ICARDA at a glance

Who we are

The International Center for Agricultural Research in the Dry Areas (ICARDA) is a global Research for development non-profit organization with a vision of improved livelihoods of the resource-poor in the dry areas of the developing world.

ICARDA promotes sustainable agriculture development in dryland countries through collaborative and responsive research. The Center works closely with the national agricultural research systems, policymakers, local communities, and non-governmental organizations to bring its research outputs to field and deliver impact on the ground – our core strength.

ICARDA in numbers

1) Actively implemented over 180 projects in 2014
2) Works in over 50 countries, with offices in 17 of them
3) Employs around 450 skilled staff from over 44 countries

Our focus in drylands

ICARDA strives for better livelihoods in drylands through a strategic focus on:

- food and nutrition security
- rural poverty
- water productivity
- land degradation
- sustainable management of natural resources

With cross-cutting priorities of:

- climate change adaptation
- gender equity
- capacity development.

What we do

ICARDA delivers science-based systems solutions that help build resilience and sustainably intensify the productivity of dryland agroecosystems. Its integrated research outputs include new crop varieties; water productivity technologies; **agronomic practices; natural resource management; rangeland and small ruminant production; and socioeconomic and policy analyses and options.**

ICARDA
Science for Better Livelihoods in Dry Areas

Scientific Agricultural Research for Development of the Arabian Peninsula

21 Years of the Achievements 1995-2016

ICARDA
Science for Better Livelihoods in Dry Areas

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Agricultural Research & Extension Authority, Yemen

ICARDA

Science for resilient livelihoods in dry areas

Ministry of Works, Municipalities Affairs and Urban Planning

Public Authority for Agricultural Affairs & Fish Resources, Kuwait

Ministry of Agriculture and Fisheries, Oman

Ministry of Municipality and Environment, Qatar

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Ministry of Environment, Water & Agriculture
المملكة العربية السعودية

وزارة التغيير المناخي والبيئة
MINISTRY OF CLIMATE CHANGE & ENVIRONMENT

Agricultural Research & Extension Authority, Yemen

21 Years of the Arabian Peninsula Regional Program Achievements 1995-2016

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The Editors

Foreword

The Arabian Peninsula (AP) comprises seven countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates and Yemen. This region is characterized by low and erratic rainfall, high evaporation rates and temperatures. Soil and water salinity is also high and can increase rapidly as a result of irrigation with brackish water.

From its headquarters in Aleppo, Syria, the International Center for Agriculture Research in the Dry Areas (ICARDA) has paid attention to the needs of AP countries since the late twentieth century, by addressing the need for strengthening cereal crops research (wheat and barley) and training. In 1995 ICARDA created an office in United Arab Emirates (UAE) to serve the seven countries of the Arabian Peninsula and hence APRP is born.

Since its establishment, APRP was focusing on strengthening agricultural research and human resource development in all AP countries. Water scarcity problems were given a priority in all research initiatives undertaken by the program, in collaboration with the National Agriculture Research Systems (NARS) of AP countries. For example, the shortage of feed for livestock was addressed by utilizing adapted indigenous forage species, which utilize less water, compared with exotic forages. Therefore, suitable indigenous forage species were collected in all seven countries and evaluated under field conditions for their water use efficiency. Buffel grass, which was developed from this research, is now well known among farmers and growers as forage and uses significantly less water compared with the exotic Rhodes grass. Similarly, research on protected agriculture under controlled greenhouse conditions, maximized farmer yields and income with minimal water use. Moreover, the research on protected agriculture has emphasized the use of integrated production and protection management (IPPM), which resulted in healthier vegetables due to the minimal use of chemicals (fertilizers and pesticides) in the production process.

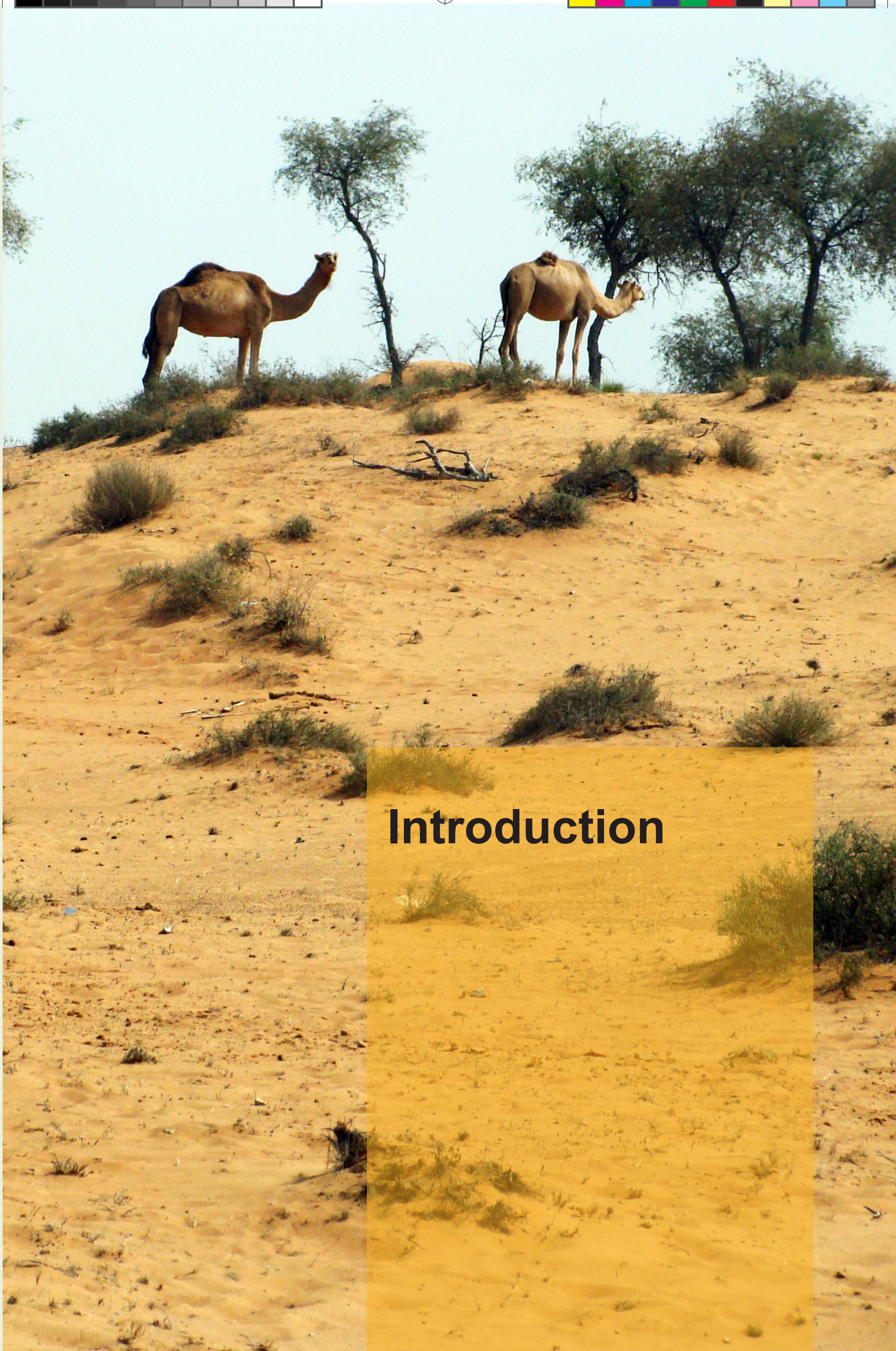
From the beginning of the APRP research activities were grouped into three main areas: (a) irrigated forage and rangeland, (b) protected agriculture, and (c) human resource development through training and workshops. Over 700 technical staff from the seven countries have received training since 1995. This is in addition to hundreds of growers, extension agents and researchers who received technical training and technical backstopping by ICARDA scientist during field days, on the job training and seminars. Furthermore, the program was successful in developing a network among AP scientists, whereby they exchanged knowledge and experiences through regular meetings, travelling workshops and conferences. The impact of this pillar is probably by far the most important than the other two other pillars, generating better understanding and cooperation among colleagues in the same fields. This is reflected in the voluntary comments registered by farmers/growers and administrators over the years.

This publication demonstrates the scope of research and human resource development over the years, and highlights some of the accomplishments resulting from the collaborative efforts of the seven AP countries and ICARDA-APRP over the years.

Aly Abousabaa

Director General

Introduction



Introduction

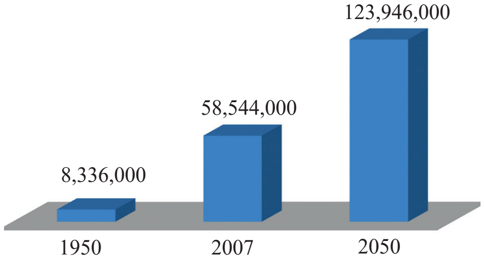
The Arabian Peninsula (AP) comprises seven countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, and Yemen. The region has a total land area of 3 million km2. It is characterized by arid and semi-arid climates. Rainfall is highly spatial and temporally variable, with annual precipitation of less than 50 mm to 250 mm, although some areas in Oman and Yemen receive much more. Temperatures are generally high; some locations reach 50°C in summer when the relative humidity is also high. The soils of the region are fragile and subject to wind and water erosion, and degradation through salinization. Over 95% of the AP land area suffers from some form of desertification, and over 80% is classified as degraded due to wind erosion. The AP is characterized by extreme aridity and limited renewable water resources. Rapid economic development in the latter half of the twentieth century led to significant changes to the traditional agricultural systems of the Peninsula, with major implications for the sustainability of the natural resource base.

Water demand greatly exceeds the available renewable water supply, and is met mainly from non-renewable ground water and desalinated water. Irrigation is by far the largest user of water in the Peninsula. Continued use of non-renewable ground water for irrigation to meet agricultural production targets has led to declining ground water levels and salt intrusion in coastal areas. Greater water use efficiency in irrigated agriculture would therefore have a major impact on water conservation. Rangelands have been encroached on for urban expansion or cultivation, or have been degraded to unproductive levels due to overgrazing. This has resulted in the loss of indigenous plant species, low rangeland productivity and increased soil erosion. Indigenous rangeland plants, adapted to the harsh arid environment, are a valuable genetic resource of great economic value, not only for the peninsula but also for other parts of the world.

Population

The region's population was 32 million in 2002 (WB 2004), and with current annual growth rates of 2.0–6.9%, it is estimated to reach 64 million by 2025 and over 123 million by 2050 (Population Bulletin June 2007; Figure 1). The total commodity demands resulting from AP population growth has led to a rapid increase in food imports. Food imports are expected to more than double by 2010, if per capita consumption and domestic production do not change.

Figure 1. The population of the Arabian Peninsula, 1950 to 2050.
Source: Population Bulletin, June 2007.



Agriculture in the Arabian Peninsula

Agricultural areas are limited to less than 1% of the AP land area (Table 1) but consume about 86% of the available water (United Nations Environment Programme). On the peninsula as a whole, 80% of the cultivated area is irrigated. In this sub-region, with the exception of Yemen, the whole cultivated area is irrigated (FAO).

Bahrain, Kuwait, Qatar, and UAE have modest agricultural sectors; their cultivated areas are relatively small and scattered, and support a small proportion of the total population. Per capita food imports are consequently higher than in the more agriculturally oriented countries, with all cereals being imported, particularly wheat and wheat products. Agricultural production depends mainly on groundwater irrigation and to a lesser extent on winter rainfall (November–February). As for the countries with more substantial agricultural sectors, their agricultural production is constrained by severe biotic and abiotic stresses that include heat and salinity, as well as a lack of improved cultivars, cultural practices, and trained labor. Due to rapid economic development in the latter half of the twentieth century, the agricultural systems of the AP have changed dramatically. Increased production of crops and livestock has been significant. Though economic growth has been substantial, the increased production has often been at the expense of sustainable economic development and has often degraded natural resources. Modern irrigation technologies, such as center-pivot and drip irrigation, have enormously increased the irrigated area. Yemen and Saudi Arabia have by far the largest agricultural labor forces. Crops range from cereal grains, melons and other fruits, to aromatic herbs and spices, coffee, and the stimulant 'Qat.' The main livestock are cattle, asses, camels, sheep, and goats.

Challenges:

The AP is a water-limited region with extreme aridity and limited renewable

Table 1. Agricultural land in the AP countries (1000 ha)

	Agricultural area	Arable land and permanent crops	Country area
Bahrain	10	6	71
Kuwait	154	18	1,782
Oman	1080	80	30,950
Qatar	71	21	1,100
KSA	173,983	3,798	214,969
UAE	559	254	8,360
Yemen	17,734	1,669	52,797
	193,406	5,846	310,029

FAOSTAT | © FAO Statistics Division 2007 | 24 September 2007 water resources. In most areas the annual precipitation is far below the potential crop water requirements. Hence, with the exception of a few areas in Yemen, all arable crop production requires irrigation. Another short-coming of the region is that the renewable supply of water per capita is amongst the lowest in the world. According to the World Bank, the average renewable water supply for the Middle East and North Africa is 1250 m^3 per capita per year; for the AP it is about 100 m^3, compared with a global average of 7260 m^3.

