer systems for cooling, heating, irrigation and fertilization Trained technical personnel and continuous maintenance are needed to manage these

houses The main vegetable crops grown are tomato and cucumber, although some growers cultivate beans, muskmelon, strawberry, cut flowers and houseplants

Ordinary Plastic Houses

These greenhouses are made from galvanized pipes bent into semicircles (arches) with a plastic cover, the standard area covered is about 500 m^2 (9 m × 56 5 m) Most growers use this type of non-cooled greenhouse owing to its simplicity and ease of construction Tomato, cucumber, squash and hot and sweet pepper are the main crops cultivated in these houses during the cool and mild seasons

Problems and Constraints

- Unavailability of experienced technical personal
- Soil and water salinity and the high cost of water desalination units
- Marketing and low prices of produce
- Spread of pests and diseases as a result of the lack of integrated control programs

Water Use Efficiency

There is a need for more research in this field to rationalize water use, and reduce fertilizer wastage and operational costs

Fertigation

This method of fertilization was introduced into Saudi Arabia in the 1970s as a result of the widespread use of modern irrigation techniques About 850,000 ha currently use center pivot systems (sprinklers) and 2000 ha are drip irrigated Soilless culture is limited to about 10 ha of vegetable production using soluble fertilizers

Integrated Pest and Disease Control

The density of plants in the greenhouse provides a favorable climate for the spread of pests and diseases that cause a great loss in crop quality and quantity The most important diseases are powdery mildew, downy mildew, brown rot, early and late blight, and viral and bacterial diseases To control these diseases growers use pesticides extensively which lead to various problems such as

- increase in production costs
- emergence of new strains of pathogens that are resistant to pesticides
- pollution of crops and environment (residues)

Consequently, it has become imperative to apply integrated production and protection control methods to reduce pesticide use These methods include the following

Cultural methods

- Using sterilized soil in the nurseries
- Exercising precautions at the nursery with attention to tools and their periodic fumigation, to prevent contamination with diseases and pests
- Solarizing the greenhouse soil to reduce soil-borne diseases
- Using healthy seeds and uninfected seedlings
- Growing resistant cultivars—at present there are cultivars that are resistant to some fungal diseases such as wilts caused by *Fusarium* and *Verticillium*
- Removing weeds and other undesirable plants from inside and outside the greenhouses, as they act as a secondary hosts for pests and diseases
- Ventilation The opening vents of greenhouses must be covered with insect-proofing nets or screens More attention should be given to ventilation in order to reduce humidity (high humidity promotes diseases such as botrytis and mildew)
- Cleaning tools and equipment before use to reduce the risk of disease transfer
- Providing balanced fertilization induces vigorous growth of the plants and consequently improved resistance to diseases Excess use of nitrogen leads to reduced root systems as well as tender and slack tissues that are susceptible to diseases
- Applying manure and organic fertilizer, which helps improve soil fertility, increase natural enemies, and destroy pathogens during the decomposition process
- Applying green manure Growing certain crops and mixing them with the soil will increase soil organic-matter content, which will improve the soil properties and increase its water-holding capacity, it will also enrich the soil with nutrients, particularly after decomposition of the green manure
- Removing and burning all dead and infected plants and leaves
- Pruning of lower leaves can increase aeration and reduce humidity build-up

- Crop rotation It is advisable to use a certain cropping rotation to avoid planting the same crop or a crop of the same family in the same soil in successive seasons, so as to prevent disease or pest build-up over time

Chemical methods

Chemical spray has been and still is the most common method of controlling pests and diseases because of its quick action and ease of use Chemicals will still be used, but the following points should be taken into consideration

- Minimize preventive sprays
- Use the proper chemicals at the right time
- Apply the recommended dose and follow all the instructions on the label
- Use a suitable sprayer to ensure good coverage and distribution of chemical
- Diversify pesticides to avoid emergence of new resistant strains of pests and diseases
- Treat infested portion of plants or location within greenhouse specifically, if possible, i e do not treat uninfected plants

Protected Agriculture in the United Arab Emirates

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Abstract

In the late 1970s, protected agriculture (plastic-house technology) was introduced to the UAE to help relieve some of the constraints facing the agricultural sector By 1996, there were 6356 plastic houses occupying 202 3 ha within the four agricultural regions of the country Plastic-house design developed from simple semicircular tubes (3 m high, 6 m wide, 36 m long), through straight-sided houses with arched roofs (3-m high sides, 8 m wide, 36 m long), to modern semicircular tunnels constructed from galvanized pipe (3 5 m high, 8 m wide, 36 m long, with 2 m between supports) The main crops grown under protected agriculture are tomato, cucumber, pepper, sweet melon and phaseolus bean To promote and develop protected agriculture further, several new technologies have been introduced, including higher-quality plastic films, closed plant-nutrition systems, and cultivars tolerant to abiotic and biotic stresses In addition, research is needed to improve climate control, pest management and plastic-house structure

Introduction

The United Arab Emirates lies between 27°N and 22°S latitude and 51°W and 57°E longitude The land surface of the mainland is about 77,700 km^2 The soils are generally coarse sandy

The UAE's climate is characterized by low and erratic rainfall and high temperatures reaching over 45°C in summer and as low as 8°C in winter The relative humidity is generally high at the coast reaching to about 98%, with an annual mean of 50% Rainfall is generally light to moderate and occurs mainly in winter, the average annual rainfall is 110 mm The average wind speed recorded for the whole area is 6 km/h, with evaporation values reaching 11 mm/day

Though the UAE is an oil-exporter, agriculture and asthetic greenery are high priorities for the government, and considerable effort has been made to secure and increase the level of food self-sufficiency, increase the green area, and combat desertification The agricultural sector has achieved remarkable growth during the last 20 years, but there is still a need to increase the production of some vegetable crops, fruits and cereals Some of the main constraints to agriculture are the harsh climate, the limited areas of soils suitable for farming, the shortage of good-quality irrigation water, and field cultivation is subject to different diseases and pests, particularly virus vectors

One of the means adopted to overcome some of these constraints is protected agriculture The technology of plastic houses was introduced in the late 1970s with the following objectives

- To intensify cultivation (reducing the input cost)
- To protect the plants from the severe weather
- To protect the plants from pests
- To conserve irrigation water, fertilizer and pesticides
- To prolong the growing season

The increase in protected agriculture throughout the UAE is indicated by the numbers of plastic houses and the land area devoted to protected agriculture (Fig 1), by 1996, there were 6356 plastic houses covering 202 3 ha

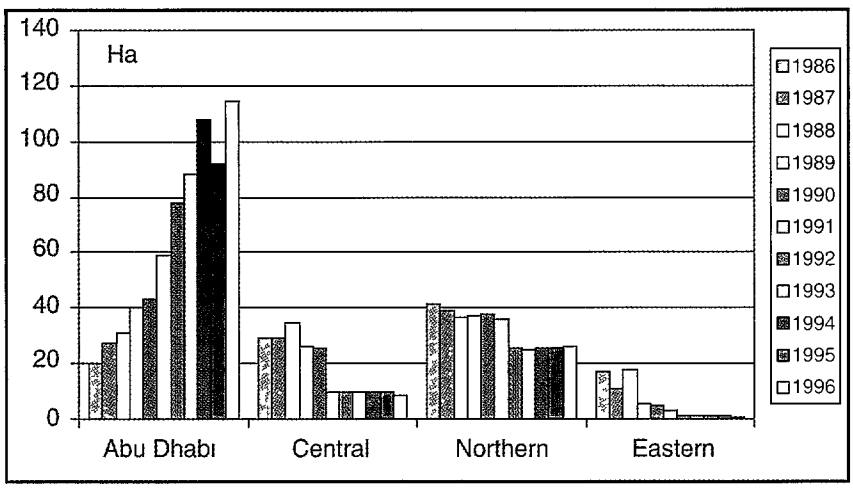

Figure 1. Development in area (ha) of plastic houses in different regions of the UAE over 11 years period from 1986 to 1996.

Plastic House Structure

The dimensions of the plastic houses currently used are 36 × 8 × 3 5 m Many modifications have been made to the design and dimensions, the structure, diameter of the galvanized pipes and the type of construction materials The first plastic-house design was a semicircular tunnel, 3 m high, 6 m wide and 36 m long, the second design was straight-sided with arched roof (3-m high sides, 8 m wide,

Crops

The main crops cultivated under protected agriculture (PA), along with some example cultivars, are as follows

- **Tomato:** Agora, Grandure, Noble, Montecarlo, Carmelo
- **Cucumber** Farol, Cheyenne, Rawa, Rania, Bonus, AlAmir, Queen
- **Pepper:** Tenno, Glaxy, Helder, Amigo
- **Sweet melon:** Polydor, Juice Jania, Ogen, Amcosweet
- **Phaselous bean:** Santil, Serpo, Diamond

Diseases and Pests

The common diseases and nematodes that affect PA vegetable crops are listed in Table 1

Research Needs

To develop and promote PA in the country, the following approaches have to be introduced

- New **high-quality plastic films** better adapted to the prevailing conditions and complying with international standards
- Closed plant **nutritional systems**, with balanced application rates, intervals, etc
- New crop cultivars
  - **Tolerant to salinity,** temperature, drought, etc
  - Cucumber cultivars **tolerant to downy mildew**
  - Non-traditional crops
- Studies on climate control and optimization of plant environment
- Studies on integrated pest management, including biological control
- Technology transfer to improve
  - Plastic-house structure (design, size, strength)
  - Ventilation
  - Soil sterilization
  - Mechanization of cultural practices

Table 1. Common diseases and nematodes affecting selected protected-agriculture crops in the UAE.

Crop	Disease	Causal agent
Cucumber & Melon	Downy mildew	*Pseudoperonspora cubensis*
	Powdery mildew	*Erysiphe cichoraceorm*
	Damping off	*Phythium* sp
	Foot rot	*Fusarium* sp
	Fruit rot	*Botrytis* sp
	Wilt	*Fusarium oxysporium*
	Root-knot nematode	*Meloidogyne* sp
	Lesion nematode	*Tylenchorhynchus* sp
	Angular leaf spot	*Pseudomonas lachoyonans*
Tomato	Early blight	*Alternaria solani*
	Late blight	*Phytophthora infestants*
	Damping off	*Phythium* sp , *Phytophthora* sp
	Wilt	*Fusarium oxysprium*
	Leaf mold	*Cladosporium fulvium*
	Blossom end rot	Calcium deficiency
	Root-knot nematode	*Meloidogyne* sp
Pepper	Alternaria fruit rot	*Alternaria alternata*
	Blossom end rot	Calcium deficiency
Bean	Dry root rot	*Fusarium solani*
	Root rot	*Pythium* sp
	Bean rust	*Uromyces phaseoli*

Protected Agriculture in the Republic of Yemen

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Abstract

By the end of 1997, there were about 2000 plastic houses in Yemen (mainly in the highlands), run by farmers (95%), private sector (4%) and public-sector cooperatives (the remainder) Most greenhouses in Yemen are single-span types with galvanized iron frames They are all plastic houses (mostly UV-resistant), and sizes vary between 6 × 54 m and 9 × 60 m The most important crops grown under protected agriculture (PA) are cucumber (90%), tomato (5%), pepper and eggplant (5%), there are also a few floricultural greenhouses Irrigation is either by drip system (promoted by national and international specialists)—with imported components, specially filters—or by surface system (for those who cannot afford to operate a drip system) Fertigation is managed by specialist technicians, but there is no standardization of chemicals applied (and their formulations), dosages or application methods Plant diseases are generally controlled chemically The promotion and development of PA is mainly in the hands of the Ministry of Agriculture and Irrigation and the private sector The following constraints hinder the PA sector in Yemen greenhouse design and structure (high temperatures in summer with poor ventilation, promoting fungal diseases), location of greenhouses, polyethylene cover is short-lived, prone to storm-damage and to condensation, hybrid seeds are expensive and cultivar import is unpredictable, farmers lack experience in chemical use, resulting in harmful residues in harvested vegetables, numerous problems with the PA infrastructure (e g shortage of trained personnel, insufficient research, lack of information, lack of an overall development plan for Yemeni PA)

Introduction

The Republic of Yemen is located in the south part of the Arabian Peninsula, between latitudes 12° and 20°N and longitudes 41° and 54°E The country is bordered by Saudi Arabia to the north, the Arabian Sea and Gulf of Aden to the south, Oman to the east and the Red Sea to the west, the total area is 5 5 million hectares, with a human population of 16 million The total arable land is about 1 7 million hectares, of which 1 2 million hectares is cultivated—54% is rain-fed, 37% irrigated by groundwater and the rest flood-irrigated

Yemen has a predominantly semi-arid to arid climate The variation in elevation causes differences in climate conditions, ranging from hot and humid on the coast to relatively cool and dry in the mountains, with moderate temperature and humidity on the plateaux

The climate pattern should allow for year-round production of vegetables, but this is not possible because of the small and scattered patches of arable land, the limited water resources, the low yield per unit area, and the poor roads between the production areas and marketing centers

Thus, to improve vegetable crops so that they can compete not only in local markets but also abroad, it is necessary to pay more attention to the quantity and quality of these crops along with natural-resources preservation—mostly water—with optimum utilization of cropped area Protected agriculture is considered an important means of increasing the productivity and quality of most vegetable crops

There has been an increase in interest in protected agriculture (PA) in Yemen, except in areas where its development and expansion are hindered by other factors Such limiting factors include limited national experience in PA and lack of adoption potential by certain farmers (mainly due to the high cost of PA establishment) The demand for plastic houses has increased and their use has spread in some regions where there were 20 protected houses belonging to four agri-research stations and others belonging to public-sector cooperatives, there were approximately 2000 plastic houses by the end of 1997—of which 95% belonged to farmers, 4% belonged to the private sector and the remainder belonged to public-sector cooperatives These plastic houses are mainly located in highland regions (Dhamar, Sana'a, Sa'dah) no protected agriculture is practiced in the coastal region

Average temperatures are principally affected by elevation The difference between the average temperatures of the warmest and the coolest month of the year is not constant over agro-ecological zones In the coastal, western and southern areas, it is generally less than 10°C, but in the arid interior it increases to about 15°C Above 2300 m altitude frost occurs regularly between mid-October and March

In the mountains, relative humidity varies between 30 and 60%, except in the high-rainfall areas where values between 50 and 70% are observed In the arid interior values are below 40%

Clear skies predominate in Yemen during most of the year Annual average values are between 6 and 10 hours of sunshine per day The net solar radiation per year is lowest in the coastal zone (below 5500 MJ/m^2 per year), somewhat higher in the high-rainfall areas (5200–6000 MJ/m^2 per year) and in the dry interior (5500–6000 MJ/m^2 per year), and highest (6000–6500 MJ/m^2 per year) in the mountains and inter-mountain plains

Average wind-speed in most of Yemen is low to moderate (<1 to 2 m/s), except on the coast and at well-exposed locations in the mountains (2–2 5 m/s)

Protected Agriculture

Greenhouse Design

Most of the (sparsely spread) greenhouses in Yemen are single-span plastic houses formed of 21–24 arcs of galvanized iron water-pipes (diameter 3 8–5 1 cm, spaced at 2 5 m) The typical area of the greenhouse is 324–540 m^2, with dimensions of 6 × 54 m and 9 × 60 m, and height 3–3 5 m Each house has two doors, whose design depends upon the financial resources of the owners

The common type of plastic cover is a UV-resistant polyethylene sheet of 150–200 μm thickness, which is manufactured locally

Significant Crops Grown under Protected Agriculture in Yemen

Cucumber forms 90% of the production in greenhouses, followed by tomato (5%) Other crops include pepper and eggplant (5%), and there are a few greenhouses which produce mainly floricultural crops

Productivity and its Relation to the Protective System

The average production of cucumber and tomato under farmers' and some private-sector companies' conditions are shown in Table 1

Table 1. Cucumber and tomato production in protected agriculture (two seasons per year) compared with open field (one season).

Crop	Protected agriculture		Open field
	Mean yield/season (t/ha)	Total yield (t/ha per year)	(t/ha per year)
Cucumber	130	260	15
Tomato	185	370	30

Table 1 shows that productivity under protected agriculture is higher than that in open field for the same crop Cucumber productivity was 17-fold greater under PA, while that for tomato reaches 12-times its productivity in a non-protected system This is what makes PA so economically important

Greenhouse Management

Land is prepared according to the farmers' own experience and extension recommendations

The soil is sterilized chemically using methyl bromide, chloropicrin, Basamide and Vydate Sterilization is carried out under the supervision of a specialist, however, many farmers are not practicing soil sterilization because they are not aware of its importance

Some farmers—particularly in Sa'dah and Sana'a governorates where there are many greenhouses—are skilled in pruning, in addition, there are some laborers trained in pruning in some private companies

Several farmers use a drip irrigation system which was initiated by national and international specialists Most of the materials for drip irrigation systems are imported, specially the filters, but the plastic pipes can be made locally Generally there have been no experiments to determine the water-use efficiency and optimum water requirements for crops in the greenhouses Recommendations are available from other practices and from experiments conducted in other countries with similar conditions

A number of farmers use a surface irrigation system since they do not have the financial resources to install and manage a drip irrigation system

Soluble fertilizers are often applied with the drip irrigation system or as foliar spray This practice has been implemented and managed by technical cadres However, there is wide variation in the chemicals used, their formulation, dosages used and methods of application

The most common diseases in PA are downy and powdery mildews on cucumber, and fusarium on tomato Viral diseases are not common except for leaf-curl virus on tomato Arthropod pests comprise aphids, thrips, spider mites and white fly Diseases are commonly chemically controlled

Institutes Involved in Protected Agriculture in Yemen

The Ministry of Agriculture and Irrigation is the main supporter for PA in Yemen The Ministry supports the industry by

- making some raw materials available to the private sector and farmers,
- facilitating imports of agricultural materials , in particular seeds and fertilizer for PA

The private sector plays a major role in adapting PA systems, i e establishing the greenhouses, and making the essential materials (seeds and fertilizer) available In addition, the private sector plays a supervisory and extension role for some greenhouse growers

In recent years, the Agricultural Research and Extension Authority (AREA) has supported PA by establishing relevant research and extension units However, the capabilities of AREA are limited AREA projects support and develop priority research activities to solve the present problems of farmers, but there is no source of support for its research activities in PA The Arabian Peninsula Regional Program of the International Center for Agricultural Research in the Dry Areas has a mandate for PA, and may support research activities in AREA in the future

Problems and Constraints of Protected Agriculture

A. Technical constraints

1 Plastic-house structure design The current design has disadvantages of increased temperature during summer, which decreases ventilation and increases the humidity, leading to spread of fungal diseases

2 Selection of an unsuitable *location for the plastic-house* structure—negatively affects the greenhouse and the crop

3 Problems of using plastic materials

- The life of plastic is short (1 5–2 years)
- In heavy storms, the plastic material may be destroyed and this may lead to loss of the crops before the end of the season
- Condensation of water vapor on the internal walls of the plastic house leads to
  - (a) reduced penetration of light
  - (b) dropping of water on the plants, which damages them

4 Seed problems

- The price of hybrid seed is very high
- The farmers have difficulties in selecting good cultivars owing to the absence of cultivar screening and evaluation
- No local production of hybrid cultivars

5 Constraints related to chemical use Farmers' lack of experience in using chemicals under PA leads to several problems such as residual effects on human, plant and environment health

B. Management and research constraints

1 Shortage of trained personnel (i e growers, workers and national specialists), including within research cadres, consequently, no extension and training program for growers

2 Lack of technical supervision on PA

3 Lack of baseline information

4 Insufficient scientific research in PA

5 Lack of research units for PA in different ecological zones, thus, lack of research and extension recommendations for cultivars, water-use efficiency, optimum water requirement and fertigation

6 Inadequate plant protection methods

7 Marketing problems

8 Inadequate storage and transportation

9 Lack of an overall development plan for the PA system in Yemen

10 No exchange of information with other Arabian Peninsula countries

Summary of Discussions

Kuwait

Some work has been done at PAAAFR to test deep-water hydroponic systems, with good results KISR will be conducting a study to determine the cost-effectiveness of these systems

Brackish water used mainly for irrigation and in cooling systems is increasing soil salinity and shortening the life of cooling pads Some producers are, therefore, using desalinated water for their cooling systems, but the brackish water is cheaper and many producers are still using it Some growers are now washing the soil to reduce its salinity KISR and PAAAFR tested various cultivars for their salinity tolerance and heat resistance The use of brackish water for irrigation is expected to decrease in the future, as the total dissolved salts in the water varies between 3000 and 9000 ppm depending on the area

In Kuwait, most of the growers are small-holders who adopt PA as a sideline food-production, and are not interested in profit They are basically interested in technology, but are not yet prepared to pay for it

Oman

The disease and pest organisms on PA crops in Oman are tomato leaf curl virus and aphids on tomato, red spider mite and aphids on pepper, and red spider mite, downy and powdery mildews on cucumber

The price quoted for the greenhouses is high, working out to US$30–40/m^2, however, this price is for the complete house, including (improved) irrigation system, cooling and heating systems, and many (if not all) of the components are imported

Qatar

Cucumber is the major PA crop in Qatar because it is the most suitable crop for PA production, its price is stable through the year, and growers can produce about 3½ crops per year Tomato is more prone to viral attack and its price fluctuates through the year

Saudi Arabia

The major constraints to the expansion of PA in Saudi Arabia are the lack of technicians in the various aspects of PA, water and soil salinity, low market price of PA vegetables making it uneconomical, diseases and pests, unguided use of water and fertilizer, reducing water-use efficiency

Yemen

The postharvest constraints to PA are formidable, some growers have abandoned PA completely as a result of marketing and competition Basically, there are no marketing channels, storage or transport facilities Thus, remote farmers have immense difficulty in selling their PA produce

Despite the low productivity of PA in Yemen, the number of farms has increased This is a result of farmers changing over from field cropping to PA

In coastal areas, temperatures average 27–30°C and relative humidity (RH) about 80%, thus, both need to be dealt with in greenhouses In dry mountainous areas (e g central highlands), temperatures are generally below 12°C, and sometimes below 0°C, so RH is the climatic factor requiring control and not temperature

Farmers adopting PA, tend to opt for the crop with the best income, i e cucumber Some crops grow better in the field than under PA, e g melon

Greenhouse Climate Control

Evaporative cooling depends on the outside RH In general cooling is required between 10 a m and 4 p m , so it is necessary to know the air RH during that period, rather than the daily average for the season In summer, evaporative (fan-and-pad) cooling is mostly operated normally, but in winter it is advisable to cut off the water supply to the pad wall

Fan-and-pad cooling is often inefficient as the pads clog with sand and salt The salt problem can be overcome either by using sprayed water for evaporative cooling, or by ensuring that the pad water supply is desalinated This should extend the life of the pads

The RH in summer affects the achievable temperature difference between the inside and outside of the greenhouse Inside temperature is critical to crop growth with as little as 1°C affecting crop production In areas of high RH, the required inside temperature may not be achievable, and production does not meet targets Thus, under fan-and-pad cooling, condensation and disease are not the principal causes of loss of production

In the UAE, irrigation-management recommendations are based on research trials Drip irrigation is considered best there Where researchers can determine crop water-requirements on station, growers are encouraged (by extension) to adapt them to their own circumstances This is considered the best option, as growers and researchers may use different planting dates (affecting temperature), water of different qualities, different irrigation systems, and different soils In addition, the growers themselves tend to be uneducated or illiterate, so climate data and computer technology would be of little value to them Some private-sector PA companies have opted for automation using computers, such systems in use in Saudi Arabia may become available in the UAE through ICARDA's mediation

It is difficult to train the (non-AP-national) growers to the technical capacity required to utilize climatic data, so a question facing the AP in the future is whether to try to train the growers, or to opt for full automation with nationals operating the systems (requiring less laborers)

Integrated Production and Protection Management

Nematodes are the major soilborne-pest problem in PA in the AP, but the PA growers deal with the problem quickly *Pythium* and *Phytophthora* soilborne fungi are also major pests in PA Soil-sterilization is not common practice in the AP, however the UAE is doing something about this Among other diseases, insect-transmitted viruses (especially of tomato) are spread rapidly

In Qatar, the Environmental Protection Agency is responsible for pesticide registration, however, there is no direct control of on-farm pesticide use, growers merely buy the registered pesticides and use them Most growers are not aware of the required waiting period between application and harvest In the UAE, the Ministry of Agriculture and Fisheries conducts pre-registration trials to prepare guidelines for pesticide use Registration is essential before a chemical (pesticide) may be imported It is not known whether growers follow the Ministry guidelines in applying pesticides In Yemen, there is a diversity of chemicals used on farm, but growers do not follow application guidelines because of the lack of extension information

Biological control has been used successfully in Oman, but so far only on field fruit-trees, it has not yet been extended to PA The UAE does not use biological control yet either

In at least three of the countries, information on pests and diseases is qualitative only—there is little or no quantitative data available Experience in the diseases of PA crops is limited in the region

Structures and Climate Control for Protected Agriculture in Arid Environments

Structure and Covering Materials for Greenhouses in Arid, Hot Climates

Christian von Zabeltitz
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Abstract

To check the suitability of a region for protected agriculture, the climate data should be compared with those for other regions and with the main requirements of the plants The choice of greenhouse structure and covering material depends on the main problems of plant production at the location, the requirements of the plants, the general design criteria for the region and on the available construction materials Greenhouses should be built less in accordance with national traditions and more with regard to general cropping needs and conditions of the climatic zone where they are located