Of the 3 million km^2 land area of the AP, about 50% is rangeland, mostly in Saudi Arabia. Rangeland conditions are very poor and in some areas well below the production potential. Large areas are classified as empty lands, and others have few species at very low densities. There are signs of deterioration of both the soil and plant components of the rangeland ecosystem. Overgrazing is the main cause of rangeland deterioration, which is reflected in livestock feed shortages. In attempts to alleviate feed shortages, farmers have relied on growing exotic forages with high water requirements. Excessive use of groundwater has lowered water tables, increased salinity, and in severe cases, led to croplands being abandoned (Figure 2). In 2003, the AP's arable and irrigated area was less than 8 million ha.

AP countries are facing great challenges in developing more sustainable land and efficient water usage while preserving its environment and heritage under the current rate of population growth. The issues of food security, water management, productivity, sustainability and environment are closely interconnected. If current inefficient practices continue i.e. rapid depletion of water resources, extinction of native species and their knowledge, then environmental destruction will be a significant outcome.

The exceptional socio-economic context and fragile environment of the Arabian Peninsula required cautiously designed activities to address its agricultural development constraints. Furthermore, the emerging worldwide crises, such as global warming and increased water scarcity, in addition to economic crises as result of a dramatic reduction in oil prices, amplifying the importance of agricultural research for development.

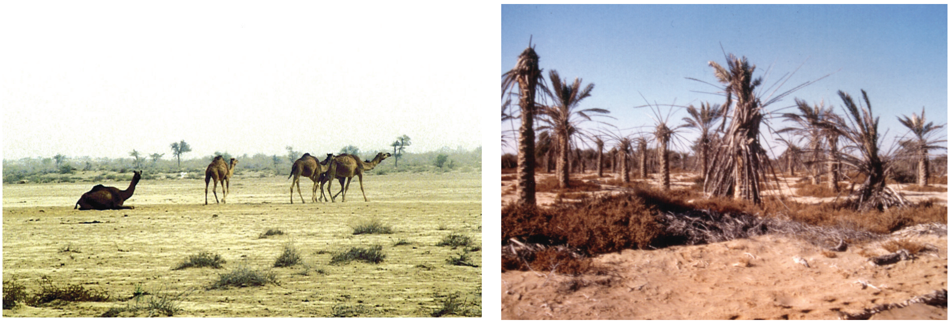


Figure 2. Overgrazing by increased animal populations (left) has resulted in loss of valuable indigenous species and degraded much rangeland to low productivity. Extensive exploitation of groundwater (right) has lowered the water table, increased salinity, and in several cases, led to crop lands being abandoned.

ICARDA evolution in the Arabian Peninsula

Since its establishment in 1977, ICARDA has actively collaborated with AP countries to provide technical backstopping focused on its mandated crops and areas of research, exchange of germplasm, and human resource development through trainings and scientist visits. In 1988, ICARDA began a unique program for the AP countries. Its main objectives are summarized below.

1. **Strengthening Barley and Wheat Research and Training in the Arabian Peninsula (1988–1995)**

The project concentrated on identifying cultivars of ICARDA's mandate crops suitable for the environmental constraints of the AP. The most important of these limitations are abiotic stresses associated with high temperature, water availability and salinity. Although this project was aimed primarily at improving wheat and barley production, it also helped to identify priority needs and current gaps in agricultural research.

This project was supported financially by the Arab Fund for Economic and Social Development (AFESD).

2. **Strengthening Agricultural Research and Human Resource Development in the Arabian Peninsula (1995–2000)**

Goal: Increased food security in the AP, by increasing the productivity of field crops and livestock, based on the optimization of water use efficiency, conservation of natural vegetation, prevention of soil degradation and desertification, and strengthened cooperation among participating countries and relevant regional and international organizations.

ICARDA worked on the principal agricultural problems facing the region, such as the scarcity of renewable water and inefficient water use; the degradation and resulting desertification of large rangeland areas of the region; and the need to develop an efficient, protected agricultural industry for high-quality high-value produce with reduced environmental and product contamination by agricultural chemicals.

The project was financially supported by the Arab Fund for Economic and Social Development (AFESD) and the International Fund for Agricultural Development (IFAD).

During this project, the program expanded its scope to the three themes of rangelands, water, and protected agriculture, in response to the corporate priorities determined by the seven AP countries. Agroecological characterization was also emphasized, as it has had a significant impact on all three themes.

In 1997, the ICARDA Office of the Arabian Peninsula Regional Program (APRP) was established. The office commenced with a senior scientist acting as regional coordinator and was strengthened further in mid-1998 with the recruitment of protected agriculture and water/irrigation specialists. In May 2001, a Rangeland Specialist was appointed. With this team of scientists in place more rapid progress was made toward the objectives of the three main research themes of (i) on-farm water use and irrigation management; (ii) rangeland, irrigated fora ges, and livestock; and (iii) protected agriculture.

3. Sustainable Management of Natural Resources and Improvement of Major Production Systems of the Arabian Peninsula (2000–2005)

Goal: Developing more productive and sustainable rangeland and irrigated production systems, including protected agriculture, through the more efficient use of natural resources in the AP—in particular, water, energy, and indigenous plant species.

Phase II of the APRP focused on the sustainable management of natural resources and improvement of the major production systems of the AP. The program was governed by a steering committee of representatives from the seven AP countries, ICARDA, and donors. The program activities, which included research, were monitored through annual technical coordination meetings. During Phase II there were seven Regional Steering Committee Meetings (RSCM) and six Regional Technical Coordination Meetings (RTCM) in different participating countries, and at ICARDA's HQ. The program was also assessed by a two-man IFAD mission in June 2005. The research outputs and activities during Phase II centered on applied research in the following themes:

- Water resources management
- Forage/rangeland management
- Protected agriculture and agro-ecological characterization.

The project was financially supported by the Arab Fund for Economic and Social Development (AFESD), the International Fund for Agricultural Development (IFAD) and the OPEC Fund for International Development (OFID).

4. Evaluation and Restructuring of Agricultural Research Systems in the GCC Countries (2004)

This assessment was conducted in response to a request to ICARDA from the Gulf Cooperation Council (GCC) and was attended by ICARDA-APRP. The study analyzed the current status, structure, and strategies of NARS in the Arab States of the Gulf. The outcome is especially important for national and international organizations concerned with agricultural research and development in the region for three main reasons:

- To enable NARS leaders to assess their present research system better and identify gaps, in comparison with other countries.
- To promote regional cooperation among the NARS of the GCC and with the international scientific community.
- To realistically present the weaknesses, constraints, and challenges facing existing NARS structures.

5. **Supporting Rural Development and Food Security in the Terraces of Yemen: Adoption of Sustainable Protected Agriculture Technology for the Production of Cash Crops in Taez Region (2005–2007)**

Goal: Enhance rural development by adopting sustainable production techniques that utilize marginal lands and less water to produce high-value crops, and to increase rural incomes and employment opportunities.

Rainfed terraces are major producers of Yemen's food crops, but the returns to farmers are low. The low income from farming has contributed to a rural exodus, particularly among men seeking other employment opportunities, and consequently, the maintenance and productivity of terraced lands has declined. Encouraging farmers to remain on the land has been successful only where irrigation water is available and cultivation of cash crops is possible.

The project promotes the adoption of affordable and sustainable protected agricultural systems in the mountain terraces of Yemen. Some 35 simple greenhouses were installed at selected pilot sites with participating farmers. These use water more efficiently to produce high value crops.

The main objectives were to increase farmers' incomes through cash crop production in greenhouses and to increase water use efficiency, thereby enhancing the returns to farming, promoting the maintenance of terraced lands, and conserving the environment and natural resources. This will provide the basis for rural development and food security, among the main policies of the Government of Yemen. The main components are:

- Market and community surveys
- Technology transfer and adoption
- Socio-economic assessments
- Capacity building and training.

The project is financially supported by the French–Yemen Food Aid Program.

6. **Technology Transfer to Enhance Rural Livelihoods and Natural Resource Management in the Arabian Peninsula (2008–2013)**

Goal: Improved livelihoods of poor farmers and pastoralists in the AP through the adoption of sustainable production and natural resource management technologies.

This project was designed to build on the results of the previous research projects on water use efficiency, irrigated forage, rangeland rehabilitation, and protected agriculture.

The technology packages developed during the previous projects would generate positive impacts on the welfare of poor farmers in the region and on the management of the natural resource base and environment. The immediate project objectives are to:

- Test, evaluate, and disseminate improved technology packages that increase crop and livestock production and productivity, increase water use efficiency, and conserve rangeland resources.

- Enhance the capacity of national research and extension programs to promote both the adoption of the targeted technologies and communication among stakeholders.

The project was financially supported by the Arab Fund for Economic and Social Development (AFESD), and the International Fund for Agricultural Development (IFAD).

7. The sustainability of achievements and efficient technology packages transferred in the Arabian Peninsula (2014–2018)

Goal: To contribute to Arabian Peninsula countries food security, natural resources conservation and improve the livelihood of rural communities. Activities regarding the transfer of technologies to project pilot growers are continued in all AP countries. ICARDA has emphasized sound research techniques across the region. The importance of proper experimental design and accurate measurements of parameters were incorporated in all experiments.

Specific objectives:

- Test, enhance and develop technology packages suitable for the Arabian Peninsula environment to increase crop and animal production while conserving natural resources.
- Transfer and disseminate the improved technology packages to increase crop and livestock production and productivity, increase water use efficiency and conserve natural resources.
- Enhance the capacity of national and extension programs to promote the adoption of targeted technologies and enhanced communication among various stockholders.

The project was financially supported by the Arab Fund for Economic and Social Development (AFESD), and the International Fund for Agricultural Development (IFAD)

8. Promoting agricultural research for development and smart transfer of technologies in Abu Dhabi, United Arab Emirates (2015-date)

The Abu Dhabi Food Control Authority (ADFCA) became a CGIAR member in 2014. This was followed by an agreement with the International Center for Agricultural Research in the Dry Areas (ICARDA) for undertaking joint research for development activities in Abu Dhabi, supported by ADFCA membership funds.

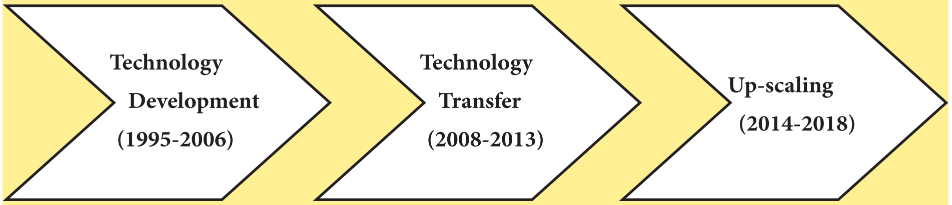
The overall objective was to enhance agricultural production systems in Abu Dhabi through initiating a comprehensive research and a digital extension system for development program addressing integrated pest management for tackling major date palm pest infestations in Abu Dhabi; as well as crop, water and production management of vegetables, date palms and irrigated forages in Abu Dhabi.

Overall, all research and development activities were in close collaboration with the NARS of the seven AP countries. ICARDA put considerable effort into establishing a regional network through annual meetings, seminars, and workshops to connect local researchers and scientists, and to attach them to other regional and international networks.

The program evolved over the following stages:

- Technology development (1995-2006)
- Technology Transfer (2008-2013)
- Up-scaling (2014-up to date).

Even though during each period the APRP has focused on a different theme, ICARDA continues to seek new horizons for supporting agricultural development and natural resource management in the Arabian Peninsula, through scientifically sound research and development activities where modern state-of-the-art technology is used to achieve this vital goal. Proportionate to new challenges, containers, and priority in the region ICARDA has conducted new technological sound research activities to develop a proper solution. These include, but are not limited to the safe use of Thread Waste Water (TWW), better greenhouse cooling systems and the utilization of renewable energy.



- Strengthening Agricultural Research and Human Resource Development in the AP.
- Sustainable Management of Natural Resources and Improvement of Major Production Systems of the AP.

- Technology Transfer to Enhance Rural Livelihoods and Natural Resource Management in the AP

- Improving food security & sustainable natural resources management through enhancing integrated agricultural production systems in the Arabian Peninsula
- Improving agricultural production systems and conserving natural resources under changing climate in the Arabian Peninsula

Adoption and uptake of the technologies generated by AP program

The importance of technology transfer of Research and Development (R & D) project results has been properly recognized by national as well as international research donor organizations and public sectors. Technology transfer is seen as an important mechanism for stimulating development processes, reducing poverty and elevating societies' standard of living.

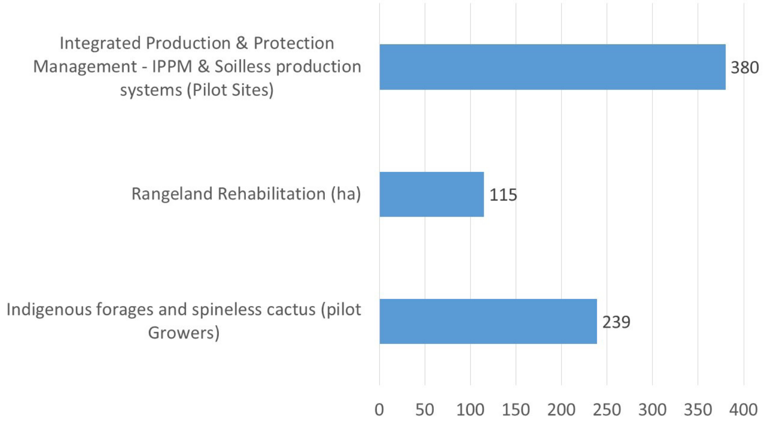
Considering the importance of technology transfer, technology packages developed during the last phases of APRP have been transferred to the farmers through a set of demonstration and pilot sites using participatory approaches in collaboration with NARES. The pilot farmers and NARES benefited from technical backstopping and support from ICARDA specialists.

These technology packages were adapted at selected pilot sites, established in private farms, aiming to increase the farmer-to-farmer interaction and speed-up the adoption rate.

The selection of the pilot sites was based on certain characteristics and conducted in close collaboration with national programs in all seven AP countries. Pilot growers were selected among the active segment of the rural areas. In addition, the following criteria for the selection of pilot growers were considered:

1. Easy access to the farm and availability of the required production facilities such as greenhouses, irrigation network, etc.
2. Willingness of the growers to participate and follow project recommendations.
3. Willingness of the growers to share cost in terms of labor, production system, irrigation network, water, etc.
4. Willingness of the grower to share information with other growers, and use their farm as a demonstration site for conducting field days and training courses.

Technology transfer was considered the most important component of the project. During the implementation period, technical backstopping was



continuously provided by ICARDA using different participatory approaches such as Training of Trainers, Farmers Field Schools (FFS), Field days and farmer workshops. Several publications, technical notes and training/field manuals were published and disseminated. The project was able to provide more technology transfer opportunities than originally planned, and this is thanks to NARES in-kind contributions.

The 619 pilot sites and 115 ha of rangeland rehabilitation were developed directly under program activities. Nevertheless, the actual number of pilot sites are far greater than these figures. There is no specific study or official number for actual growers adopting these technologies in the AP countries but some official reports indicate a significant increase. For instance, in across the AP region, the total number of greenhouses adopting one of the IPPM techniques such as double doors, insect proof net, yellow stick, etc. is quite high. Similarly, the soilless production systems have been adopted by growers rapidly. In UAE, officials from the Ministry of Climate Change and Environment claimed that the number of greenhouses with soilless production systems exceeded 1100 greenhouses in the northern region alone.

Highlight policy uptake and dissemination of the projects technologies

The project impacts have also influenced the policy and agricultural development strategies in all AP countries. For instance, on the basis of the high water productivity of Buffel grass, the Abu Dhabi Emirate in the UAE took the decision to stop the cultivation of Rhodes grass, replacing it with Buffel grass to save water and provide farmers with favorable loans with built in catalytic matching grants to speed up the adoption of the program technologies.

On the basis of the high water productivity of hydroponics culture and reduced pesticide use, Oman, UAE, Qatar and Bahrain adopted a catalytic incentive policy for farmers to adopt IPPM and convert conventional soil culture into soilless production.

- The Oman Government supports farmers by providing infrastructure, credit, technical advice, and financial assistance
- In UAE, the Ministry of Water and Environment covers 50% of the cost of greenhouse structures and soilless production systems;
- In Bahrain, government allocated a large grant to support growers to
- adopt greenhouses and soilless production systems.
- The Abu Dhabi Farmers Services Centre has determined that Buffel grass is a more sensible alternative to Rhodes grass, and the organization has begun educating farmers about proper cultivation methods.
- In Oman, the Ministry of Agriculture and Fisheries supports growers to replace Rhodes Grass with Buffel Grass.

Coordination and the Network

All ICARDA's AP projects and activities are governed by Regional Steering Committee Meetings (RSCM). The RSCM involves the National Coordinators of AP countries, ICARDA's Assistant Director General-International Cooperation, donor representatives, the ICARDA regional coordinator, and ICARDA scientists. The RSCM are held once a year to review, amend, and approve annual work plans and budgets in one of the AP countries. The Regional Technical Coordination Meetings (RTCM) are also held annually in one of the participating AP countries. During the RTCM, the scientists, extension agents, and other end-users from national institutions and ICARDA review the past year's results and finalize work plans for the coming season. During the RTCM, annual work plans and budgets are developed jointly by ICARDA scientists and NARS, based on proposed action plans. ICARDA is responsible for reviewing the proposals and action plans, finalizing the annual work plans and budgets, and providing the final documents for RSCM approval.

Participants at the APRP Regional Technical Coordination Meeting in Kuwait in 2002

APRP Regional Technical Coordination Meeting held at Sana'a, Yemen in 2002

APRP RTCM held in ICARDA, Aleppo, Syria in 2003

Participants at the APRP RTCM, Muscat, Oman, in February 2005

Participants at the APRP RTCM opening session, Muscat, Oman, in December 2005

APRP RTCM held at ICARDA HQ, Aleppo, Syria in 2008

APRP Regional Technical Coordination Meeting held in Dubai, UAE, 2009

APRP Regional Technical Coordination Meeting held in AFESD, Kuwait, 2010

APRP Regional Technical Coordination Meeting held in Qatar, 2011

APRP Regional Technical Coordination Meeting held in Dubai, 2012

APRP Regional Technical Coordination Meeting held in Muscat, Oman, 2013

APRP Regional Technical Coordination Meeting held in Dubai, UAE, January 2015

APRP Regional Technical Coordination Meeting held in Bahrain, December 2015

APRP Regional Technical Coordination Meeting held in Kuwait, 2016

A significant program achievement was a secure network of scientists and researchers from the region that has been continuously praised by the researchers and government officials of AP countries. The program meetings, conferences, and workshops have been important in strengthening collaboration and understanding among NARS scientists and researchers in the AP.

The external reviews of this program

External referees have reviewed APRP progress and achievements three times since 2005. An IFAD Supervision Mission visited the project to oversee activities in the United Arab Emirates, Yemen, and Oman between 5 and 22 June 2005. The mission report highlighted the following:

There has been a significant progress in the collection of valuable germplasm by the AP countries and in the identification of potential indigenous species for the production of forages. Similarly, progress has been made in improving seed multiplication methods and seed technology of native range/forage species.

The capacity of research scientists in designing and conducting experimental work, writing papers and presenting research results in technical and scientific meetings has improved through specialized training, dissemination of publications and printed material, and participation in conferences and workshops.

Networking amongst national programmes and scientists comprises a major achievement of the APRP. Bringing together so many scientists, researchers and team leaders from member countries, either in annual meetings or in workshops and training courses, contributed significantly to the dissemination of knowledge and the building up of capacities.

Then again, an ICARDA-commissioned mission was fielded from 25 November to 20 December 2013 to carry out an external completion review Mission of the ICARDA-implemented Arabian Peninsula Regional Program (APRP). The review approach based on field visits and assessments, interactions with farmers, research and development teams and review of annual progress reports and work plans and budget focused on: (i) output achievements; (ii) impact of the technologies generated; (iii) relevance, sustainability and scaling up of technologies; (iv) lessons learnt and recommendations to enhance the performance of the follow-up five-year phase (2014-2018).

The reviewer highlighted in this mission reported that as a whole APRP played:

- A significant role in giving agriculture the needed priority and increased investment, such as the example of incentives programs in the expansion of protected farming and soilless production in Oman, UAE, Qatar, and Bahrain;
- A policy influence role such as the example of Abu Dhabi in banning the plantation of the Rhodes grass water-consuming forage and its replacement with the indigenous Buffel grass, introduced and promoted by the Program; and
- A capacity development and enhancing regional integration role among participating countries.

Multidisciplinary research and development teams, with a variable level of experience, were established and covered several disciplines, including forage crops, rangelands, protected agriculture, irrigation, crop protection, genetic resources, and extension. Annual work plans and budgets and progress reports were prepared on time by the Program Technical Committee and regularly endorsed by the Program Steering Committee during their joint meetings held annually in one of the participating countries on a rotating basis. The quality of work plans and annual reports improved overtime significantly as a result of training received and experience gained by the national teams.

The project impact reported as:

Increased water productivity

- Buffel Grass versus Rhodes Grass
- 1.52 kg of dry matter /m^3 of water for Buffel grass versus 0.36 kg of dry matter/m3 of water for Rhodes grass in Oman: a five-fold increase
- Protected agriculture
- 48 kg of tomatoes /m^3 water in soilless culture versus 7 Kg/m^3 in soil based
- protected culture in UAE : a seven-fold increase
- Increased water productivity by 60 to 100 % of cucumber per m3 of water
- in a soilless closed system
- Reduced use of pesticides in IPPM
- A 40 to 60% reduction in pesticide sprays in greenhouses where
- IPPM technology is applied.

Yield increase in protected agriculture

- Increased yield of tomatoes by 192% in soilless culture compared to soil-based protected culture in UAE
- Increased yield of cucumber by 40% in soilless closed system in addition to water saving and reduced fertilizer and pesticide use compared to soilless open system in Oman
- Increased yield of cucumber by 50% in soilless closed system with automated nutrient management compared with closed system with manual nutrient management in Oman

Farmer's income

The increased water productivity and yields and cost reduction from water saving and reduced pesticide use resulted in higher income for farmers

In conclusion, the external reviewer mentioned that:

The APRP research work is of high return

- Given its proven capacity as a water-saving, irrigated forage crop, the indigenous Buffelgrass is a low cost/high return alternative to replace the water demanding Rhodes grass in the Arabian Peninsula
- Both the open system soilless culture as well as the closed system with automatic control of nutrients are the way forward for the intensification

and diversification of protected agriculture production systems for high return cash crops in the context of increasing water shortages and salinity in the Arabian Peninsula

The last external review conducted in August and September 2017 to review the project achievements during the period between 2014 and 2017 where it's preliminary report highlighted the following points:

On the introduction and adoption of technologies, the establishment of new pilot farmers' sites included a total of 109 pilot demonstrations (118% against target) on irrigated indigenous forage grasses and 21 accessions of spineless cactus; four pilot demonstrations (100 % of target) on feed block productions using crop residues and agro-industrial by-products; a total of 106 pilot demonstrations (101% against target) on soilless and IPPM production technology packages.

On problem-solving research, the Program has initiated as work in progress, station trials and surveys covering seven priority thematic areas of regional relevance. Almost all research themes achieved promising preliminary results to build on.

For component 3 on capacity building and institutional strengthening, the achieved outputs included: (i) regional level short-term group training of 144 national research and technology transfer staff and pilot farmers; (ii) short-term country level group and individual training of 74 participants; (iii) on the job training for over 100 participants through technical implementation support by ICARDA scientists; (iv) strengthening of research facilities with the rehabilitation of two meteorological stations; and (v) institutional partnerships developed with two universities to conduct joint research.

Major results, lessons learned and future directions

The achievements of ICARDA in the AP are demonstrated by the useful technology packages developed by APRP in rangeland rehabilitation, irrigated forages, on-farm water management, and protected agriculture. ICARDA-APRP adopted and tested the developed technology packages at some private pilot farms although these have not yet been fully transferred to a broader range of poor farmers and end-users

The technology packages proved to have positive impacts on the welfare of poor farmers in the region, and on the management of natural resources, and the environment. To fulfill these goals and objectives, ICARDA and NARS in the AP sought traditional donors as well as new donors to support a new ICARDA-APRP program to up-scale and transfer these technologies to end-users, and for further development. The packages include:

1. Promoting an integrated production system for indigenous forage species with high water use efficiency for AP farmers.
2. Developing an integrated production system for spineless forage cactus.
3. Enhancing adoption of new forage and rangeland production systems by

providing large quantities of seeds of suitable species.

4. Developing participatory technology for rangeland rehabilitation through water harvesting and re-seeding techniques.
5. Increasing adoption of IPPM for high quality cash crops, reducing pesticide residue and hazardous chemical use.
6. Increasing adoption of high intensity techniques for more water use efficient production of high quality cash crops.

Transferring the project-targeted technologies to end-users necessitates good and strong links between the agricultural policy makers, as well as National Agricultural Research Systems (NARS) and National Agricultural Extension Systems (NAES) in AP countries. A regional coordination and understanding is necessary to avoid the duplication of efforts and optimize the use of limited resources.