Greenhouses for arid zones should have the following characteristics good light transmission, effective ventilation, sufficient tightness (resistance) to sand, dust and loss of moisture, wind-proof construction, low-cost construction, evaporative cooling if necessary and possible, avoidance of heat loss at night, simple but efficient solar desalination system, low operating cost

Besides conventional constructions, special closed-system greenhouses have been developed for desert regions, which have good energy balance and water-saving operation Incoming heat energy during the daytime can be reduced by the shape of the greenhouse and by specific covering materials, which reduce the transmission of near-infrared radiation (above 600 nm)

If the outside air humidity is not too high, evaporative cooling may be necessary Fan-and-pad cooling systems are sensitive to sandstorms and direct solar radiation Operation with brackish or saline water is essential, but the pads tend to clog with salt and sand A simple spray cooling system has been developed which is more resistant to desert conditions, and is highly efficient

Greenhouse Climate Control in Arid, Warm Countries: State of the Art and Prospective

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Abstract

Protected agriculture has expanded markedly in the Mediterranean region over the past 20 years to help improve agricultural productivity However, the plastic houses commonly used are designed for temperate or moderately warm regions and need upgraded climate control to overcome overheating in summer and overcooling in winter when used in warm, arid regions The greenhouse climate is dictated by the soil inside the greenhouse, which constitutes the major thermal mass, the 'greenhouse' effect itself, which can be controlled mainly by ventilation in most greenhouses, the crop's transpiration, which has a dominant effect on temperature and vapor-pressure deficit Structures commonly used in the region are small (low and small volume) and have inappropriate roof-slopes (reducing light transmission), taller structures with appropriate roofs would improve light transmission, ventilation, inertia against external climatic variations, and drainage of condensation Few greenhouses in the region are heated, and the economic benefit of heating has yet to be proven Cooling is, however, essential and several methods are available—static or forced ventilation, evaporative cooling (pads, misting, sprinkling), shading (screens, white-washing) Roof ventilators are efficient, but present practical problems because of their location Evaporation is the most efficient cooling mechanism, especially if the outside air is dry, but many systems require good-quality water Shading has good prospects, but requires further research Information (real-time data) is required for adequate climate control—this is generally lacking in the region, however, the cost of sensory equipment is likely to fall to affordable levels Modeling and simulating crop-responses to management decisions in greenhouses also have potential for improving climate control, coupled with questions of economics, technology adaptation, and suitability of different crops Overall, technology is not the main constraint to efficient climate control of greenhouses in the warm and arid regions, rather the need is for adapting the technologies developed for temperate climates, and training the farmers in the proper management of improved structures and equipment

Summary of Major Issues Arising and Discussion

Greenhouse Design and Structure

The prevailing greenhouse structure in the region is still the single-span, round-arched tunnel covered with a single-layer polyethylene (PE) film of 200 μm The disadvantages of this type of greenhouse were underscored by several speakers This design should be improved in order to avoid problems encountered with ventilation requirements, insect-proofing, useful cultivated area and climate control It is also necessary to arrange for gutters in order to collect rainwater in a reservoir Therefore, there is a need for guidance on a suitable greenhouse type for the region as well as norms and standards for construction parts and covering materials During the lectures and discussions, the following recommendations were made on possible improvements

- The roof shape and inclination should allow water condensation droplets to slide down and the greenhouse volume should be increased (multi-span greenhouses are more suitable)
- The recommended greenhouse orientation for a single-span round-arched greenhouse is east–west when light is the limiting factor during the winter months, however, the greenhouse may be oriented differently according to light interception, wind resistance and ventilation requirements It was recommended that a technical leaflet be prepared to assist growers in orienting greenhouses according to local conditions

There are a certain number of large-scale greenhouses in the region run by commercial companies These companies are pressured by sales agents and do not have easy access to specialized services from experts with a technical background from whom they can get pertinent unbiased technical advice on investment or general crop management To fill this gap, it might be useful to establish a technical advisory committee (composed of national focal points) at the national or regional level from which commercial growers can seek advice and technical assessment

Covering Materials

The predominant covering material , because it is the cheapest is UV-stabilized 200 μm PE film Other types of film should be tested, including anti-drop and infrared-opaque films as well as other new films (such as a recently imported multi-layer film from India to Qatar) Films with IR-opaque properties could be recommended for inland sites to decrease the high radiative heat losses during clear nights in winter and increase greenhouse and plant temperature

It may be worthwhile to make an agronomic and economic assessment of cheaper 100–120 μm films which have a life of only one year It was emphasized that it is of utmost importance to have the film properly fixed to ensure that the greenhouse is tight, and to avoid direct contact with the steel pipes, which have to be protected against overheating

There are already some positive results on the use of photo-selective films However, additional research and validation are still required before they can be recommended to the growers Their effect on the behavior of insects inside the greenhouse needs further study

There is no advantage in using double films if the film is not well fixed and the greenhouse is not perfectly tight Good results can be obtained using single-layer covers which are properly fixed

Climate Control

The temperature inside the greenhouse should be adjusted in relation to the requirements of the species grown and not necessarily with respect to the temperature difference between outside and inside The temperature inside the greenhouse should be monitored in relation to the vapor-pressure deficit (VPD)

Heating

Some countries have reported frost damage, which has sometimes destroyed the crop Supplemental heating using simple low-cost (gas or oil) burners with hot-air blower or hot-air-distribution plastic sleeves is recommended

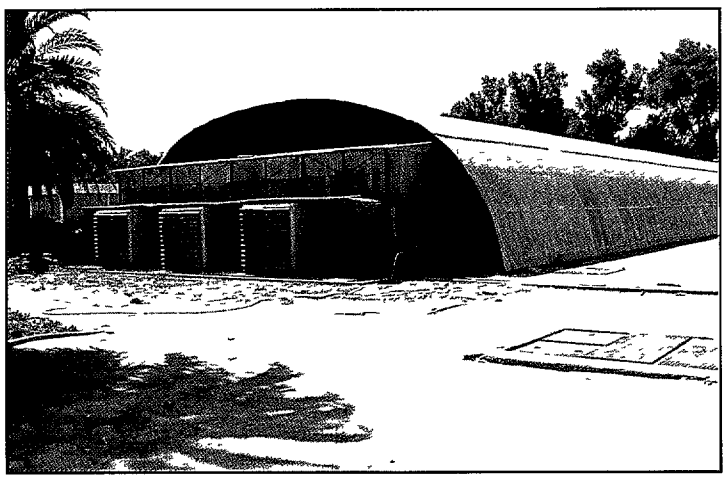
Consideration could be given to the potential for the use of a passive solar heating system, however, this system only allows heating by a few degrees (3–5°C) above the outside temperature Its effectiveness, particularly when the air temperature goes below zero, is not well established Furthermore, the efficiency of the system diminishes as the plants grow and cast shade on the solar water-tubes inside the greenhouse

Cooling

In order to extend the growing period (i e from May to September), cooling is needed Where fan-and-pad cooling is available, the farmers need advice on proper operation of the system Some simple recommendations are, for example, that pads need to be protected from direct sunshine and must never dry out, implying that water has to be applied in excess In addition, brackish water can be used Horizontal pads using water in excess can work perfectly well, and may be preferable to vertical pads Commercial pads, which become clogged, should be replaced To provide the growers with this type of basic information on fan-and-pad management, simple extension leaflets could be prepared and disseminated

Experiments should be conducted on improved cooling systems (evaporative cooling) Preference should be given to technology that can be locally manufactured and maintained with nozzles adapted for use with brackish water

Positive-pressure cooling systems need further study, including economic comparison with negative-pressure cooling systems



Positive-pressure evaporative cooling system at the Research Station of PAAAFR, Kuwait

For evaporative cooling systems, the instructions provided by the manufacturer are to be carefully observed when mounting and operating the system

Evaporative cooling depends on outside humidity and its efficiency has to be calculated The use of air-conditioners is too expensive for greenhouses In order to improve the efficiency of cooling systems, lowering the humidity of the incoming air before it enters the greenhouse would be very expensive

For solar desalination of water for cooling or irrigation, active desalination systems are more efficient than passive ones The energy required for pumping can be obtained from photovoltaic panels (probably only economic in remote areas) Technical details were given of an experimental solar desalination unit studied at the Technical University of Hanover Its capacity was 4–5 L/m^2 for an average radiation of 5 8 kW/m^2 day The actual capacity will be dependent on the solar radiation prevailing at the site where the unit is used Eventually this technology could also recycle the drainage water

Shading

In late spring and summer, high temperature prevails in the region In order to reduce the requirements for cooling, some type of shading could be used The most appropriate combination of shading with ventilation and/or cooling needs to

be investigated further A preliminary assessment could be made through modeling based on available climate data

Ventilation

The type of ventilation required is linked to the height and the volume of the greenhouse In static ventilation, the higher the greenhouse, the better the chimney effect When forced ventilation and cooling are applied, the height of the greenhouse can be more restricted (3 2–3 5 m)

Forced ventilation can be recommended for climate control It is more efficient than static ventilation and can be easily automated The efficiency of forced ventilation is limited by the distance between the fan and the pad (about 35 m) The system should be properly calibrated in order not to exceed an air velocity of 0 5 m/s in the greenhouse Precautions should be taken to avoid sucking insects entering the greenhouse—adequate insect-proofing is needed

Humidity control

Plant growth may be negatively affected by the reduction in air humidity due to excessive ventilation with incoming cool and dry air during the winter Therefore, it may be necessary to regulate the fan speed and the number of air renewals to avoid water stress or increased water consumption The control of humidity inside the greenhouse based on the adjustment of the air VPD could be a subject for applied research in the medium term At VPD values exceeding 20 millibars, stomata begin to close and plants may suffer more or less severe water stress, here, applying intermittent cooling is a possibility, even in winter, spring and autumn, because it can be used to lower the VPD

Carbon-dioxide enrichment

The need for CO_2 enrichment is not clearly established for greenhouses in the Arabian Peninsula in view of the prevailing high radiation during winter months Furthermore, the need for prolonged ventilation periods during the day represents an obstacle to efficient CO_2 enrichment

Automation

Simple automation for ventilation and heating, as well as for irrigation, is required

Concern was expressed with regard to situations where high temperatures prevail combined with high humidity outside the greenhouse (RH>80%) This could be managed through more efficient ventilation, combined with shading Simple automation devices would be helpful to improve climate monitoring This may require further investigation which could be undertaken through existing models using climatic parameters specific to a given region

Site Selection

The region is endowed with very favorable climatic conditions for greenhouse crop production during winter When compared for example with Almeria in Spain, it can be deduced that the Arabian Peninsula countries have the environmental and agronomic potential for producing high-quality vegetables which could compete on export markets The best regions for greenhouse crop production are located in the coastal zones The humidity in winter should not be a handicap provided that ventilation is managed in a convenient way In the continental areas with greater temperature amplitudes, the conditions are less favorable—because of cooler nights during winter, heating will be required, and because of very warm and dry weather in summer, cooling systems will be essential for growing crops during this period

Therefore, it is recommended that the agro-climatic characterization that has already been initiated to identify the areas with the best potential for the greenhouse-crop sector (temperature, solar radiation, evapotranspiration potential (ETP), water availability and quality) be completed This information could be processed and analyzed using geographic information systems (GIS) and the experience of the Central Laboratory for Agricultural Climates, Egypt (CLAC) in agrometeorology

Agro-ecological characterization is of primary importance for the selection of the best sites for greenhouse establishment Agricultural extension staff and growers should have this information available to enable them to select the most appropriate microclimates and areas APRP is already collecting and processing agro-ecological information within the region

Concern was expressed with regard to methodologies of technology transfer to the producers and farmers The solution of establishing 'model' or 'reference' greenhouses was envisaged which would allow the farmers to see and compare the proposed improvements

Future Activities and Research Priorities

Priority Target Area and Beneficiaries

Research and demonstration should concentrate on simple, low-cost technologies affordable by small- or medium-scale growers

In general, the activities proposed belong to one of the following groups

- Training and demonstration for technology transfer
- Technical guidelines and demonstrations

- Applied research and demonstration for investigation and validation
- Information management and databases

Activities have been classified in three categories based on the time estimated for producing an impact or quantifiable output short term (activities which could be initiated immediately), medium term (activities which could be initiated as soon as possible and should produce tangible results within three years), and long term (activities which could be initiated as soon as possible and should produce tangible results within five years or more)

Short Term

There are a certain number of technical improvements which could be immediately proposed to the growers and are expected to have a positive impact It is therefore suggested that training activities for existing extension field officers and growers be undertaken

Selected technical topics for immediate improvement at the farmers' field level are

- Orientation of greenhouses
- Fitting of plastic films
- Proper installation, operation and maintenance of fan-and-pad cooling systems
- Shading of greenhouses

S 1 Training

S 1 1 Training of trainers and government technicians (extension services) for interaction with farmers

- Prepare technical booklets for training purposes
- Implement technical training seminars

S 1 2 Training of growers (producers) and farm technicians

- Prepare training materials and guidelines for growers (simple hands-on extension leaflets)
- Implement training of growers possibly using the farmers' field school approach (participatory training)

The participating countries rated this training component as high priority to be implemented as soon as possible.