Developing and strengthening a regional mechanism for coordination and integration of activities related to technology transfer and raising the ability levels of National Agricultural Extension Systems (NAES) of AP countries would further enhance and speed-up the technology transfer process.

ICARDA-APRP successfully managed to establish a regional network for National Agricultural Research Systems. This happened through several regional meetings, an expert consultations session and usage of modern communication systems. The same mechanism would be implemented to establish a regional network for National Agricultural Extension Systems and a linkage between these two networks. This would establish a suitable regional mechanism for transferring technology, facilitating feedback related to on-farm activities to research centers and expediting problem solving processes. This Network will also help to introduce and train NAES on the latest agricultural extension approaches and methodologies suitable for transferring the project's targeted technology.

To enhance the interaction between regional scientists and extension agents and international scientific societies, the Program would develop and support modern extension means, such as Smart Extension Diaries and sponsor AP NARS

and NEAS staff to attend regional and international conferences and meetings, and to share activities and achievements.

For the future, ICARDA will continue to seek new horizons for supporting agricultural development and natural resource management in the Arabian Peninsula, through scientifically sound research and development activities. As in our previous work, modern state-of-the-art technology will be used to achieve this critical goal. The work is continuing but not limited to:

- Rangeland resources characterized and mapped for prioritization for rehabilitation and technological interventions
- Restoration and rehabilitation of degraded pilot rangeland sites

- Development and implementation of suitable participative management strategies
- Indigenous irrigated forages and spineless cactus
- Enhanced greenhouse design and more efficient cooling systems
- Enhanced IPPM and soilless production systems - including organic production
- Integrated crop-livestock production systems (alternative feed resources)
- On-farm water resource management (rain and mist water harvesting, treated waste water, and desalination)
- Use of treated waste water for the production of perennial forage crops and
- spineless cactus
- Agricultural extension systems are enhanced, and improved technology packages are transferred to end users as well as strengthening the agricultural extension system using a "SMART Extension Diary" (SED) approach
- Transfer of the project's targeted technology packages to growers, farm
- owners, and other end users
- Enhanced capacity of national research and extension programs and growers
- to promote and adopt the targeted technologies.

Forage and Rangeland

Abstract

Indigenous species are the basic tools to arrest desertification of in AP countries, primarily caused by overgrazing, and also to conserve valuable natural resources. The AP native plant biodiversity of over 3500 species is being rapidly depleted. Over 90% of the land area suffers from some form of desertification and 44% is severely or very severely degraded

There were nine collection missions for major indigenous forage grasses, legumes, shrubs, and trees in UAE in 1998, in Oman in 1998 and 2001, in Bahrain in 2002, in Qatar from 1998 to 2004, in Saudi Arabia in 2002 and 2003, and in Yemen 1998. The ultimate objective was to utilize the most promising germplasm for rangeland rehabilitation and irrigated fodder production. The mission outcomes were collated in the book "Collection of Valuable Indigenous Plant Species of the Arabian Peninsula"

A potential solution to water and rangeland problems in the AP is developing production and rehabilitation systems based on indigenous species, because they are already well adapted to the regional environments. Water use for irrigated forage may be reduced, compared to conventional forage species. Conventional species are likely to suffer significantly if irrigation is reduced, in comparison to indigenous species.

Priorities of rangeland, forage grass and shrubs species were identified in most AP countries following collection missions.

Buffel grass or Lebid (*Cenchrus ciliaris*) was identified as forage of high feed quality and high water-use efficiency; the forage can be harvested ten times a year, with an average annual dry matter yield of up to 20 t/ha. The water use efficiency of Lebid (the amount of water needed to produce 1 kg of dry matter) was 0.81–1.88 m^3 compared to Rhodes grass with 1.18–2.13 m^3.

The constraint of seed availability for the indigenous species was addressed in all AP countries through the establishment of seed technology units.

Introduction

The Arabian Peninsula, experiences some of the most extreme climatic conditions found on Earth and has in recent years also experienced large changes in human activities. These have contributed to desertification together with a considerable loss of the plant biodiversity of the Arabian Peninsula. Within these countries, there are very diverse ecosystems, which encourage species diversity and are likely to reflect genetic variation within those species found across these ecosystems.

This native plant biodiversity is probably, in the context of sustainable agricultural production and arresting desertification, the most important on Earth.

The native plant biodiversity of the Arabian Peninsula, which comprises over 3500 species (Ghazanfar & Fisher, 1998), is being rapidly depleted. Over 90% of the total land area now suffers from some form of desertification, and 44% is severely or very severely degraded (UNEP). The primary cause is overgrazing.

Since the late 1960's the region has experienced a sharp increase in numbers of animals, mainly because of improved veterinary services and the subsidy that allows the purchase of processed feed and baled hay. Producers have also become very reluctant to sell surplus unproductive animals. In 1998, it was estimated that there were 24 million head of livestock, comprised mainly of sheep, goats and camels.

Overgrazing (Figure 3) not only lowers the productivity of these ecosystems, but also results in a change in plant species richness and the relative abundance. Herbivores, because of their dietary selection, select palatable species, which are quickly taken out, thus leaving an ecosystem dominated by unpalatable and sometimes poisonous species (Al-Rowaily, 1999). Overgrazing is seriously threatening the genetic resources and biodiversity of these important palatable forage species; species, which in the past were, and could again be, the basis for a sustainable system of animal production.

Further more and due to the rapid economic development in the latter half of the twentieth century, the agricultural systems of the AP have changed dramatically. Increased production of crops and livestock has been significant. Though economic growth has been substantial, the increased production has often been at the expense of sustainable economic development and has often degraded natural resources. Modern irrigation technologies, such as center-pivot and drip irrigation, have enormously increased the irrigated area.

The main approach adopted by the Arabian Peninsula Regional Program (APRP) to address the problem of degraded rangelands, shortage of feed for livestock and limited water for irrigated forages lies in the utilization of adapted indigenous forage species.

Collection missions were therefore carried out in different countries of AP (Figure 4). A book was published "Collection of Valuable Indigenous Plant Species of the Arabian Peninsula" to document these missions and the genetic material collected. Special emphasis is given to the passport data,

Figure 3. Overgrazing resulted in unpalatable species (top), and degradation of tree cover (middle), indicated by grazing line too high for browsing camel which now feed on tree barks (bottom).

Figure 4. Collection missions of indigenous plant species were carried out in different AP countries including Yemen (left) and Oman (right).

which would guide researchers, taxonomists and range management specialists, where to look for that particular species. The priorities for different countries were identified as follows: Panicum turgidum and Pennisetum divisum in Bahrain; *Cenchrus ciliaris, Coelachyrum piercei, Lasiurus scindicus,* and *Panicum turgidum* in UAE; *Cenchrus ciliaris* and *Coelachyrum piercei* in Oman; *Panicum turgidum*, *Pennisetum divisum*, *Lasiurus scindicus*, *Cymbopogon parkeri*, and *Chrysopogon aucheri* in Qatar; *Cenchrus ciliaris*, *Coelachyrum piercei*, *Panicum turgidum*, *Pennisetum divisum*, and *Stipagrostis ciliata* in central Saudi Arabia; and *Andropogon distachyos*, *Dechanthium annulatum*, *Pennisetum macroarum*, and *Pancium turgidum* in northern and southern Yemen. Shrub species were identified in northern Saudi Arabia. These included *Atriplex leucoclada*, *Salsola velosa*, *Salsola tetrandra*, *Atriplex halimus*, and *Tragnum nudatum*.

Seed production was enhanced by the establishment of Seed Technology Units (STU) in UAE, Oman, Saudi Arabia, and Yemen (Figure 5). By the end of 2005 The STU in UAE produced more than 1000 kg of Buffel grass and more than 700 kg of Da'e seed.

Figure 5. Seed Technology Units were introduced to different AP countries.

Indigenous Irrigated Forages (Buffel grass)

The Arabian Peninsula Regional Program (APRP), in close collaboration with the National Agricultural Extension Services, has launched the indigenous Buffel grass as irrigated forage to replace the high water requirements of the exotic Rhodes grass. Buffel grass has been cultivated at about 100 pilot farms and demonstrated by National Agricultural Extension Services for up scaling. While mitigating the up scaling needs for quality seed, seed multiplication fields and three Seed Technology Units were established in Emirates, Oman, Qatar, Saudi Arabia and Yemen. This Buffel technology package is an output of a decade-long collaborative research for development program of the APRP, with a parallel focus on capacity building and institutional strengthening of National Agricultural Research Services.

In Emirates: Evaluation of indigenous forage grasses as, affected by the frequency of harvest and irrigation, was studied under drip irrigation. Buffel grass or Lebid (*Cenchrus ciliaris*) was more productive than Tomam (*Panicum turgidum*); Da'ay (*Lasiurus scindicus*); Dakhna (*Choelachyrum piercei*) and Rhodes grass (*Chloris gayana*). Buffel grass was affected the least of all the species when the level of irrigation was reduced by 50% or 75%. It was the highest in water use efficiency where the amounts of water to produce one kg of dry matter ranged between 0.81 and 1.88 m^3. The second best was Rhodes grass where the values ranged between 1.18 and 2.13 m^3. Dakhna showed poor performance under the conditions of the study which did not withstand the repeated clipping.

Within this context, it can be stated that each ton of dry matter (DM) of Buffel grass produced would save about 850m^3 of water compared to Rhodes grass,

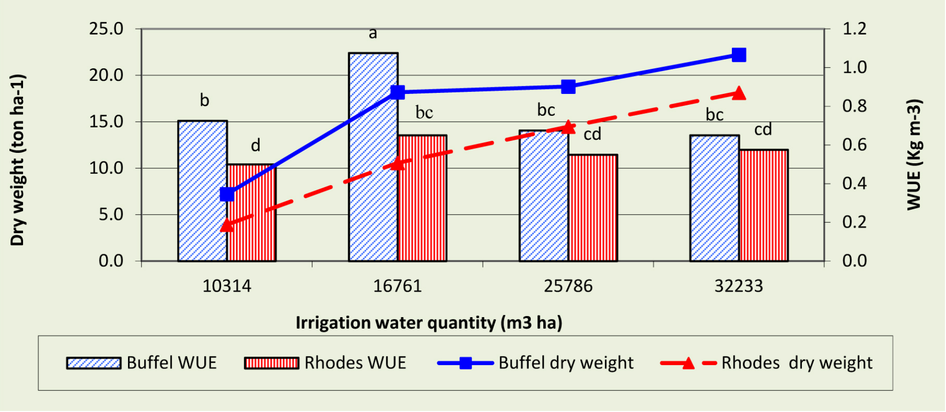


Figure 6. Total dry yield (ton ha⁻¹) and average WUE (kg m⁻³) under average water quantities per cut different (mm/cutting cycle) for both Buffel and Rhodes grasses in Oman.

the exotic species. Other production processes are the same for both forages. Even the mineral and nutritional facts are the same.

In Oman, a study was conducted to evaluate the response of Buffel (*Cenchrus ciliaris*) and Rhodes grasses to different irrigation levels using line-source sprinkler irrigation system. The experiment consisted of four irrigation treatments based on the reference evapotranspiration (ETo): 125, 100, 65, and 40% of ETo and the two grass species as sub-main treatments in strip plot design with four replications. The results indicated that both Buffel and Rhodes grasses gave higher dry yield when irrigated with 125% ETo and Buffel grass showed higher yield than Rhodes grass at all irrigation levels. Dry yield of Buffel grass reduced as irrigation quantity decreased with no significant difference between 25786 m^3/ha (100% ETo) and 16761 m^3/ha (65% ETo) levels. Buffel grass irrigated with 16761 m^3/ha (65% ETo) gave higher WUE compared to other irrigation levels and also gave same Rhodes grass dry matter yield irrigated with 32233 m^3/ha (125% ETo) (Figure 6).

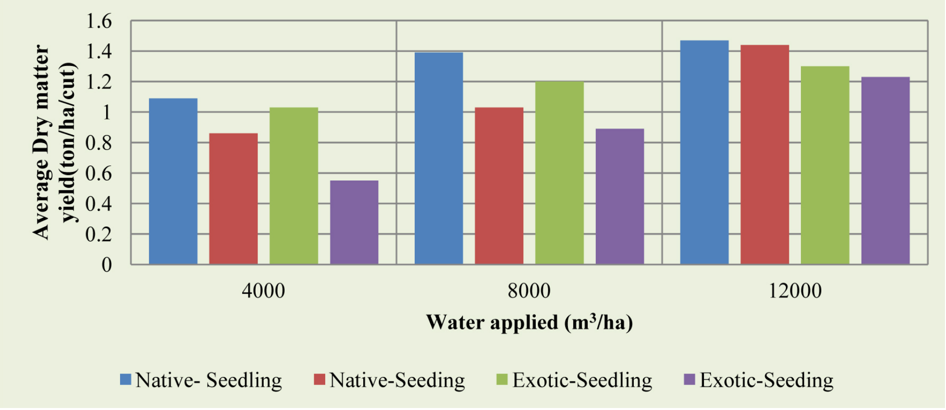


Figure 7. Average Buffel grass dry matter yield (ton ha⁻¹ cut⁻¹) as affected by variety and planting methods under sprinkler line source experiment at Al Jouf, KSA (2013).

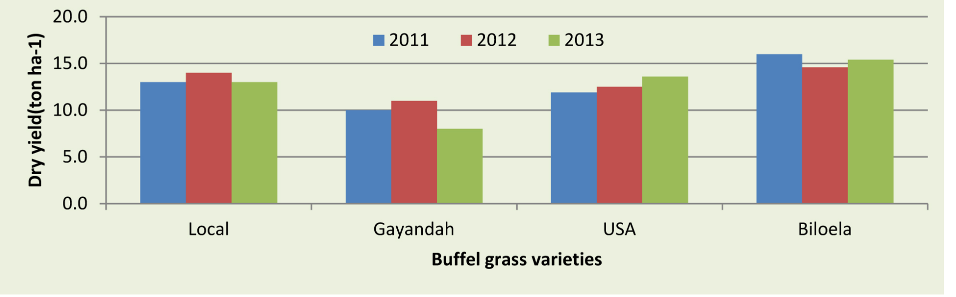


Figure 8. yield (ton/ha of Dry matter) of four varieties of Buffel grass in Qatar 2011-2013

In Yemen: Productivity of three *Cenchrus ciliaris* accessions were evaluated under conditions in the northern highlands and the coastal plain of Lahj. In the highlands, the experiment aimed to evaluate the growth of three introduced accessions of *Cenchrus ciliaris* (USA, Biloela and Gayndah) under the highland conditions in comparison to Al Zila indigenous accession (the control). Statistical analysis revealed significant differences ($P< 0.05$) among the studied accessions. The accession Biloela has higher productivity in green fodder weight in an average of 12.5 ton/ha followed by local accession (10.50 Tons/ha), Gyandah 9.30 Tons/ha and USA 7.5 Tons/ha, whereas the air dry weight was 6.01, 5.78, 5.36 and 3.99 Tons/ha for accessions Biloela, local, Gyandah and USA, respectively. However, in the coastal area, the Alzila and USA accessions were more efficient and their water productivity reached an average of 2.8 Kg DM/m^3.

In Qatar: On-station yield stability trials under drip irrigation for the native Buffel grass species and three exotic ones (Biloela, Gayanda and USA) conducted in pilot farmer's fields during 2011-2014, demonstrated that Biloela registered the highest production in dry matter (16 t/ha) followed by the local species (13 t/ha). On the other hand, the native Buffel grass accession registered the highest yield stability (Figure 8).

In Saudi Arabia: A study was implemented in 2012 in the Camel and Range Research Center at Al Jouf in order to assess the impact of irrigation levels (50, 75 and 100% of crop requirements corresponding respectively to annual

Table 2 - Effect of nitrogen application on three selected forages total dry yield (ton/ha) irrigated with treated wastewater at Dhaid Research Station during 2014 growing season.

Forage	Without N Application	With N Application	Mean
Alfalfa	11.46 d	13.13 d	12.30
Buffel Grass	33.99 ab	36.14 a	35.07
Rhodes Grass	27.11 c	31.89 b	29.50
Mean	24.19	27.1	

Figure 9. Direct grazing on Buffel grass, Yemen

irrigation quantities of 4000, 8000 and 12000 m^3/ha) on the productivity of exotic and native Buffel grass established by seedlings and direct sowing. The results indicated that applying12000 m^3/ha of crop water requirements gave the highest dry matter yield and the native Buffel grass using seedling planting had the optimum yield when applying 8000 m^3/ha (Figure 7).

In UAE: The nitrogen fertilizer application effect on selected forage crop yields with Treated Waste Water (TWW) irrigation is being studied. This experiment started in 2014 at the Al-Dhaid Research Station where all data were collected for three cuts of selected forage crops (Alfalfa, Rhodes and Buffel grass). Plants, water and soil were fully analyzed (including heavy metals) before starting the experiment, and after the last cut. The primary results showed that there were no significant effect of applying N on yield for Alfalfa and Buffel grass, while the Rhodes yields were increased significantly by applying N fertilizer (Table 2). Also, the results indicated that Buffel grass yield is significantly higher than Alfalfa and Rhodes with or without N fertilizer application. The best yield production is recorded for Buffel grass using TWW (33.99 & 36.14 ton/ha) compared with Alfalfa and Rhodes, respectively, under the same conditions or in comparison to the previous records (20 ton/ha) using ground water at the same station.

Rangeland rehabilitation

A technical package of rangelands rehabilitation practices to improve the productivity of degraded pasture introduced in an advanced stage of validation at research stations in Qatar, Saudi Arabia, and Yemen. The practices included rangelands protection through enclosure complemented by water harvesting through contour lines and pits to reseed native pastoral species and the planting of fodder shrubs.

To enhance the production of high quality seed for indigenous forage species the project established seed technology units in all AP countries. In addition, seed health unit were completed in Saudi Arabia and, Qatar while in Oman a seed health unit was established by the Ministry of Agriculture and Fisheries where ICARDA-APRP provided technical backstopping and training.

In Yemen: The rangelands rehabilitation work started in 2003 and is ongoing at the research site of Wadi Al- khun in Wadi Hadramout (Figure 10). The work focused on pasture productivity improvement through the application in a fenced area of one hectare of a set of practices combining soil and water harvesting through contour line ploughing and terracing, reseeding of the disappearing best annual and perennial native forages and transplanting the most palatable native fodder shrubs and trees that are also rapidly disappearing due to severe rangelands degradation. The results achieved indicated that the regeneration of the vegetative cover through reseeding is feasible but constrained by:

Figure 10. Water harvesting for rengland rehabilitaion in Yemen

- low seed germination,
- hard seed coat
- low survival rate of young plants due to limited soil moisture.

The very small seeds of annual plants germinate easily with a better survival rate compared to the hard seeds of perennial plants. Moreover, most plants regenerate better when they are seeded or planted after a heavy rain. Also, the productivity inside the enclosure reached the equivalent of 150 fodder unit/ha compared to that of 43 fodder unit /ha in open grazing. The study revealed that short term protection from grazing improved plant cover and perennial species percentages in the pasture.

The efforts to rehabilitate Wallan community rangeland have been continued. The area (20 donums) was planted (2004) with four shrubs utilizing different water-harvesting techniques. Closing the range from grazing by Wallan

Figure 11. Productivity of degraded rengeland is enhanced through enclosures and water harvesting techniques, in Yemen.

community for two years now resulted in more than double the forage yield (36.5% cover in 2004, compared to 21.5% in 2003). The data collected in June 2005 indicated an increase in pasture productivity from 0.5 t/ha in 2003 to 1.8 t/ha in 2005.

In Saudi Arabia: Rangelands rehabilitation work started in 2009 at Al-Jouf Rangelands and Camel Research Center. The work focused on applying water harvesting through contour lines and pits ploughing to reseed *Salsola villosa* and *Atriplex leucoclada* over an initial area of 2 ha using 2 kg of seeds per/ha. The following results were achieved:

The use of contour line and pit ploughing equipment are both relevant practices for the regeneration of rangelands vegetative cover even without reseeding. This is so when minimum stock of pastoral plants is available in the pasture to maintain a natural seed bank;

- Reseeding through pit ploughing is more effective particularly on flat land
- *Atriplex* tends to suffer more during prolonged droughts;
- The native Haloxylon salicornicum regenerated naturally without reseeding as a result of contour lines and pit ploughing
- The reseeded plants tended to disappear after a three year consecutive drought, particularly with contour line planting in flat areas; and
- On the basis of the above promising results the rangeland rehabilitation work had been replicated over 20 ha as a first step in Wadi Al-Amaria.

the assessment of the rehabilitation (planting shrubs of *Salsola vermiculata* and *Atriplex leucoclada* with water harvesting techniques) made in the communal rangeland of Tamriat (50 ha), showed that even if the species *S. vermiculata* presented a better establishment rate than *A. leucoclada*, the density of both species tended to be reduced due to severe drought. However, these management measures allowed the regeneration and increased density of *Haloxylon salicornicum*.

In Qatar the work focused on station assessment of Atriplex species for potential use in rangelands rehabilitation and the introduction station assessment of five perennial pastoral plants, native to the Arabian Peninsula with foundation seeds obtained from Al- Jouf Rangelands and Camel Research Center in Saudi Arabia;

Figure 12. On-station assessment of Atriplex species in Qatar

and (iii) monitoring the Musawar Al Otaria rangelands rehabilitation experience as designated protected area within a larger desert rangelands.

The on-station multiplication, productivity and chemical quality assessment of seven Atriplex species including the local *Atriplex leucolada*, demonstrated their high variability in terms of biomass production, protein and dry matter content. The protein content ranged from a minimum of 12.51 % for the local *Atriplex leucoclada* to a maximum of 19.90 % for *Atriplex torreyi*. The dry matter content ranged from a minimum of 30.35 % for *Atriplex halimus* to a maximum of 89.52 for *Atriplex halimus*.

Spineless cactus

The history of Cacti goes back to the early sixteenth Century (1519) in Central America, from where it spread to Europe (Spain) in 1952 and to East Asia (China, India) and then South Africa in the period 1700 to 1780. Cacti are drought tolerant and adapted to a wide range of soils and climates. They have developed phonological, physiological and structural traits favorable to their development in arid environments. For example, the biomass generated per unit of water in Cactus is three to four times higher than C3 and C4 plants. Their excellent phonological adaptation to arid environments, including the presence of spines on pads, which are modified leaves capable of condensing water from the air. The pads are covered with a waxy layer which limits evaporation. The stomata (openings in the plant epidermis, through which gases and water vapor pass) are sunken on the pads, plus they close when light and temperature are high, therefore minimizing water losses from evaporation during the day time.

The root system of Cacti is shallow and fleshy, which spread horizontally 4 to 8 meters. Water absorbed through the roots is combined immediately with hydrophilic mucus (mucilage), from which the water evaporates very slowly. Cacti are able to store large quantities of water in their succulent organs. Therefore, a shower of a few millimeters of rain, which has no value for other crops, can be efficiently utilized by Cactus. The shallow spreading root system is able to abort water from the soil when other crops cannot do so. An important physiological adaptation of Cacti to arid environments is the ability to uptake CO2 at night, which also reduces water loss.

The plant can easily be grown from pads, and is therefore not costly for establishment and maintenance. The plant has a high potential for very high yields (over 90 t/ha/year under 500 mm in Tunisia). Cactus is a multi-purpose plant: it is a source of survival fodder kept close to the farm. The fodder is high in water, ash, Ca, soluble carbohydrates, Vitamin A and digestible organic matter (DOM). However, it is low in crude protein and fiber. Therefore, cactus can best be supplemented with Atriplex (high protein content), as well as with cereals in alley cropping (a good source of fiber). There is no need to supplement animals with grain or molasses, just a good source of protein and fiber.

Figure 13. Spineless cactus under evaluation for fruit production in Qatar

The multipurpose value of cactus includes fruit production for human consumption. Also, cactus has many cosmetic and medicinal uses beside its famous use for dye. The plant is very suitable for rehabilitation of marginal land when associated with water harvesting techniques and for erosion control (gullied areas).

For all these factors and valuable characteristics, ICARDA-APRP introduced the Cactus into AP. With the help of ICARDA's North African Regional Program (NARP), 38 accessions of Spineless Cactus (Opontia spp) were introduced from Tunisia into Oman in 2005 (Annex V). The accessions were planted at Rumais Research Station and since then, these accessions were exchanged with NARS in different AP countries for testing, evaluation, and use.

In Saudi Arabia, about 1000 seedlings (pads) of cactus were distributed among five growers in Al Jouf in 2012. The study aimed to determine the water requirements of spineless cactus, and confirmed there was no significant difference between two irrigation levels (2500 and 5000 m^3/ha/year) on growth and production. Moreover, the study showed that cactus has good drought tolerance. Also, some accessions showed good tolerance to frost and very low temperatures.

Joint research and demonstration activities were conducted on the 38 Cactus accessions in AL-Jouf Research Centre. The investigations focused on the tolerance of spineless cactus to the frost that occurred in April 2012 and February 2014. After the significant rise in temperature, the plants began to improve, and the frost tolerant accessions produced fruits.

Again, in the Al Jouf region the optimum water requirement of Spineless Cactus proved to be 2500 m^3/ha/year, of which 1550 m^3/ha are needed during the hot period (March-September), and 750 m3/ha during the relatively cool period (October-February),

In Qatar a comparison study was conducted for the selection of cactus accessions, which have the potential for both fruit production and animal feed. The study showed that the average number of new pads per year should be more than 37, while the number of fruits should be more than 10 per year per plant. Of 38 accessions, ten met these characteristics.