S 2 Information

S 2 1 Country blueprints (detailed identification of country status and constraints)

Some countries consider that a more in-depth survey/study might be required to identify the needs and constraints of the greenhouse crop sector more precisely It was also indicated that a technical document would be published on the 'state of the art,' compiling the information obtained through country case studies and missions carried out under the umbrella of the APRP

S 2 2 Set up national and regional technical advisory committees to assist private commercial growers in decision-making

The country representatives considered this proposal useful It was considered that, although it could be established in the short term, it would need to be maintained on a long-term basis It was therefore suggested to consider it as part of the networking activities It was clarified that the technical advisory committee is expected to give an independent opinion on investment and crop management decisions to be taken by large-scale commercial growers The committee would be composed at the national level of one or more knowledgeable persons The national committee members would join into a regional technical advisory committee, which could operate as a network The committee, through its professional contacts, would be able to seek advice from abroad whenever required It would serve as a buffer and technical reference for growers who need an independent opinion to compare and evaluate the advice and recommendations received from commercial sales agents

Medium Term

M 1 Training

M 1 1 Continue training program for growers and national extension staff initiated under S 1

M 1 2 Develop a national/regional capability and the resources to design and assemble greenhouses and fill a local advisory capacity for maintenance

M 2 Guidelines and demonstration—Greenhouse design and modeling Design a model greenhouse to be established in each country in cooperation with a pilot private grower This would be compared with the prevailing local model (conventional single-span tunnel) within the context of an overall integrated production and protection approach (physical measurements—light, humidity and temperature—as well as crop response) This would also include experimenting with new films, including anti-drop and IR-opaque films, as well as other commercial films of interest (e g the recently imported multi-layer film from India in Qatar) It would also be useful to make an agronomic and economic assessment of cheaper 100–120 μm films which have a life of one year

The idea of conceiving and establishing 'model' or 'reference' greenhouses, targeted for the small- and medium-scale farmers was rated as high priority. The country representatives considered that this would be a

live demonstration of what could or should be done They felt that it would be easier to convince the farmers to adopt a new greenhouse model if they could see it for themselves and verify that good crop results could be obtained It was stressed that the study of improved greenhouse types would be undertaken based on the specific requirements of the individual countries and their climatic conditions This program component would therefore be implemented as an application of the overall climate characterization initiated by APRP

M 3 Applied research

M 3 1 Automation Develop simple automation devices for ventilation, humidity control and irrigation management

M 3 2 Climate control

- Experiments should be conducted on improved cooling systems (evaporative cooling) which can be locally manufactured and maintained with nozzles and pads adapted for use with brackish water
- The most appropriate combination of shading, ventilation and cooling needs further investigation A preliminary assessment could be made through existing greenhouse climate models available in EU countries (France, The Netherlands, Belgium) and by using specific climate data (radiation, temperature, humidity) available in the Arabian Peninsula
- The control of humidity inside the greenhouse and more specifically the VPD needs to be investigated as part of the ventilation management Excessive ventilation may induce high evapotranspiration rates and growth stress due to high VPD (>20 mbars)

M 4 Information management and databases

M 4 1 Continue with the agro-ecological characterization, which will be required to identify the areas (sites) with the best potential for the greenhouse-crop sector (temperature, radiation, ETP, water availability and quality) Integrate this information using CLAC and GIS experience and data

This activity is considered of high importance for the AP countries and should serve as a powerful tool for the selection of areas (sites) which have the highest agro-ecological potential for the development of the greenhouse-crop sector The countries emphasized that it should be linked to GIS whenever this was already available in the country

M 4 2 Write and publish a technical handbook on greenhouse management in the Arabian Peninsula

The participants showed a high level of interest in this activity—the region is lacking scientific and technical documentation specific to the Arabian Peninsula.

M 4 3 Make an agro-economic assessment to evaluate greenhouse crop production in winter only (with ventilation only), versus year-round cultivation (including cooling) An 'input–output' approach should be adopted to substantiate the study economically

It was indicated that this assessment should be made with due consideration for the climatic zones in individual countries

Long Term

L 1 Training

L 1 1 Training of scientific staff at Masters and PhD degree level

L 2 Applied research

L 2 1 Investigate the potential for the use of passive solar heating systems

Networking Activities

Networking involves the active and voluntary participation and contribution of members in selected countries with some additional funding from outside These activities are in addition to those mentioned in the chapter on Networking

A Training

- Joint training courses and training workshops on selected topics (e g vegetable-seedling production, identification of insects and other pests, irrigation management, fan-and-pad cooling operation)

B Joint applied research projects

- Participation of a restricted number of countries in a well-defined project of interest to the region with a clearly defined objective, quantified outputs and a precise time-frame

Soilless Culture and Water Use Efficiency

Soilless Culture and Water Use Efficiency for Greenhouses in Arid, Hot Climates

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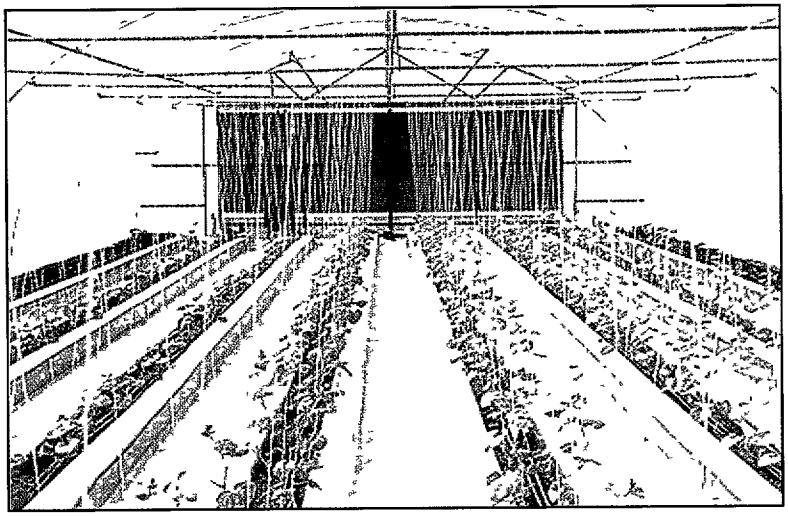
Abstract

Soilless cultivation is intensively used in protected agriculture to improve control over the growing environment and to avoid uncertainties in the water and nutrient status of the soil It also overcomes the problem of salinity and the accumulation of pests and diseases

Soilless culture is carried out in two main ways Firstly, by using an inert substrate Rockwool is the most widely used, although materials like perlite, sand, gravel and rock-like chippings are also used Organic material such as peat is sometimes used Secondly, true hydroponic techniques where there is a minimum of substrate and plants are generally grown in a recirculating nutrient solution

In the past the substrate systems have been 'open' with the surplus nutrient running to waste This has been wasteful of water and nutrients and has resulted in pollution of groundwater Disposal of the used substrate has also resulted in an additional pollution problem As a result of this there has been a reduction in the amount of substrate used and the development of 'closed' substrate systems This has brought substrate systems closer to the true hydroponic systems like nutrient film technique

Nutrient film technique (NFT) maximizes water-use efficiency by recycling all the water and nutrients not used by the plants A thin film of nutrient solution maintained between two polyethylene sheets is provided to the plant roots, which grow into it A pump delivers the solution to the higher end of the system, and the solution then flows under gravity back towards a storage trough (the system requires a minimum 1-in-100 gradient) Because of the risks of power and pump failure, most systems have both a back-up power supply and two pumps Control of nutrient concentration is critical and tends to be automated via a conductivity meter, however, caution is required because of the risk of non-nutrient salt build-up giving false nutrition readings The main requirement in changing from a soil-based system to NFT is the upgrade in management skills—the whole system reacts much faster than conventional agriculture, and so needs more careful monitoring and closer management



Cucumber in a closed soilless system at Al Sulaiteen Agricultural Complex (Qatar)

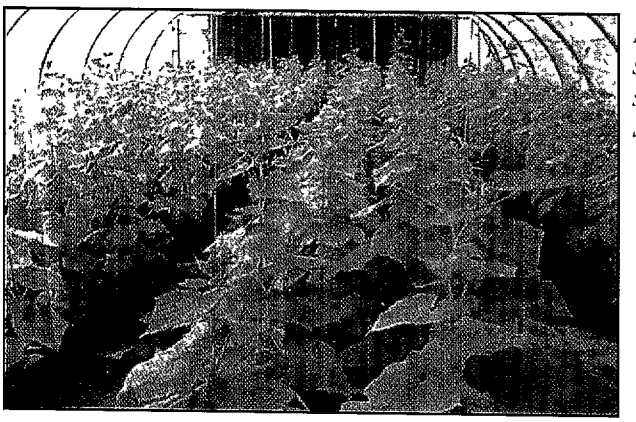
Summary of Major Issues Arising and Discussion

Traditional techniques in protected agriculture may be highly productive but their relative use of water may be high due to run off and infiltration, thus, the water-use efficiency may be relatively low In arid countries, rapid evaporation from the soil surface may also lead to salinity problems Soilless techniques offer a way of improving water-use efficiency and obtaining better water management in crop production

A good grower may achieve the same yield in soil as in soilless cultivation, but is likely to use 50–100% more water as a result of water losses from over-watering the soil and evaporation from the soil surface If we consider yield per unit of water applied, soilless systems may increase yield substantially over soil-based systems

There are two main types of soilless cultivation

Open systems where the water and nutrients are supplied as in conventional soil culture and the surplus (about 25%) nutrient and water is allowed to run to waste The attraction of this technique is its similarity to soil as a growing medium and many similar techniques have been developed using a variety of inert media such as rockwool, sand, vermiculite, perlite and pumice The two most important features relating to the substrate are that it is inert and that it has a great water-holding/release capacity The maintenance of an appropriate water and nutrient level within the substrate is essential to prevent plant stress



Production of cucumber in sand bags—open soilless system, Ottoria Research Station (Qatar)

Waste substrates can be used as a soil conditioner but its use is very limited Rockwool can be recycled (re-used) for up to three years, after which it loses its water-holding capacity

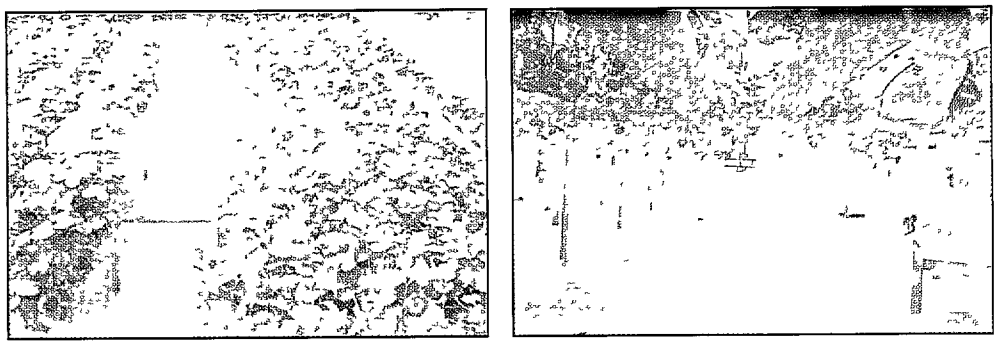
A major disadvantage of open systems is that a proportion of the water and nutrients must be allowed to run to waste This lowers water-use efficiency and contaminates groundwater supplies with salts There is also a pollution problem arising from the need to dispose of the substrate on an annual or biannual basis

Closed systems, such as nutrient film technique (NFT), where a film of solution is trapped between two sheets of polyethylene to form a growing channel This provides a good contact between the recirculating solution and air, which is sufficient to maintain the oxygen level required by the roots without additional aeration of the solution Because the solution is continually moving, there is very little short-term variation in salinity, unlike in the soil where salinity rises and falls with the water content It is possible, therefore, to grow plants in much higher salinity in NFT solutions than would normally be used in soil-based production

The main advantages of the closed systems over the open ones are the reduction in water and nutrient loss to the environment resulting in better water-use efficiency Also, closed systems use minimal substrate, so the problem of pollution of the environment from its disposal is also reduced

Advantages of soilless systems

- Nutrients and water are applied more evenly to the plants, therefore reducing wastage and providing a situation closer to the ideal growing conditions
- Soilless cultivation has the capacity for increased yield Improvement in crop production could be more than 10-fold