The study on spineless cactus as a forage crop was conducted in two research sites and one pilot farm. The study aimed to measure and compare the crop productivity and fruit quality of 38 accessions of cactus. Preliminary observations confirmed the excellent growth of the plantation with high production and quality of the fruits. After harvesting the fruits and measuring the production indicators, a statistical analysis was conducted in order to select the best species. In terms of fruit production, the best accessions were selected as:

1- 69219 (GRASSA CAREF – 68);

2- 69198(CAREFIN – 1);

3- 74083 (SEFROU) and;

4- 74111 (O. LAEVIS SP4).

he spineless cactus was introduced to three pilot farms in 2012. This was in addition to the one grower who adopted the cactus in 2011. With this new plantation the total area under cactus in Qatar has reached 7500m2. A total of seven pilot farmers were also reached in 2014.

In UAE, one experiment was conducted in March 2013 at AL-Dhaid Research Station to assess the impact of three irrigation levels (50, 75, and 100% crop water requirements) on the production of five selected spineless cactus accessions. The average number of new pads for four cactus plants per treatment was measured. The results showed no significant differences among the irrigation levels on the number of new padgrowth during the establishment phase. The study is continued through 2014 which showed that two accessions from Italy (OF1 Hetapentica 69233) and Algeria (O.Tomentosa 69210) achieved the highest number of shoots when adding 50 and 75 % of the water requirements, while Carfen-1 69198 accession gave the lowest values.

In collaboration with Abu Dhabi Food Control Authority (ADFCA) in UAE, ICARDA-APRP established a spineless cactus mother plot using 40 accessions from different climatic zones of the world in April 2012. The nursery was established using single pads in Baniyas Research Station, which was monitored for six months following establishment, before transplanting to another field when the accessions developed six pads. In January 2014, the number of pads per plants recorded showed the following accessions had produced the highest number of pads: Nil-I, Nil-II, R-14, Nil-III, 69245, 73056 and 69198, which produced 38, 33, 31, 31, 28, 28, and 28 pads per plant, respectively. Similarly, the study on cactus accessions is continued in the Ministry of Environment and Water Research Station at Diba, where ICARDA and the Ministry developed a mother nursery for 38 spineless cactus varieties.

In Oman, and in close collaboration with the Ministry of Agriculture and fisheries (MAF), a leaflet about cultivation techniques and the harvesting of spineless cactus was developed. The leaflet was printed (1000 copies) and distributed among growers.

In Yemen, studies on the yield of different spineless cactus accessions are ongoing in northern and southern highland areas. The studies comprised 38 accessions introduced by ICARDA as well as one local accession in each area. The primary results indicated that the local accession has the highest yield. In Taez, the local accession produced 142 new pads, which was followed by accession 69248 (introduced by ICARDA) with 102 new pads.

Protected Agriculture

Abstract

The extensive use of chemicals to control diseases and pests in greenhouses results in complex problems of insect resistance, and health and environmental hazards. Crops can be protected by control measures that avoid heavy reliance on pesticides, thereby reducing the use of hazardous chemicals. These control measures are part of an Integrated Production and Protection Management (IPPM) program developed by APRP and implemented in all AP research stations and in pilot private farms.

In Yemen, IPPM techniques were introduced and successfully practiced by growers, which involved keeping the relative humidity low and using irrigation sparingly. Plants were strong and healthy, and had low incidences of pests and disease. The crops were sprayed twice with a safe chemical, compared with the six applications typical in plastic houses without IPPM.

Applying IPPM techniques for protected agriculture resulted in:

- 80% reduction of agrochemical use in protected agriculture greenhouses in Yemen
- 61% increase in yield in Oman
- 45% increase in greenhouse grower incomes in Yemen
- 15% increase in grower cucumber production in Oman
- More than 50% water saving in all AP countries.

Soilless techniques can improve water use efficiency, and water and fertilizer management in crop production. The main objectives are to increase yield quality and quantity per unit of water, area, and manpower. The soil-less growing techniques developed and adapted by ICARDA are being adopted in AP countries.

High-density cropping or vertical soilless cultivation is an excellent system for high-value production, such as herbs, green vegetables, and fruit. The system uses a tower of interlocking stackable Styrofoam pots, which have drainage holes and are filled with soil-less media. Nutrient solution is collected in catchment channels under the lowest pot and re-circulated. The system was adapted for strawberry production in marginal and non-productive lands in Kuwait, Oman, Saudi Arabia, and Bahrain.

Since the year 2000, ICARDA has conducted several collaborative adaptive research and agro-economic studies with NARS scientists in AP countries. Yields were increased significantly and productivity per unit water increased by > 70% compared to soil-based systems. Thus growers could increase their production area without requiring more water.

Transfer of this technique to growers has begun in Kuwait and Oman through on-farm research. Strawberry production using the vertical hydroponics system was highly successful, with several advantages over traditional soil-beds. In Kuwait the benefits were:

- 463% increase in yield
- 700% increase in crop density
- 98% reduction in water consumption
- 63% reduction in fertilizer consumption
- 59% reduction in production costs.

Introduction

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 in which environment and production timing can be controlled and yield improved. It plays an important role in supplying the region's market with fresh products that cannot be grown otherwise.

Protected agriculture—with its associated growing systems—can significantly reduce the amount of water and fertilizers utilized in growing high value fresh products compared with open field production. The total yield of protected agriculture per year is tripled as compared to open field yield.

The success of protected agriculture in increasing farmer incomes encouraged other donors to support ICARDA in similar projects. Through the French–Yemen Food Aid Program, the French Embassy funded an ICARDA project in mountain terraces of Yemen, introducing protected agriculture and IPPM techniques to growers, and 35 greenhouses were established in growers' fields. ICARDA and the Ministry of Agriculture and Irrigation in Yemen, collaboratively provide technical backstopping to the pilot growers. Socioeconomic studies showed that farmers significantly increased the water use efficiency and also increased their income up to 400% by producing high quality cash crops in a single span greenhouse of 270m^2.

The scarcity of fresh water in the AP is becoming more of a challenge due to the tremendous increase in the population over the last few decades. Efficient water use is the most economically and environmentally preferable solution, especially in drought conditions and increasing competition over limited water supplies. Soilless production systems are based on the use of inert growing media with controlled nutrient solutions. By circulating and reusing irrigation water this system significantly reduces water consumption and improves yield and water productivity compared to conventional soil systems.

ICARDA-APRP, with the help of NARS in AP countries, enhanced the use of protected agriculture where environment and production can be controlled and improved with lower amounts of water compared with open field farming. Also, due to soil texture and salinity problems, using a hydroponic system is found to be the best solution to reduce water consumption and increase yield, quality and quantity.

Integrated Production and Protection Management (IPPM)

The extensive use of chemicals to control diseases and pests in greenhouses results in complex problems of insect resistance, and health and environmental hazards. Crops can be protected by control measures that avoid heavy reliance on pesticides, thereby reducing the use of hazardous chemicals. These control measures are part of an Integrated Production and Protection Management (IPPM) program developed by APRP and implemented in all AP research stations and in pilot private farms. Overall, the total yield of the IPPM treated greenhouse was increased by 60% compared to the control greenhouse (no IPPM). This was mainly due to the spread of disease and pests in the control greenhouse. Although chemical treatments were applied in the control greenhouse, due to insufficient protection and high humidity the damage was high. In conclusion, the production of cucumber crops with no chemicals (pesticides) is possible by adopting the IPPM program which consists of simple techniques for the growers to adopt in all AP countries. The components of IPPM package include:

- Greenhouse climate management
- Irrigation and fertilization management
- Agro-management practices
- Mechanical protection
- Biological control
- Chemical control.

In **Yemen**, IPPM techniques introduced and successfully practiced by growers, involved keeping the relative humidity low, covering ventilation with insect proof nets and using plastic mulch as well as applying irrigation sparingly.

Plants were strong and healthy, with a low incidences of pests and disease. Application of IPPM increased water use efficiency by about 50% and cut the pesticide applications from18-22 to 2-3 per season.

Introducing IPPM under farmer conditions in Yemen indicated significant reduction in the use of chemical sprays

Cucumber yield was 15.2 kg/m^2 under IPPM while in the control the total yield was 12.9 kg/ m^2. Accordingly, the water-use efficiency (WUE) was significantly better under IPPM (32.5kg/m^3 compared with 21.8kg/m^3 for the control).

The economic assessment of the two treatments indicated that IPPM treatment secured an average return of 157% compared to 111.8% for control. Farmer incomes also increased by some 40%.

Farmer assessments of the IPPM technique were positive. This was reflected in the increased demand for mesh and plastic mulch in local markets.

In **Oman** pilot farmers using IPPM reduced the number of applications by 38%. For instance, the application of chemical and biological/natural substances to control

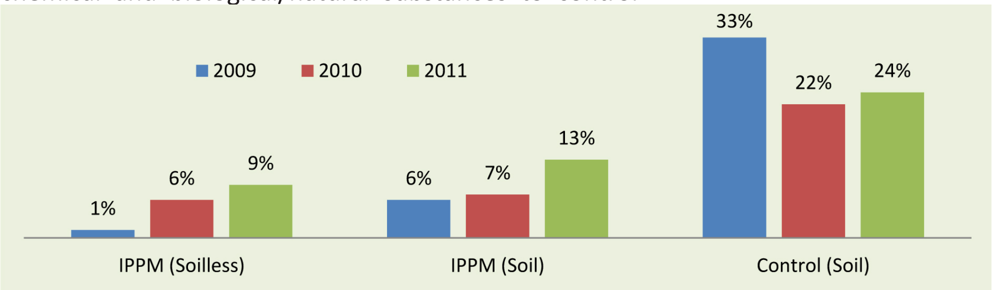


Figure 14. Mean percentage of Wilt and Damping-off diseases in cucumber grown under IPPM in soilless and soil cultivations with regular farmers practices (Control) in Oman.

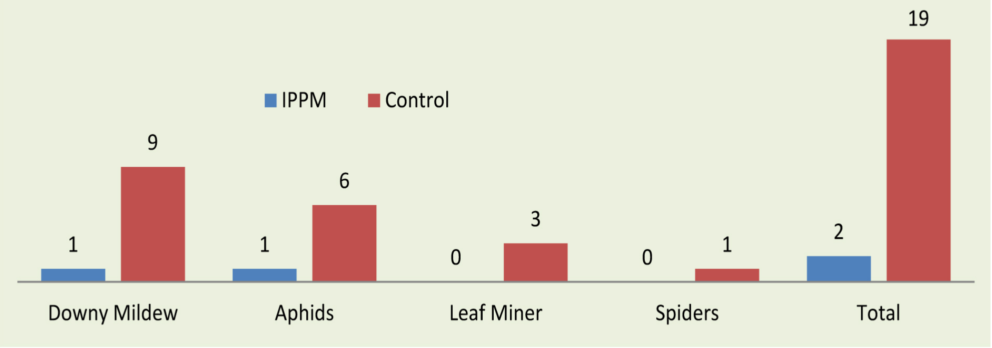


Figure 15. Number of Spry under GH for IPPM and Control units in Oman.

the Downy mildew was of two and five sprays, respectively, in IPPM greenhouse scompared to control. Infestation with nematode was also reduced in IPPM (26%), compared to control (47%). Figure 14 shows that Damping-off and Wilt disease was found significantly higher in control (regular practices by the farmers) than IPPM and soilless for three subsequent years.

The effect of planting time and greenhouse setup on the incidence of major pests of cucumber has been studied in Oman. A comparison of infestation levels of leaf miner on cucumber in three green houses at different planting times indicated that the mean infestation is high in February and low in September, while planting in June recorded the lowest incidents of infested leaves.

Two Cucumber varieties, Printo F1 and Hana F1 were planted to evaluate their performance in yield and quality attributes under cooled greenhouse and non-cooled greenhouse covered with insect proof net, respectively during the 2003/04 season at Rumais Agricultural Research Centre. The results revealed that although cooled greenhouses produced higher production than non-cooled greenhouse by 10%, the cost of production is high and extra production will not cover this cost. Therefore, production in net house would be more economical (Figure 16).

Eggplant as a trap crop for the management of whitefly on Cucumber was investigated. Cucumber crops were planted twice during October 2004 and January 2005 as Plantings I and II in net houses. The cucumber crops were grown under soilless systems with plastic bags and sands. Potted eggplants were grown as trap crops on the outside of the net house to study the impact of eggplant on the incidence of whitefly on cucumber.

Yellow sticky traps (YSTs) were hung on eggplants to monitor the presence of whitefly.