Tube culture techniques for the production of strawberries on raised benches —an example of a closed system (Ottoria Research Station, Qatar)

- The system can be automated to control and maintain the nutrient levels in the solution
- One important difference between NFT and soil-grown crops is that in NFT water and nutrients are brought to the roots as they are continually bathed in the solution, whereas in the soil the roots must grow through the soil to obtain water and nutrients
- Water-use efficiency can be at least doubled compared with soil-grown plants, since water is only introduced into the system when it is lost through the plant
- Allow precise monitoring and control over the nutrient solution which minimizes water and fertilizer usage and maximizes production
- Solution concentration may be used to control growth, e g a high-conductivity nutrient solution stresses the plant reducing vegetative growth
- The risks of disease spreading to the crops in NFT are relatively low The use of chemical insecticides and fungicides in solution is an effective control measure
- In cucumber grown in NFT a small amount (<1%) of silica in the solution gives good protection against powdery mildew
- The initial investment in structure, troughs, etc , and control systems is returned by the improved efficiency in the use of water and the consistent quality and quantity of crops produced

The biggest requirement when changing from conventional to soilless cultivation is the upgrading of management Failure to do this can result in failure of the whole system The simple reason is that, in traditional production the soil acts as a buffer to the decision-making process In soilless growing there is less of a buffer,

the reaction time of the crop to changes in nutrient-solution supply is less and decisions have to be taken at relatively short notice The systems have to be actively managed

Disadvantages of soilless systems

The main disadvantages of soilless systems are the initial cost and the increased technical demands on the management

It is easy to adopt hydroponics technology The pipe-work is standard Equipment for measuring pH and conductivity, and (if possible) for conducting solution analysis is needed Ready-made nutrient solutions for hydroponics are available on the market Management of a hydroponics system is a mater of experience it is advised that workers (researchers, extension workers and growers) should start small with soilless techniques and develop confidence in the system

Future Activities and Research Priorities

Water-use efficiency is considered one of the most important issues for protected agriculture in the Arabian Peninsula (AP) It is mainly linked with growing techniques and systems The use of cultivation systems appropriate to each condition (soil or soilless cultivation) is strongly advised, but consideration should be given to alternative techniques and to the development of related technologies

Training

The participating countries recognized the importance of conducting training programs in water and water management for different target groups using local, regional and international resource persons

Major issues for training include

1 Management of greenhouse irrigation systems

2 Soilless culture techniques

3 Nutrient solution composition and management

Applied Research and Experiments

Activities with research experiments were considered highly important for the AP The major research issues that are highly recommended are

- Water requirements conduct experiments to determine water requirements for various crops under different greenhouse conditions
- Irrigation systems and techniques improvements on existing irrigation and fertigation systems with the aim of reducing water and fertilizer wastage
- Soilless culture adaptation and development of suitable soilless culture This would require many experiments on
  - Growing medium
  - Nutrient solution composition and formulation
  - Solution temperature
  - Crop and cultivar responses

Information and Technical Publications

There is a lack of up-to-date scientific and technical documentation specific for the region

- Write and publish technical handbooks and guidelines on
  - Modern irrigation systems for greenhouses
  - Soilless culture techniques and management
  - Plant nutrition and fertigation.
- Study the economics and techniques of producing transplants in centralized nurseries using soilless techniques
- Economic assessment of different growing systems This assessment should take into account production per unit of water, labor, and land

Networking and Databases

- Develop regional mechanisms to exchange experience and to transfer available technologies between the countries of the region
- Pooling available knowledge on
  - Crop water-requirements
  - Nutrient requirements and nutrient-solution composition
  - Control systems and automation

Postharvest Issues for Protected Agriculture Production

Postharvest Handling and Monitoring of Quality for Vegetables Produced in Greenhouses in Hot, Arid Climates

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Abstract

The general trend for increased vegetable production throughout the world may be attributed to improved cultivars, agricultural technology and increased demand Increased consumer demand is partly as a result of increased awareness of the nutritional value of such food However, consumers also demand a certain (high) quality in vegetable produce Postharvest losses account for 10–50% of harvested vegetables world-wide—a significant waste Losses may be caused by natural or handling processes, but all must be reduced Respiration and transpiration (which continue after harvest) are key to natural decay and require careful control via handling and environmental optimization (temperature, relative humidity, air composition) To maximize vegetable shelf-life, only good-quality vegetables should be harvested, and these either early or late during the day at the right stage of maturity—quality can only be maintained after harvest, not improved Careful handling at all stages is needed to prevent physical damage If possible, transport and storage facilities should be refrigerated (to optimum storage temperature), otherwise transport should be done during cooler parts of the day and other cooling mechanisms used (e g shading or reflective containers) Quality standards need to be monitored, and certain aspects (e g pesticide use and residues) should be covered by governmental legislation

Summary of Major Issues Arising and Discussion

Consumers expect vegetables to be of a certain quality when they buy them Proper postharvest handling is a complementary factor that can minimize vegetable deterioration between harvest and consumption Postharvest losses are due to technological or non-technological causes

Postharvest losses include physiological changes and vitamin C degradation of vegetables, these may be affected by postharvest temperature and respiration rate Physiological losses—e g deterioration in texture, flavor and aroma—are less

obvious, but add to the losses of vegetables Respiration rate is a good index of the potential postharvest life of a vegetable since it increases with the rate of deterioration

Rough and careless picking, packing, loading and unloading cause mechanical damage Rots are usually the greatest single cause of loss because most micro-organisms enter through mechanically damaged tissues

Vegetables contain as much as 80–95% water Water is lost not only through respiration, but also through transpiration and other metabolic processes Temperature, relative humidity, gases, micro-organisms and insects are the most important environmental factors that affect water loss from vegetables

Three main factors reduce losses controlling growing factors, harvesting good-quality vegetables and avoiding physical damage The cultivar, conditions during growth, the amount of care provided during production in terms of water supply and nutrient elements, and the control of insect pests, diseases and weeds determine the quality of the produce at harvest and subsequently

A simple and inexpensive way of minimizing losses after harvest is to practise care in harvesting and throughout the handling chain Another important point to remember is that, once harvested, the fruit's quality can only be maintained, not improved Thus, it is best to start with good-quality vegetables and maintain their condition

For easy, quick and cost-effective methods of monitoring the postharvest environment, the use of biosensors or 'electronic nose' is a potentially useful future approach

The ultimate need for high quality is to maintain the freshness of vegetables, minimize their deterioration, and improve other quality aspects This can be achieved through controlling growing factors, selecting the best cultivars, appropriate vegetable maturity, selecting good-quality vegetables at harvest, pre-cooling, avoiding physical damage, and controlling abiotic and biotic factors

The discussion of this paper was entirely about pesticide residues The question arose as to who provides the standards for allowable pesticide residues in (protected) agricultural produce, are the standards the same for example in the EU as they are in the Arabian Peninsula (AP) countries? It seems that there is as yet no uniform law (standard) on pesticide residues in the EU, at present, each country has its own standards The relevant laws usually regulate the crops to which a pesticide may be applied, the number of applications per season, and the duration between the last application and harvest (which has a direct influence on the residue level in the harvested product), in addition to allowable (safe) residue levels in marketed produce Globally, it seems that only a few countries have strict pesticide-residue regulation, for example the USA, Japan and EU countries

In response to a question about which AP countries apply residue regulations, or are at least trying to establish standards for such, Oman has a toxicology laboratory and has been preparing standards since 1996 However, they have a major problem with protected-agriculture (PA) cucumber, as the last pesticide spray is too close to the harvest date and delay of harvest results in oversized cucumbers Diseases of PA cucumber are not the main concern, as modern fungicides have low (human and environmental) toxicity and the fruit can be harvested shortly after the last spray Insecticides, however, are a bigger problem In fact, there are no insecticides currently approved for PA cucumber in Germany—the only answer to insect pests is biological control, but even here it is unlikely that imported biocontrol agents would be effective, so research is needed to identify suitable organisms in the AP countries themselves

Kuwait has strong pesticide research Control is implemented through inspections conducted by both the agriculture department and the municipalities In addition, Kuwaiti consumers are particularly alert to the quality of food products

Two useful references for those seeking to establish pesticide-residue standards are the FAO *Code of Conduct for Safe Use of Pesticides* and the FAO/WHO *Codex Alimentaris*

One of the main issues of pesticide residues is that standards need to be enforced and policed In the UK, supermarkets set their own rules and regulations, and test produce before buying In continental Europe, there is closer contact between the farmers and the trade, which results in contract farming and consequent 'safer' produce

Vegetables grow in a very short time under PA and timing of harvest is critical (often daily) Thus, spraying is simply not an option Integrated production and protection management (IPP) recognizes that it is essential to combine production and protection management It is really the only way forward for PA, although it is costly The cost repays itself through quality produce without the need to resort to 'organic' farming

Future Activities and Research Priorities

Start quality management in the field

Establish quality criteria according to the market and consumers' requirements (size, color, grading, etc)

Rationalize the use of chemicals to avoid residues in harvested produce

Introduce proper storage facilities

Integrated Plant Production and Protection

Recent Developments in Integrated Production and Protection Management for Greenhouse Crops Cultivation

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Abstract

The paper gives an overview of the expansion of the greenhouse sector, with specific reference to the Mediterranean region, where greenhouse cultivation has witnessed spectacular development during the last 15 years Reference is made to the particular interest of greenhouse crop technology in the context of FAO's special program for food security The intensification of crop rotation under protected agriculture is posing a threat to the environment, through the increased use of pesticides and the disposal of drainage water and waste products Integrated production and protection management (IPP), is proposed as a strategy to develop an economically viable and sustainable production system which should lead to a substantial reduction in the use of pesticides and the preservation of the environment Adequate cultivation practices in conjunction with coordinated climate control and use of improved cultivars are essential components of IPP, which includes integrated pest management (IPM) Experiences gained and activities undertaken by the FAO Regional Working Group for Greenhouse Crop Production in the Mediterranean Region are used as an illustration

Integrated Foliar Disease Management for Greenhouses in Arid, Hot Climates

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Abstract

Integrated foliar disease management (IFDM) is the utilization of all suitable techniques to prevent leaf-disease outbreaks or to reduce leaf-disease spread below economic threshold In protected agriculture, IFDM comprises greenhouse sanitation (weed control outside the greenhouse, removal of crop debris, soil sterilization, and washing greenhouse walls with sterilant), physical control (insect-proof screens, sticky traps, environmental regulation—plant nutrition, temperature, irrigation levels, free water, humidity and air circulation—, and location of greenhouse), cultural practices (host-plant resistance/tolerance, crop-rotation, disease-free seed and transplants, sterile growing media, and worker behavior in handling diseased and healthy plants), biological control (antagonists of disease-causing organisms), and, chemical control (limited use of fungicides) The aim is to reduce pesticide use (which contaminates the environment), although fungicide will remain an essential component of IFDM for the foreseeable future [The full paper reviews 26 diseases affecting four groups of greenhouse crops]

Integrated Management of Soilborne Pests for Greenhouses in Arid, Hot Climates

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Abstract

Soilborne pests (fungi, bacteria, nematodes and weeds) may severely limit production in protected agriculture Pests may be naturally present in the soil, or may be introduced through air, water, cultural practices, or infected seed or transplants Integrated pest management (IPM) is being developed to reduce dependency on pesticides The focus of IPM for protected agriculture should be plant root health Components of IPM include cultural practices, biological control and physical methods For arid, hot environments, the use of soil solarization is recommended It is passive soil-heating, providing effective, low-cost soil disinfestation Solar energy is captured using clear plastic or glass sheets (permitting 90–98% light transmission) and may raise soil-surface temperature to 75°C (sufficient to kill many fungi, bacteria, nematodes and weeds) The activity combines physical effects (heating) with chemical (hydrothermal breakdown of organic matter) and biological shifts (recolonization of disinfested soil by fast-growing micro-organisms) In hot, arid environments, soil solarization alone should adequately control soilborne pests, however, cool weather, heat-resistant or deeply buried pests may necessitate the use of low doses of pesticide or bioactive organic matter incorporated into the soil, combined with solarization The use of bioactive organic matter (or biofumigation) requires field-testing to determine appropriate doses Soil solarization is most useful in greenhouses or containerized soil—in which effective control can be achieved in 1--7 days Excessive heating must be avoided, otherwise soil organic matter may be decomposed

Summary of Major Issues Arising and Discussion

The Need for an Integrated Plant Production and Protection Strategy

The increased use of pesticides and the disposal of drainage water and waste products calls for the development of an integrated production and protection management (IPP) program for vegetable production in protected agriculture suitable for the Arabian Peninsula

The essential components of IPP are similar to those of integrated pest management (IPM) with more emphasis on the production techniques and activities and the management of the greenhouse These essential components are (i) coordinated climate control in the greenhouse, (ii) adequate cultivation practices, (iii) the use of improved adapted cultivars, which together will reduce dependency on use of pesticides and provide adequate control of insect pests and diseases which seriously limit crop production in protected environments

Pesticides and Health Hazards

Public awareness about health hazards which accompany the extensive use of pesticides in many countries around the world is pushing growers to use less and less of these chemicals in vegetable production in general, and in protected agriculture in particular Growers are everywhere profit driven In the Arabian Peninsula, at least at present, consumers are not prepared to pay higher prices for 'organic' or 'bio-products ' However, this could change in the near future, and consumers might shift to buying products with labels indicating that ecologically friendly approaches were used in their production Growers need to be prepared for this market evolution Encouragingly enough, some markets in the region (e g Egypt) are responding positively to organic farming

It is obvious that there is a public demand to reduce the use of pesticides as much as possible In the short term, it is unlikely that we can produce crops economically in protected agriculture without using pesticides A better approach is minimal use of pesticides, with emphasis on those that are selective Other control strategies need to be used, such as resistant varieties, biological control, and appropriate cultural practices—components of IPM However, to succeed in adapting IPP approaches, research under local environments is essential to permit the development of IPM packages which will be acceptable to the growers

In the long term, however, and with heavy investment in research on biological control, biotechnology, soil solarization, etc , we might be able to achieve zero or close to zero pesticide use Some countries (e g Switzerland) are already producing grapes without spraying the crop A few years ago, nobody would have imagined this to be possible We need to be optimistic

Solarization and Soilborne pests

Plant root health is essential to produce a good crop and an IPP approach to control soilborne diseases and insect pests should include cultural practices, biological and physical control methods

Since an arid, hot climate is prevalent in the Arabian Peninsula (AP), the use of soil solarization is highly recommended Soil solarization under AP conditions may raise soil surface temperature to 75°C, sufficient to kill many soilborne fungi, bacteria, nematodes, insects and weeds

The use of bioactive organic matter (biofumigation) enhances heating efficiency by soil solarization, but this requires field-testing under AP conditions When applying solarization, however, it is essential not to excessively heat the soil to avoid soil organic-matter decomposition

Concern was expressed that solarization could be harmful to beneficial organisms in the soil, such as mycorhizae, which have a positive role in reducing stresses and improving nutrient up-take Even though there is little research in the region to properly address this issue, the general feeling is that temperatures below 45°C will cause little damage When temperatures exceed that level, it is expected that the mycorhizae population decreases, but returns to original levels in 2–3 weeks

The addition of chicken manure or crop residues (e g of cabbage), at the rate of 5 tonnes per hectare, greatly enhanced the efficiency of solarization in controlling soilborne pathogens There was no difference between incorporating a fresh crop residue or letting it dry on the soil surface before incorporating it into the soil It is essential not to use too much residue, as this could have negative effects

Integrated Pest Management

It is essential to apply IPM approaches to control diseases and insect pests which attack the above-ground parts of the plant Growers often choose to use pesticides excessively for control There is some progress in the AP in this direction, but experimentation should be increased to make full use of the available technology at the growers level The main components of such an IPM strategy are (i) greenhouse sanitation, (ii) physical control (insect proof, sticky traps, etc), (iii) cultural practices, including host resistance and healthy seeds or seedlings, and (iv) biological control

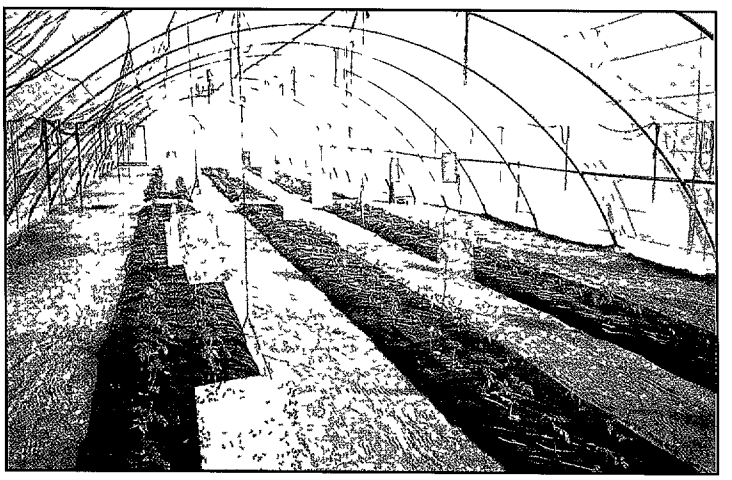
Biological control of insect pests and diseases, in the short term, should be the subject of research, using biological-control agents indigenous to the AP It is also essential to define the optimal conditions under which such indigenous biological-control agents will achieve their full potential Agricultural research stations and universities in the AP can collectively contribute significantly to such an effort

Training in Integrated Plant Production and Protection

Training needs should be identified at the regional and country levels Based on such an assessment, the most appropriate training material will be designed to fulfill the needs and serve the country where it will be used Such training material will, as much as possible, be based on available experience in the region

There are some technologies available, which can be adopted in several regions, e g the production of healthy, high-quality seedlings

There are also some publications available, produced over the last decade by different institutions and international organizations, which can serve as a good starting point with some up-dating of the details Nevertheless, the basic principles are available



Implementation of IPP at the Research Station in Bahrain This illustrates the use of plastic mulch, yellow sticky traps, insect-proof nets on vent openings and use of a double door with insect-proof nets

Future Activities and Research Priorities

The identified activities needed to enhance IPP in the Arabian Peninsula cover (i) surveys, (ii) research and demonstrations, (iii) training, (iv) networking, (v) database development, and (vi) policy recommendations Activities were put in three categories short term—activities that can be initiated immediately, medium term—activities that can be conducted during the coming 2–5 years, and long term—activities for the coming 5–10 years

Short Term

S 1 Surveys—to permit prioritization of different activities related to IPP of crops in protected agriculture, it is essential to conduct the following surveys

S 1 1 To identify production constraints specific to different countries of the Arabian Peninsula

S 1 2 To determine the economic importance of different pests affecting protected agriculture in each of the Arabian Peninsula countries

S 2 Research and Demonstration Activities

S 2 1 To permit rapid impact in protected agriculture, it is essential to make use of the available technologies and demonstrate their usefulness in growers' greenhouses These technologies, however, could be modified at a later stage based on research conducted in the Arabian Peninsula countries

S 2 2 There are many simple technologies available for immediate use by farmers, which are effective in many regions around the world and can be easily adopted by growers in the Arabian Peninsula These technologies are

- proper ventilation
- water application techniques
- cooling techniques
- supplementary heating
- appropriate cover materials for the greenhouse
- use of screens for greenhouse openings to protect from insect vectors of viruses
- use of soil mulches
- control of soilborne pests by soil solarization
- use of healthy seeds and transplants
- pollination
- fertigation
- application of general hygiene principles

S 3 Training—training growers, producers (owners), workers (technicians) and extension staff in IPP approaches

S 4 Networking on IPP—it is essential to exchange experience and information related to IPP among all workers in the Arabian Peninsula Development of databases to include all existing information on IPP and to make it available to research and extension staff

S 5 Policy Recommendations—even though there was a general consensus that policy issues are the responsibility of officials in the respective countries of the AP, there was agreement among participants that scientific staff involved in IPP can provide technical recommendations to policy-makers in AP countries

Medium Term

M 1 Research

M 1 1 Continue all immediate activities mentioned above under Short Term

M 1 2 Develop economic thresholds for the most economically important pests Such thresholds are important as guides for the development of IPP packages

M 1 3 Encourage the private sector to develop central nurseries

M 1 4 Identify indigenous biological-control agents for the economically important pests in AP

M 2 Database Development

M 3 Policy Recommendations

M 3 1 Develop recommendations related to pesticide application regulations, residue levels and the 'safe period' before harvest

M 4 Training

M 4 1 Continue training as indicated for the Short Term

M 4 2 Develop simple color manuals for pest identification, identification of bio-control agents, application of solarization and integrated pest management

M 4 3 Individual training on specific areas

Long Term

L 1 Policy Recommendations

L 2 Research on economic viability of production and governmental actions required to assure viability

L 3 Research on optimization of using inputs for IPP

L 4 Research on application of biological control based on the use of indigenous bio-control agents

L 5 Training of scientific staff at MSc and PhD level

Regional Networking

Regional Networks for Protected Agriculture in the Arabian Peninsula in View of the Mediterranean Experience

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Abstract

Technical cooperation networks are playing an increasingly important role in agricultural research and development Well-conceived, adequately funded and well-managed networks can lead to effective utilization of available resources and early results Successful networks are usually preceded by an in-depth study for their necessity and membership Experience has indicated that networks could develop more efficiently if membership is initially made up of a small number of research centers or countries, keen on cooperation among themselves and with some ongoing research program in the general mandate area of the proposed network's activities Expansion can follow later The Regional Working Group on Greenhouse Crop Production in the Mediterranean is made up of 11 Mediterranean countries and was founded in 1993 It is funded by FAO and through its four technical working groups covers activities in all aspects of protected agriculture in the region With the limited funding at its disposal and biannual meetings not regularly attended by all its member countries, it has never the less managed to coordinate and assist in training and information flow to and from the various countries Its long-term viability is substantially dependent on continued donor support In view of similarities of production issues under protected agriculture between the Mediterranean and the Arabian Peninsula it is suggested that consideration be given in creating a similar network for the Arabian Peninsula

A linkage between the two networks is potentially desirable A possible structure for the projected network comprises a National Coordination Center, a Network Coordination Board and National Liaison Centers Funding for the network is of crucial importance for its long-term growth and viability, and may be achieved either from donors or through an annual subscription from member countries/institutions

Summary of Major Issues Arising and Discussion

Networks aim at maximizing the use of local expertise and resources among cooperating countries, and hence place comparatively less reliance on external manpower support The principal advantages of establishing a research network are the fostering of collaboration among scientists in various countries and exchanging information Agricultural networks in Africa and the UK also serve as channels for the dissemination of information about new crop cultivars The main difficulties, however, are maintaining and funding an ongoing research-and-development program

Networks can generally be classified into three categories

1 Associations with a formal structure, a constitution or similar agreement and a Management Committee of some sort Membership implies an annual fee Generally, work programs for such networks include publications, newsletters, meetings for exchange of information, studies and training Examples of such networks in the region include those for credit and marketing, for agricultural research, and the Interregional Cooperative Research Network on Olives

2 Associations with less formal arrangements often involved in applied research, exchange of information, training, etc In this type of network there is no constitution as such and members do not pay any annual fee Instead members provide inputs in kind which may cover part of their cost A donor or donors provide the external funding needed for the operation of the network and ad-hoc arrangements exist for selecting the chairperson (or coordinator) and other bodies necessary for the operation of the network Such networks are often set up with a long-term operation in mind, e g the Regional Working Group on Greenhouse Crop Production in the Mediterranean (RWGGCPM)

3 Associations, usually of a short-term duration, specifically set up in order to undertake a specific activity At the end of this activity the Association ceases to exist Normally such associations are highly successful, because of their specificity, adequate funding and interest on behalf of participating institutions

Networking advantages include

- The possibility of initiating joint programs for specific problems, often economizing in scarce human and financial resources
- The development of common standards, methodologies and approaches in many areas including commerce
- The facilitation of information exchange on a regular basis which often allows countries to utilize each others' experience and thus avoid unnecessary duplication

- The potential linkage between developed and developing countries enabling resources from the former to be utilized in support of developing-country problems Networks also encourage the flow of external assistance through contacts that develop
- The development of joint activities on a permanent basis for across-border cooperation in such vital areas as for example food security, migratory pest information and control, and in resolving trans-boundary issues (e g water resources and fish stocks)

The potential cooperation of the Arabian Peninsula countries in the field of protected agriculture could best be served through the setting up of a network for protected agriculture The main objectives of such a network could be, but not necessarily limited to

- Exchange of information
- Implementation of joint programs of work
- Exchange of genetic material
- Organization of joint meetings
- Organization of training courses on specialized topics
- Study tours
- Exchange of scientists (short term—aimed at examining/advising on specific problems and issues)

For a protected-agriculture network in the Arabian Peninsula it is essential that a Network Coordination Center be established in order to:

- Act as the coordination and management entity of the network
- Organize collaborative activities/joint programs
- Disseminate information and publish a newsletter
- Organize meetings, workshops and consultations, including the coordination leading to the preparation of an annual program of work
- Maintain connections with other regional and international networks in all aspects of protected agriculture

It is advisable to start with a small number of countries and to gradually expand rather than include all countries in the Arabian Peninsula as members, if they are not at this stage ready or really interested in joining the network