The results demonstrated that Eggplants could attract and

Figure 16. Growing healthy cucumber plant using IPPM techniques, Rumais Agricultural Research Center , Oman.

aggregate whitefly, and could then be easily controlled by spraying insecticides, and by mass trapping using YSTs before they could infest the main crop.

In **Kuwait,** using soil solarization in protected agriculture under drip irrigation, increased the yield of tomatoes two-fold thanks to the effective control of weed and root nematodes infestation.

Figure 17. study on soil solarization, Kuwait

In another study, a Soil Solarization and IPPM experiment was conducted with three treatments at Rabia, Wafra, Al- Hashimya (Wafra) and AbdaLi. Isolation of pathogenic fungi was carried out at three different stages of the experiment i.e. before solarization, after solarization and after cropping season. The transparent sheet gave a good step for IPPM under protected agriculture conditions in Kuwait.

Again in Kuwait, the isolated pathogenic fungi included Fusarium spp. and Phytophthora spp. dominating, but Alternaria spp., Helminthos porium spp. and Curvularia spp., were also present. The number of pathogenic fungi dominated after the cropping stage and before solarization. After the solarization stage the number of isolates was rare. Among treatments, transparent 100-micron x 2 and transparent 200 micron appeared better than other treatments in reducing the number of isolates, even after the cropping season. Other treatments like transparent 200micron appeared better in reducing isolates of fungi at Wafra. Bacterial counts were also showing the same results. Yields of cucumber were at their peak in transparent 100micron x2 (Double sheet), followed by transparent 200micron compared with control conditions. As far as profit is concerned, transparent double sheet (100 micron x 2) gave the highest and controlled conditions the lowest. Heavy metal analysis was conducted for cucumber fruit and compared with international standards (MRLs).

In Qatar, non-cooled greenhouse covered with insect proof nets performed equally well as the polycarbonate covered and cooled greenhouse in winter season. The difference (+5%) in productivity for cucumber of 10.4 kg/m^2 in cooled greenhouse and 9.9 kg/m2 in net non-cooled covered greenhouses was not very significant.

In the **United Arab Emirates**, the production of cucumber under cooled conditions and net houses were studied for a total of 18 farmers. IPPM techniques were adopted in all greenhouses. Figure 18 illustrated the average yield (kg/m²) of cucumber under cooled conditions and net houses using hydroponics systems. Net house productions in winter are as high as cooled greenhouses, although the cost of production, especially for

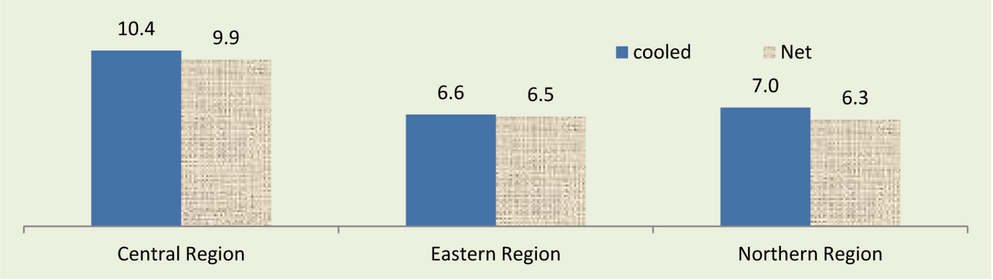


Figure 18. Cucumber production in hydroponics under cooled and net greenhouses in UAE different region (Sep-Dec 2012)

Figure 19. A large nethouse project in Qatar- Arab Qatari Agricultural Company

cooling systems is lower. Therefore, income is increased in net house during the winter seasons compared to cooled greenhouses.

Using net houses instead of cooled greenhouses showed very promising results in saving cooling water. While no water and electricity was consumed for cooling systems during September to May, the net houses in UAE produced approximately the same yield as cooled greenhouses, which used about 1.5 m^3water/m^2 greenhouses for cooling during this nine month period. It means each hectare net house would save 15,000 m^3 of water without reducing production in winter seasons.

In Al-Dhaid Research Station different ventilation systems for a single span plastic house were compared. The results indicated that the mechanical ventilation would be more expensive for growers, although it provides more control, especially during sunny days. Side ventilation would provide more adequate aeration of the greenhouse, provided that it is constructed in the top of the greenhouse. The third type of ventilation, which consists of insect proof nets covering one meter every four meters of the greenhouse and nets fitted on the front and back would provide good ventilation and protection, with less cost.

Another study proved that the water consumed by the current greenhouse cooling system is very high, compared to the irrigation water consumptive use (evapotranspiration), particularly during the hottest summer months. The on-farm trial measurements conducted on tomato production indicated that water consumption by the current cooling system (777 liter per m^2 of cooled green house) is double that of the tomato irrigation water consumptive use. This result questions the relevance of the water use efficiency of soilless culture during the summer under the prevailing high water and energy consuming cooling and ventilation systems.

Improving greenhouse structures to enhance the cooling system, not only increased the water use efficiency of the overall production system but also enhanced plant protection due to controlling the humidity and other related factors.

In **Bahrain**, a new simple oval design for greenhouses was developed and constructed. This greenhouse was constructed from two single span greenhouses connected by a circular structure on both ends as a closed system (Figure 20). Cooled air from each house end is directed to the wet pad of the other house. To reduce relative humidity, air is condensed on copper pipes circulating relatively cold water. The oval shape provides extra crop protection, the ability to economically inject additional CO_2, an improved cooling system, and recovery of fresh water from the enclosed area.

The work is continued in UAE, where ICARDA and the American University of RAK, signed an agreement to conduct a research activity on a new cooling system for greenhouses.

The new system is to enforce minimum changes on the existing systems to increase sustainability and enhance the region's adoption rates. It aims at replacing the current cooling system which uses a large amount of fresh water with a new one which uses less water and utilizes solar energy.

To study different types of cooling system, another experiment was carried out at Al-Rabiya Research Facilities, Kuwait (figure 21).

Four cooling systems were tested:

(1) positive pressure with lower air intake;

(2) negative pressure with lower air intake;

(3) positive pressure with upper air intake; and

(4) negative pressure with upper air intake. The main objective was to evaluate evaporative cooling systems for climatic control at specific temperature and relative humidity. Economic analysis rated positive pressure with lower air intake cooling systems as the most profitable, followed by positive pressure with upper air intake.

Figure 20.Round Greenhouse installed in Bahrain

Figure 21. Study on greenhouse cooling system in Kuwait

Soilless Culture/Hydroponics production systems

Soilless production systems (Hydroponics) could provide suitable solutions to the problems of harsh weather, scarcity of water and the limited land resources prevailing in AP countries. ICARDA, in collaboration with National Agricultural Research and Extension (NARES) Systems of AP countries, developed, enhanced and simplified the number of closed soilless production techniques where irrigation water is reticulated and thereby increased water productivity significantly.

Hydroponics on a larger scale is complicated and needs strong management and sensitive measurement tools. ICARDA and its partners have succeeded in simplifying the required technology to be applicable at the farm level. Various hydroponics systems for growing cash crops, including cucumbers, tomatoes, and strawberries, were tested at research stations in Bahrain, Emirates, Kuwait, Oman, and Saudi Arabia. The major hurdles and challenges for the establishment of the new systems included:

- Designing systems that used available materials at the local market and reduced establishment costs;
- Simplified systems that could be managed at the growers' farm while maintaining high yields and water productivity;

The soilless systems developed and enhanced by ICARDA have proved not only to be a practical solution for soil problems but also managed to significantly increase water use efficiency and produce more crops with less water. For instance, in UAE an experiment conducted in the Hamranieh Research Station increased water productivity 8-fold with significant improvements in yield and quality (Figure 22).

Research activities to enhance and simplify techniques are conducted by ICARDA in collaboration with NARES. Different locally available materials for growing canals including PE sheets are under investigation for better production with minimum cost. Furthermore, various media such as perlite and coco peat were also studied to enhance and simplify production at farmers' sites.

High-density cropping or vertical soilless cultivation is an excellent system for high-value production, such as herbs, green vegetables, and fruits. The system uses a tower of interlocking stackable Styrofoam pots, which have drainage holes and are filled with

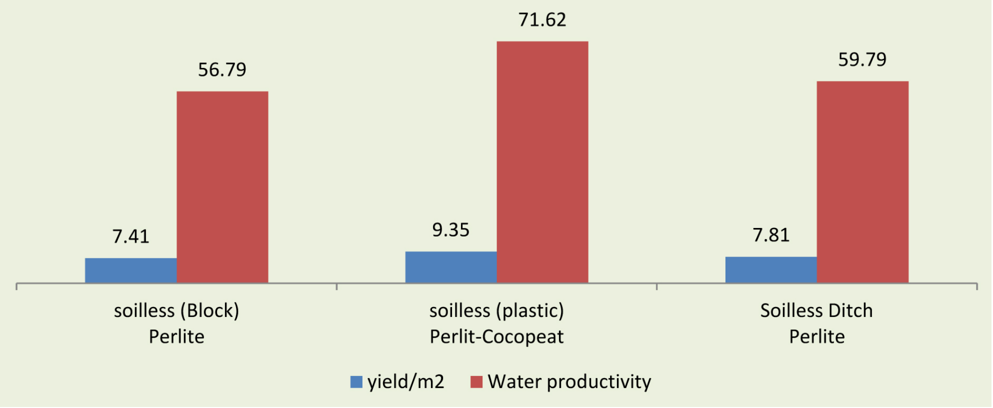


Figure 22. Yield (kg/m²) and Water productivity (Kg/m³) of cucumber under Hydroponics system with different growing materials and growing canals – Hamranieh Research Station, UAE, 2009

Figure 23.Vertical soilless production system in Kuwait and Oman.

soilless media. Nutrient solution is collected in catchment channels under the lowest pot and re-circulated. The system was adapted for strawberry production in marginal and non-productive lands in Kuwait, Oman, Saudi Arabia, and Bahrain. The vertical expansion increases the productivity per unit area. Planting and harvesting is much easier and production costs per plant will progressively decrease.

Since 2000, ICARDA has conducted several collaborative adaptive research and agro-economic studies with NARS in AP countries on soilless systems. Yields were increased significantly and productivity per unit water increased by over 70% compared to soil-based systems. Thus growers could increase their production area without requiring more water.

Strawberry production using the vertical hydroponics system was highly successful, with several advantages over traditional soil-beds. In Kuwait the benefits were:

- 463% increase in yield
- 700% increase in crop density
- 98% reduction in water consumption
- 63% reduction in fertilizer consumption
- 59% reduction in production costs.

In Oman, Qatar, Emirates, Saudi Arabia and Kuwait various hydroponics production systems were studied. The studies included different crops, media, and soilless production systems.

In UAE, studies on cucumber and tomato proved that a mixture of (1:1) coco peat and perlite as the growing media gave optimum yields and water productivity. Coco peats absorb more water which can be delivered to the plant when needed. This specification makes perlit- coco peat (1:1) more reliable on farmer fields and easier for management.

The hydroponics production system is upgraded by adding a simple automatic controller for nutrient solutions. The automatic controllers keep the balance of nutrients in the irrigation water at the best level by measuring the irrigation water pH and EC and injecting the required fertilizer automatically. The production records in UAE and Oman

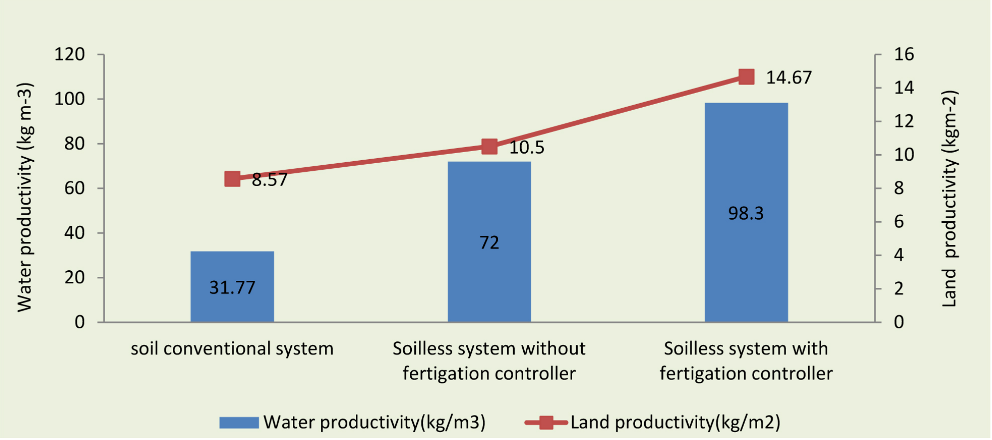


Figure 24. Average land and water productivity of cucumber in soilless production system with and without automatic controllers in comparison with the soil system for three pilot farms in Oman.

show that the automatic controller increases the yield and water productivity by about an 11% to 50% without increasing fertilizer consumption. The difference between 11% and 50% increase in production by using the controller is due to the farmer fertigation management level before adopting the controllers.