An assured source of funding will be of primary importance for the long-term viability and success of any network on protected agriculture (PA) in the Arabian Peninsula Many of the issues that networks seek to address move slowly in the absence of donor funds and proper coordination (a point which arose clearly at the meeting that established the RWGGCPM), however, part of the sluggishness of the Mediterranean Working Group was blamed upon the large number of Technical Subgroups originally created (14)

Successful networking implies continued support from governments, institutions, scientists and the farming community This is likely to occur only if the network works efficiently, and produces results which reach the farmers and are applied by them—increasing productivity for the benefit of the country as a whole

The findings of the various Technical Subgroups of the RWGGCPM are available to researchers in the Arabian Peninsula countries in the form of various publications (newsletters, meeting reports, country reports) from both FAO headquarters and the various chairpersons of the Technical Subgroups

The poor attendance at the Second Coordination Meeting of the RWGGCPM (5 countries out of 11) was attributed to the scarcity of PA scientists in the various countries and to conflicting interests (other meetings scheduled at the same time) There was no indication that countries or representatives boycotted meetings because they thought the Working Group was a 'talking shop' rather than an active entity However, it was the view of the speaker that starting a network with few members and building membership over time would be advantageous, he cited the example of an olive-cultivation network in the Mediterranean, which has successfully followed this route, although it is still dependent on donor funding

The participants showed some interest in developing regional mechanisms to exchange experience and information, and to transfer available technologies among the countries of the region The participants recognized the interest of exchanging information and know-how in order to speed up the transfer of technologies to develop the PA sector in the Arabian Peninsula They agreed that a permanent mechanism for inter-country cooperation could be established to serve this purpose on a country basis It was recommended that consideration should be given to establishing a regional network for *Greenhouse Crop Production in the Arabian Peninsula* The network would serve as a framework for

- exchanging information (existing technical documents, extension material and newsletter)
- developing a joint database
- hosting the regional technical greenhouse advisory committee

Two mechanisms for the initiation of a PA network in the Arabian Peninsula were suggested The decision of starting a network ultimately revolved around the question of whether such a network would make PA research in the region more efficient and more effective This should be answered by the various National Coordinators within the APRP—if they decided it was the right way to go, then adoption of a network should be referred to the APRP Regional Steering Committee The alternative suggestion was that the APRP-appointed Protected Agriculture Specialist should study the issue of networking further and present the findings to the Steering Committee The Steering Committee would then recommend the establishment of a network to the National Coordinators for

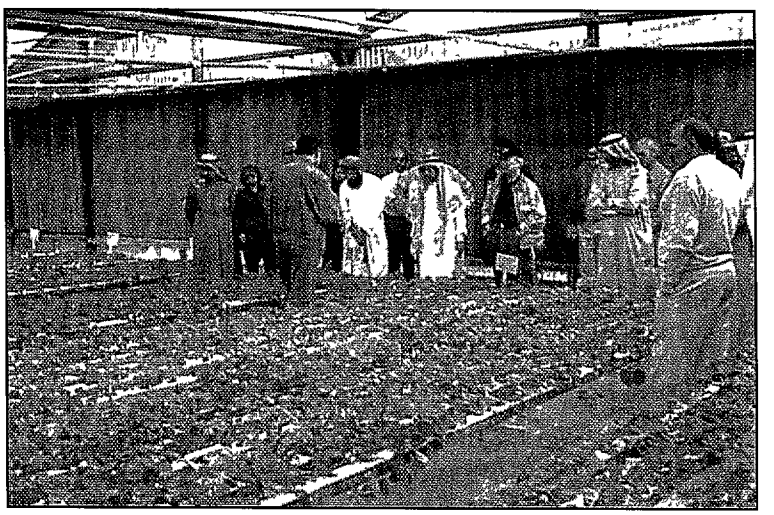
agreement and implementation Either way, it was unlikely that a formal network would be established at this (i e the Doha) meeting

Subsequent to the Doha meeting, a decision was taken to develop electronic networking through the Internet—this will be linked to the protected agriculture section of the APRP HomePage The first networked information will be the full-text version of the proceedings of the Doha meeting

Field Trips

Introduction

One day was set aside to enable all the participants to visit four protected-agriculture complexes The diversity of structures, growing systems and crops provided an excellent forum for further discussion of the major themes of the Workshop



Brief descriptions of the four complexes follow

Horticulture & Greenhouse Experimental Station, Ottoria

The Horticulture & Greenhouse Experimental Station is one of three research stations belonging to the Department of Agricultural and Water Research, Ministry of Municipal Affairs and Agriculture It is located in the middle of Qatar in Ottoria village some 35 km east of Doha

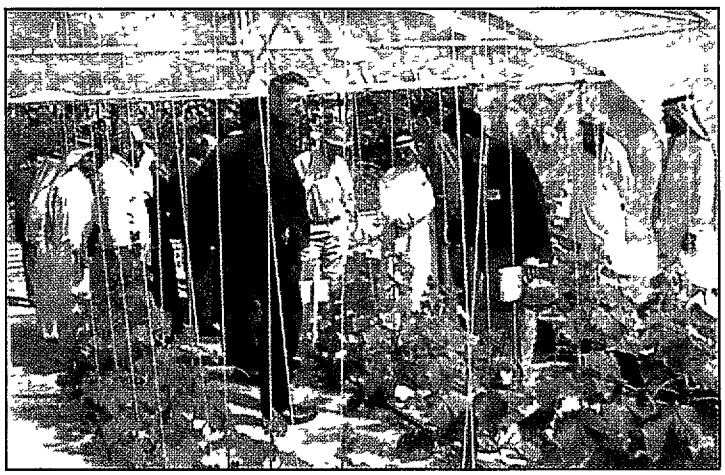
The station was established in 1979 The total area of the farm is 7 ha and consists of 12 plastic houses (2160 m²) In 1984, a modern fiberglass house with computer control was erected The total area of this well-equipped unit was 1102 m² and it consists of six compartments The unit was furnished with control room, central computer, small laboratory, stand-by generators and nutrient film technique (NFT) controlling equipment

In 1993, a major renovation plan was implemented which included the following

- Redesigning of the fiberglass unit with some major changes to overcome problems associated with orientation
- Establishing a controlled growing room within the fiberglass unit to ensure the production of good-quality seedlings
- Adding 12 plastic houses with evaporative cooling systems
- Redesigning the irrigation network for the farm and installing a modern irrigation system for the open-field experimental plots
- Installing a solar-powered water-pump and irrigation controller
- Installing a water desalination unit

The dynamic research team of the research station consists of one PhD scientist, an agriculturist, a technician with three assistants, and a foreman with 14 laborers

Participants examining the tube culture techniques, Horticulture & Greenhouse Experimental Station



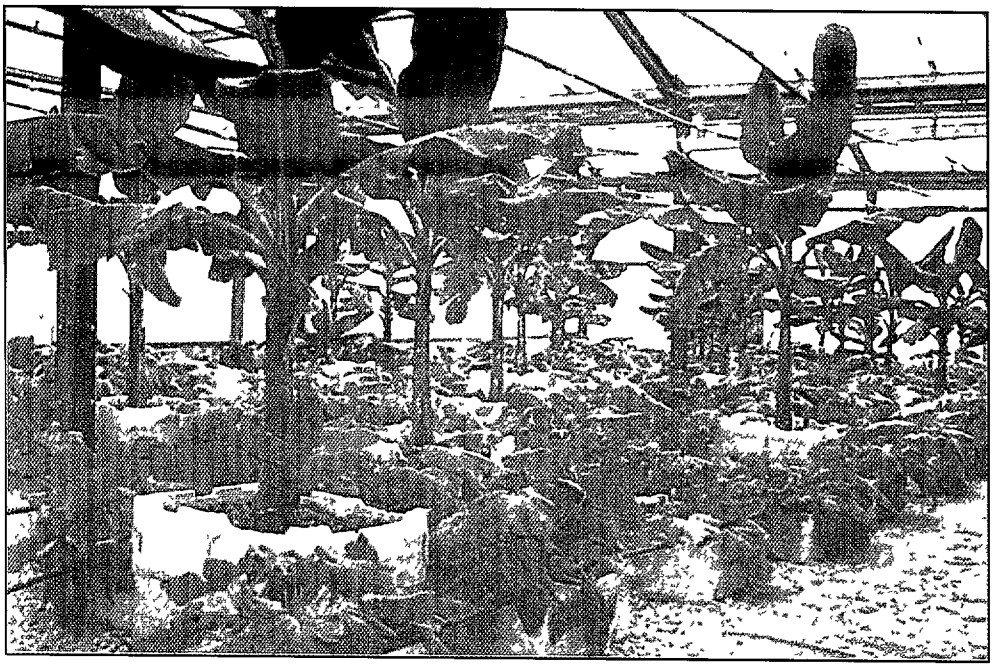
Major Research Activities

1 Development and/or adaptation of new growing systems and techniques with more emphasis on soilless culture

2 Greenhouse management, including greenhouse cooling systems, shading systems and materials, and the utilization of solar power for irrigation and water desalination

3 Crop management in relation to plant density, irrigation, nutrition, and pest and disease control programs

4 Crop and cultivar responses and performance under local conditions for cucumber, tomato, pepper, eggplant, lettuce, melon, squash, strawberry, banana and cut flowers such as roses, carnations, and bird of paradise



Banana production in protected agriculture at the Horticulture & Greenhouse Experimental Station

Arab Qatari Agricultural Production Company

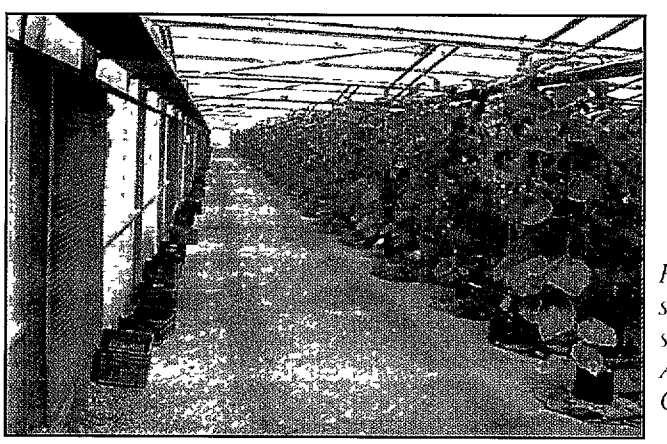
Background

The Arab Qatari Agricultural Production Company was established by the 58th decree issued by His Highness the Amir of the State of Qatar in November 1989 It is a joint-venture company between the Government of the State of Qatar and the Arab Authority for Agricultural & Investment Development (AAAID), and has capital assets of 47,000,000 QR

Assets

The assets of the Company include

- Twelve fiberglass-roofed greenhouses covering a growing area of 3 ha and run with a computerized fan-and-pad cooling system
- Six glass-roofed greenhouses covering a growing area of 3 ha run by a computerized fan-and-pad cooling system
- Three green-wholes covering a growing area of 3 ha, roofed with aluminum slots and an insect screen, without cooling
- Sixteen plastic tunnels occupying an area of 5000 m^2
- An industrial building comprising a grading and packing unit, five cold rooms, two reverse osmotic desalination plants, offices and a workshop—other buildings include officials' residence, laborers' camps, store rooms and a mosque
- Open fields covering an area of 33 ha, of which 18 5 ha are sprinkler irrigated, 3 3 ha drip irrigated, and 11 2 ha flood irrigated



Production of cucumber in sandbags in cooled multi-span house, Arab Qatari Agricultural Production Company

Objectives and Activities

The main objectives and activities of the Company are

1 Contribution to the agricultural development and food security in Qatar

2 Apical intensification of vegetable production by maximizing the utilization of greenhouses throughout the year

3 Involvement in production of cut flowers and ornamental plants, and vegetable and flower seedlings

4 Vegetable and fodder production in open fields

Other activities include introduction of some European vegetables, sale of some agricultural inputs and supply of quality products for the fresh food market

Products

The main products of the Company are

Greenhouse	**Open field**
Cucumber	Alfalfa
Tomato	Sweet corn
Sweet pepper	Squash
Snap beans	Celery
Okra	Lettuce
Cut flowers	Chinese cabbage
Indoor plants	

Greenhouse Technical Characteristics

Growing media: Coarse washed sand in plastic bags represent the media for greenhouse vegetables Rockwool and water culture have been eliminated because of their high cost and critical requirements for technical operation

Fertigation: Makes use of the A & B tanks' system where 13 macro- and micro-nutrients are fed to drippers Each group of greenhouses is given the same fertilizer formula—the quantity depends on the age of the plants Supplemental foliar fertilizers are sprayed when necessary Plants are irrigated 2–4 times daily for intervals of 2–4 minutes depending on their growth stage and climate

Temperature and humidity controls: In the 12 fiberglass houses, the control is through a central computer, the six glasshouses have individual computers

Seedling preparation: Seedlings are sprouted in peatmoss cubes in the nursery, after which they are transferred to cold-room incubators on illuminated stacks, then to greenhouses once fully developed

Pest and disease control: Prophylactic chemical pest and disease control is emphasized at pre-fruiting stages, making use of chemicals with optimum safety periods Greenhouses are sterilized with formaldeyde before planting Sandbags are treated with Previcur at planting time At fruiting stages sprays are cut down to a minimum and harvest is delayed

Shading systems: An automatic shading system is installed in the fiberglass houses Glasshouses are lightly painted with chalk suspension in summer, which is washed off in winter

Progress in Vegetable Production

Year	Quantity (tonnes)
1990	504
1991	420
1992	556
1993	946
1994	911
1995	958
1996	1187
1997	1259

Al Sameria Farm, Rawdat Rashid, Al Shahania

The Al Sameria Farm, which is owned by Sheikh Ahmed Bin Hamed Al Thani, has an area of 85 15 ha, of which 20 ha are cultivated Eight plastic houses (9 × 40 m) are used in the protected-agriculture industry, with the following crops and growing systems

Cucumber cv Shabieb, planted 10 October 1997, first production 2 December 1997, production period 60 days, 1000 plants/greenhouse, in-line spacing 35 cm, production rate 200 boxes per greenhouse (13 kg/box), total production 2600 kg in 60 days

Green beans cv Daimona and Amira, planted 15 October 1997, first production 10 December 1997, production period 60 days, 2 plastic houses, in-line spacing 35 cm, total production 500 kg

Sweet pepper 1 plastic house, 800 plants/greenhouse, planted 1 November 1997, first production 5 December 1997

Al-Sulaiteen Agricultural Complex

The Al-Sulaiteen Agricultural Complex is located at Aum-Salal Ali city, some 20 km north of Doha The total area of the project is approximately 40 ha with scope for expansion according to the requirements of different stages of the project

In March 1995, activities started at the farm with preparatory survey and geological maps A complete soil and water survey was carried out accompanied with the necessary physical and chemical analyses This was done with the assistance of the Department of Agricultural and Water Research, the Department of Agricultural Development and specialized private companies and consultants The feasibility study and design of the project were completed in December 1996 The project is designed according to the latest scientific standards and techniques to achieve the following

1 To establish an agricultural complex using suitable scientific methods and techniques to preserve natural resources and to provide the local market with top-quality fresh products

2 To establish centrally (and fully) controlled growing rooms for the production of high-quality seedlings and young plants

Fully controlled growing room Al Sulaiteen Agricultural Complex

3 To act as a technical and training center to provide consultancy, and technical and management expert systems to growers

4 To conduct research and experiments with national, regional and international research organizations

Production Sectors

Open field sector
This comprises fodder production using sprinkler irrigation, vegetable production with drip irrigation, and date palm and fruit trees under bubbler irrigatation

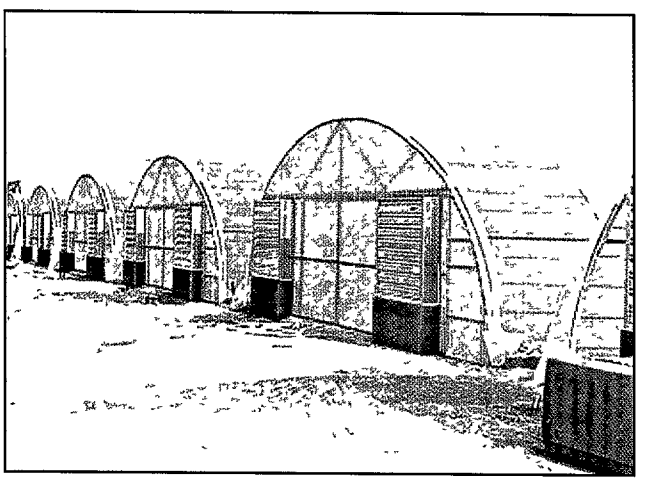
Protected agriculture sector
This sector consists of many production zones

1 Multi- and single-span greenhouses with evaporative cooling systems for the production of cut flowers, vegetables and fresh fruits on a total area of 4900 m^2 (4 9 ha)

- 30 single-span plastic houses—total area of *c* 6000 m^2 (in production)
- 2 multi-span greenhouses—total area of 9000 m^2 (in production)
- 2 multi-span greenhouses—total area of 10,000 m^2
- 5 multi-span greenhouses—total area of 22,500 m^2

2 Shaded nursery with a total area of 1500 m^2 for the production of outdoor decorative plants, fruit trees and shrubs

3 A fully controlled growing room for the production of vegetable seedlings and young plants, with a capacity of 40,000 plants/month



Single-span plastic houses with evaporative cooling system, Al Sulaiteen Agricultural Complex

Animal production sector
This section is divided into many production units that include poultry, dairy and beef cattle, and small ruminants for dairy and meat

Special production sector
Honey bees and ostrich farming

Strategy and Workplan

Protected Agriculture in the Arabian Peninsula: A Strategy and Workplan for Research and Transfer of Technology

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Introduction

Protected agriculture (PA) plays an important role in supplying the region's market with fresh products that cannot be grown otherwise due to the harsh weather and insufficient land and water resources The demand is for high-quality products Growers aim for high yields to maximize their profits The combination of high quality and yield depends on many factors such as management, production techniques, and greenhouse structure and climate control Some of the major constraints facing the PA industry in the Arabian Peninsula (AP) are human resources and marketing

The International Center for Agricultural Research in the Dry Areas (ICARDA) is the first research organization to develop a regional research program for the AP region in PA The PA research is part of ICARDA's wider Arabian Peninsula Regional Program (APRP) The major research themes for PA have been identified and agreed upon by all the county representatives of the AP These are

1 Greenhouse structure and covering materials
2 Water-use efficiency
3 Integrated production and protection

The Strategy

The development of such an important industry requires a strategy to follow, in order to achieve specific goals The decision of holding the International Workshop on Protected Agriculture for the Arabian Peninsula was part of ICARDA's strategy to identify the problems, constraints and research-and-development priorities The outcome of this Workshop—highlighted in these proceedings—can be listed under three major issues

1 Research Activities
2 Regional Networking
3 Human Resources and Training Programs

Research Activities

Research programs for PA should be initiated immediately at the national research-station level with backstopping from regional and international experts in the following activities

1. Greenhouse Structure and Covering Materials

High light intensity and temperature, combined with high relative humidity, characterizes the climate in the Arabian Peninsula region The PA structures that are widely used in the region are those that have been developed to suit cool-weather countries with low light intensity There is a great need to develop a simple greenhouse structure suitable for the region's climate Greater attention should be given to ventilation and cooling systems

The development should include the covering materials Currently, polyethylene sheets are widely used as covering materials With the existing technology, the industry should be able to develop a new film with selective wavelength transmission and longer life

Research points

- Greenhouse structure
- Covering materials
- Ventilation and cooling systems

2. Water Use Efficiency

Water, both in quality and quantity, is one of the major limiting factors for the development of agriculture in general and PA in particular in the region Successful production of high-value crops from greenhouses requires good-quality water that in many cases is produced from desalination units at a high cost Current growing systems and irrigation techniques are detrimental to the water-use efficiency

High-yielding cucumber with improved water-use efficiency using the tube culture technique

Research points

- Adaptation of soilless culture techniques
- Improve the efficiency of the drip irrigation system
- Identification of the crop water-requirements
- Automation of irrigation systems

3. Integrated Production and Protection Management

The greenhouse environment can be characterized as warm and humid with low air velocities This ideal condition for plants also provides a thriving condition for pests and diseases Pests and diseases are in competition with the growers since most greenhouse crops are of a high commercial value—any slight damage can result in a significant reduction in the market value The extensive use of chemicals to control diseases and pests results in complicated problems of resistance build-up, and health and environment hazards Also, natural enemies have been killed along with the pests (by non-target-specific chemicals) A healthy plant is usually able to withstand pest attack better than a stressed one This can be achieved by applying other control measures that reduces the use of hazardous chemicals

The ambitious strategy for integrated production and protection management (IPPM) consists of two workplans

A. Short-term plan (Immediate)

- Identification of the common pests and diseases in the region This should result in the publication of a color identification handbook in Arabic that will be useful for growers, extension workers and scientists

- Initiation of a series of on-farm experiments and demonstrations of different control techniques and measures, with the aim of preventing or minimizing the use of chemicals

1. Cultural control

- Planting schedule and crop rotation
- Irrigation and fertilization
- Use of pest- and disease-free seeds and planting materials
- Crop environment factors (temperature, humidity, ventilation)

2. Physical and mechanical control

- Growing media and techniques
- Sterilization (solar, chemical)
- Screens and nets on openings
- Insect traps

3. Biological control

- Use of natural enemies (parasites, predators, pathogens)
- Use of resistant cultivars

4. Chemical control

- Use of selective chemicals with low hazard
- Use of detergents
- Use of insect pheromones

B. Long-term plan

- Establish a central regional biological laboratory to identify the native natural enemies
- Establish a strategic plan to be adopted in the region
- Develop a training program and advisory materials
- Carry out/initiate routine screening for resistant cultivars for the commonly grown crops
- Carry out/initiate routine screening for the most effective and least hazardous chemicals

Regional Networking

There is great similarity in the climate conditions, available natural resources and social structure among the Arabian Peninsula countries As a result, PA problems—including the type of structure and covering materials, irrigation and fertigation, production forecasting, pests and diseases, and marketing—are similar across the region Networking is an efficient and economical way of sharing and exchanging the available information and experiences to tackle problems of common interest

Networking can be developed in many forms

1 Sharing of information among the AP countries, including

- An APRP Newsletter
- Exchange of existing documents
- Establishment of a database on crop and cultivar performance
- Training information
- Calendar of PA events in APRP and world-wide
- A PA section on an APRP HomePage on the Internet, including most of the above

2 Establishing a Protected Agriculture Working Group for the Arabian Peninsula

3 Establishing a Regional Technical PA Advisory Committee

Human Resources and Training Programs

Development of human resources is one of the most important activities of the APRP It has been made clear by all country representatives in the Workshop that the lack of trained personnel is a major constraint to the development of the PA industry in the region

The following are the some of the training courses to be designed for the PA research and extension personnel in the region

- Greenhouse management
- Integrated production and protection
- Soilless culture
- Growing techniques and methods
- Fertigation and nutrient solution formulation
- Growing room—principles, design and management

Implementation

The implementation of this workplan should be carried-out under the coordination of the APRP by the PA Specialist Research activities should be executed within the AP countries subject to their requirements, existing problems and constraints, and availability of research facilities and equipment Research with cooling systems is most valuable for Kuwait and Qatar, while growing systems, irrigation and fertigation are important for Yemen

Recommendations from this workplan qualifying for immediate implementation have been put forward to the Regional Steering Committee of the APRP in the form of a one-year workplan for the 1998/99 season The major part of this strategy and the related workplans will be implemented in the new phase of the APRP, which is due to start by June 1999

Summary of Discussion

Most of the short-term IPPM activities suggested in the workplan have already been conducted in some of the countries In fact, some of the countries are far ahead of others For example, the identification of common diseases and pests has already been done in Oman, the UAE has done a lot of research on solarization and recommendations are available, Oman has done some work on natural enemies (biological-control agents), with good results, for crop water-requirements, Oman uses the FAO CropWat data, either directly or modified to the environment of the country What is really required from the APRP is **coordination**, and the fostering of collaboration, integration and information exchange among the AP countries, i e networking In fact, the establishment of a PA network is a primary goal of the APRP PA project, and it has already highlighted the need for information sharing among the various PA players **within countries** as well as among the countries However, there is still concern that a network should start small and grow, rather than start big and die from lack of resources

The APRP is already in the process of establishing AP-wide databases on agro-ecological characterization and climate, research workers, on-going and completed research, and published results These databases will be extensive and require management FAO has developed several database systems (programs) which could be shared with APRP, in addition, FAO has several relevant datasets available on the Internet

This compilation of data identifies where there are gaps in our knowledge For example, the FAO may be able to access worldwide data on crop water-requirements in relation to climate, but is the follow-up information on irrigation management for each combination available? Pest problems may be identified quantitatively, but not qualitatively, biological-control agents may be identified, but their efficacy under the specific conditions may have to be investigated to determine the best formulation

None of the countries has centralized seedling nurseries for PA The private sector in Yemen has recently started to produce seedlings for PA Both Oman and the UAE have centralized nurseries for fruit trees, but not for PA vegetables, Kuwait is close to setting up a centralized nursery for ornamental plants for landscape-greenery planting There are advantages and disadvantages to centralized seedling production—buying seedlings can be cheaper for the growers because of the losses involved when growing from seed, however, UAE growers have experienced no difficulty in rearing PA crops fiom seed, and maximize the season by having their own nurseries

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Group photo at the dinner and cultural evening hosted by Mr Abdulla Al Sulatteen at his farm