The actual water productivity of cucumber crops, including water used in the cooling system, was studied in Qatar, Oman and UAE. Figure 24 shows a comparison between land and water productivity for the two systems in the three farms.

Cucumber productivity per unit of area of soilless culture was studied in Oman and UAE. The results in UAE indicated that planting cucumber with 2.8 plants per m^2 gave the maximum yield, while it was decreased by 24.5 % when the planting density increased by up to 3.6 plants per m^2. Similar results were obtained in Oman.

Various studies on vertical soilless production systems were conducted in Oman, Kuwait, UAE and Saudi Arabia (Figure 25). The experiment in Kuwait, was conducted at Al-Rabiya

Figure 25. Different soilless production systems under study in AP countries.

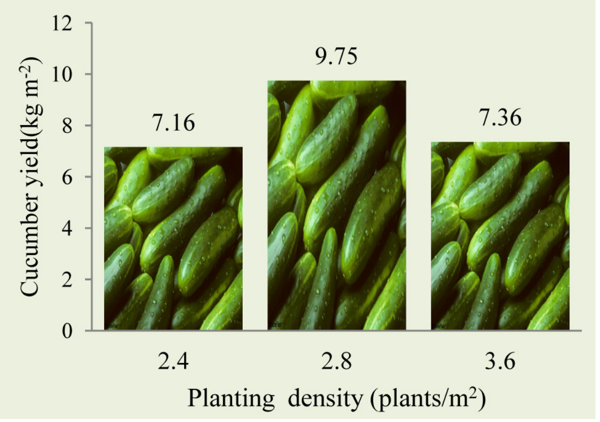


Figure 26. Comparing cucumber production under different plant density using soilless production system. UAE Feb-Jun 2009.

with vertical hydroponics system for the production of high quality strawberry with different media. Eleven media consisting of natural soil, peat moss and perlite in different proportions were tested. The experiment was conducted at a fully controlled environment with a temperature range of 17-29 ˚C, humidity levels of 45-60%, and light intensity of 23000-39000 lux. The data on the fruit yield showed significant differences among the treatments. The highest fruit yield of 6480gm/m2 was recorded with media consisting of 75% natural soil, 12.5% perlite and 12.5% peat moss. The lowest production was obtained in 25% natural soil, 50% perlite and 25% peat moss. Out of the eleven varieties tried, Regis gave a maximum yield of 6540gm/m^2.

In Oman, two media for soilless culture, namely sandy soil and perlite, were used to study effects on cucumber yield under evaporative cooled greenhouse conditions at Rummies Research Center. The perlite soil produced high yields and fruit in comparison to sandy soil.

In **Qatar**, the introduction of soilless culture with closed irrigation systems, automatic control of water and plant nutrients, use of various media under cooled and ventilated greenhouses, translated into the following results at farmers' field during 2012 and 2013:

(i) a yield of 80 t/ha for cucumber using coco peat as media and 54 t/ha using perlite as media; and (ii) a yield of 70 t/ha for tomatoes using coco peat media and 61 t/ha using Kenkari as media.

In **Saudi Arabia**, an on-farm study was conducted at six farms. Two greenhouses in each farm were selected. The soilless production systems was installed in one of the greenhouses, while the other greenhouses were left under the farmer's management as control units. A tomato crop was planted in all greenhouses. The average water productivity reached about 40 kg/m3 with the soilless system while in soil it was only 9 kg/m3 for the same farmers. Therefore, it can be stated that with the same amount of water, the soilless production systems could produce 4.5 times more than conventional soil based systems.

In the **UAE**, the cucumber productivity in perlite bags and perlite with polystyrene pots was studied. The on-farm experiment was conducted on one of the pilot farms in a double span net house. The observation showed that although the plants in perlite bags grow faster at the beginning, they would stop vertical growth after week nine. This suggests that the plant density should be lower in growing bags, although this needs further investigation.

Again in UAE, the studies on actual water consumption for production of high value crops under hydroponics including water for cooling systems were implemented for two seasons after the establishment of a number of hydroponics systems in cooled greenhouses. The results showed that the water consumed for cooling is 2 to 6 times

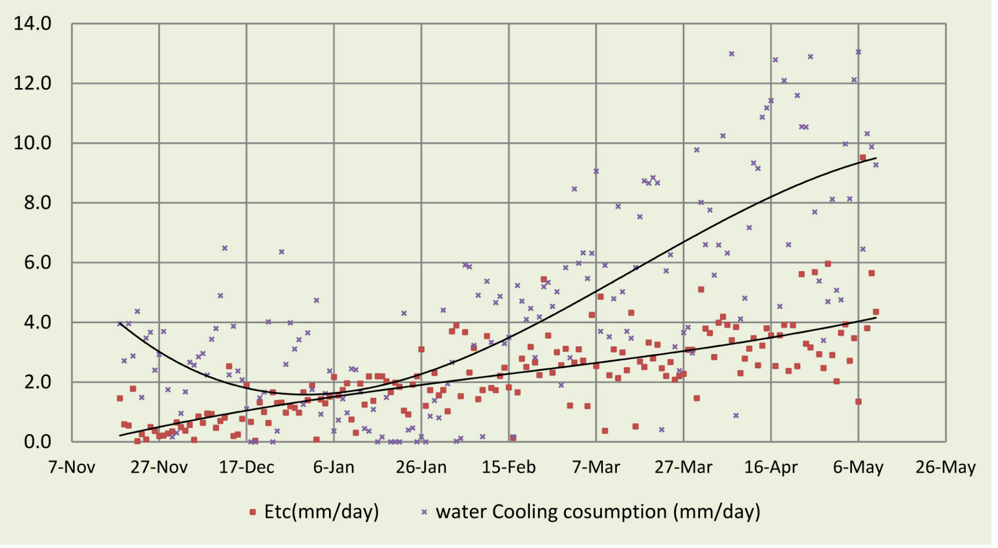


Figure 27. Daily tomato crop water consumption (mm per day) and cooling system water consumption (mm per day) at Rhas Al-Khamih Station(UAE) during 2012/2013 growing season.

higher than the total water consumed by the crop for production. This wide range value is due to the growing season (twice in winter and six times in summer) and on-farm management that included repairing leakages and continuous maintenance. Figure 27 presents the average daily tomato crop water consumption (mm per day) and cooling system water consumption at Rhas Al-Khamih Station (UAE) during the 2012/2013 growing season. It is clear that the cooling system consumed about 200% of the water consumed by tomato during the growing season and the water consumption increased

Figure 28. On-farm trial of hydroponics growing media and production systems in UAE and Qatar.

significantly during the summer.

In Yemen, an open system soilless culture trial for cucumber production conducted during the summer of 2013 in the Al-Arra Northern Highlands research station demonstrated that, compared to the conventional soil culture under greenhouse conditions, the soilless system translated into 71% water saving, a water productivity of 76 kg/m^3 versus 22 kg /m3, and a yield of 11.7 kg/m2. A cost-benefit analysis also showed that net income in soilless systems is double that of conventional soil systems.

Figure 29. Soilless production system in a private farm, Yemen.

Figure 30. Tomato crop in hydroponics system, Bahrain.

Adoption and Economic Assessment of Improved Technologies

Study by Dr Boubaker Dhehibi, ICARDA
Senior Agricultural Resource Economist

Introduction

Because of the aridity prevailing in most of the Middle East and North Africa Countries, the Arabian Peninsula (AP) is the poorest in the world in terms of water resources, both globally and per inhabitant. Arid conditions in these countries act as a natural constraint for expansive agriculture. Only 1.7% of the total land area is arable in GCC countries. As a result, 60–80% of total food demand is currently met from external sources. The agriculture contributes only around 1%-4% of the GCC countries' GDP as compared to 10%-20% for their emerging market counterparts. Moreover, rapidly growing populations and rising per capita consumption becomes the key drivers for growth in food consumption. Indeed, increasing income levels and rising prosperity are leading to a shift in food consumption patterns with the demand for food products rising fast and contributing to more intensive land use.

The scarcity of arable land and water has limited the growth of AP agriculture. With the limited potential for an agriculture sector, optimizing use of these limited resources for technology transfer in agricultural development is one of the biggest challenges facing any decision-maker including the end users and growers. Thus, developing a sustainable and improved agriculture system would have a significant impact on helping these countries to shift their agricultural priorities from self-sufficiency to food security.

The development program for the region known as Arabian Peninsula Regional Program (APRP) implemented by the International Center of Agricultural Research in the Dry Areas (ICARDA) upon request from the AP National Research Systems has been operating since 1995, through the development of proven technologies to improve the agricultural productivity and contribute to reducing the food production gap in the AP region, which is already among the largest food importers and is set to witness a significant growth in the import of food products in the coming years. Several proven technologies and improved packages for different production systems have proven their worth at research stations, such as protected agriculture and its associated techniques, irrigated forages, on-farm water management, spineless cactus and rangeland rehabilitation. However, some of these technologies have not been widely adopted. While developing improved technologies is important for farmers in this region, new technologies can only affect livelihoods positively if they are profitable.

In light of these challenges, and in order to enhance the adoption and accelerate its process and scaling up of these proven and promising technologies, this chapter attempts to provide a more or less clear picture of the economic valuation (examination of the costs and benefits on using these technologies- trade-offs with respect to the conventional ones), and their level of adoption, with special emphasis on the main factors affecting the adoption of these technologies and limiting their adoption process in the GCC countries and Yemen.

We begin with a presentation of the methodological framework used. This is followed by the data and sources of data section. Results and discussion sections are presented in the third and fourth section. In the final section we summarize our findings and their implications for prioritizing interventions, especially in the context of planning for knowledge, promoting adoption, and ensuring scaling up and the widespread use of these technologies.

Material and methods

In order to achieve the outlined objectives, two methodological frameworks have been used. The selected evaluation criterion for this study was first the economic efficiency/viability measure using a cost benefit approach. The second method used in this research is the ADOPT (Adoption and Diffusion Outcome Prediction Tool) framework. This is an MS Excel-based tool that evaluates and predicts the likely level of adoption and diffusion of specific agricultural innovations with a particular target population in mind. This criterion used for the two methods was selected considering the main objective of this research. The following sub-section presents and discusses the two applied methods.

Cost – Benefit Analysis (CBA)

Cost Benefit Analysis (CBA) is a basic approach in neoclassical economics adapted by environmental economists for the evaluation of net social or private welfare from environmental remediation/projects. This is an evident indicator arguing that a technology generating higher net benefits is more efficient than a technology generating less or negative net benefits. This systematic framework was used to determine options that provide the best approach for the adoption and practice in terms of benefits in labor, time and cost savings, etc.

According to Harberger, (1971), the CBA is considered one of the basic postulates of applied welfare economics. There are many justifications for this, but according to Boardway (1974) the one that appeals most to 'objective' economists is that aggregate monetary gains and losses measure the efficiency of a technology. If the aggregate is positive, it implies that the gainers could compensate the losess and still be better off after the technology is undertaken and vice versa. De Graaff and Kessler (2009) argued that the eventual aim of CBA is a comparison between the present value of the streams of benefits (positive effects) and the present value of all investment and recurrent costs (negative effects). In a typical CBA, the costs of the inputs are assessed and compared to the monetary estimates of total benefits that the new technology is expected to provide. The essential theoretical foundations of CBA are benefits, defined as increases in human wellbeing (utility), and costs, are reductions in human wellbeing. For a new technology to qualify on cost benefit grounds its net benefits must exceed its net cost.

A CBA tool, in the context of this research, was employed to evaluate the on-site losses and gains associated with adopting the improved technologies in ICARDA's Arabian Peninsula Regional Program. The scale of the CBA in this study is farm level and the objective is a financial analysis of the gains and losses from the adoption of these technologies. CBA is used here as a decision tool after computing all cost and benefits valued in local currency for each country and converted to US dollars.

Adoption and Diffusion Outcome Prediction Tool (ADOPT)

The Adoption and Diffusion Outcome Prediction Tool (ADOPT) is an MS Excel-based tool that evaluates and predicts the likely level of adoption and diffusion of specific agricultural innovations with a particular target population in mind. The tool uses expertise from multiple disciplines to make the knowledge surrounding the adoption of innovations more available, understandable and applicable to researchers, extension agents and research managers. ADOPT predicts the proportion of a target population that might adopt an innovation over time. The tool makes the issues around the adoption of innovations easy to understand. ADOPT is useful for agricultural research organizations and people interested in understanding how innovations are taken up. The tool has been designed to: (i) predict the likely peak level of adoption of an innovation and the time taken to reach that peak; (ii) encourage users to consider the factors that affect adoption at the time that projects are designed, and (iii) engage research, development and extension managers and practitioners by making adoptability knowledge and considerations more transparent and understandable. This tool was used to evaluate and predict the likely level of adoption and diffusion of the improved technologies in ICARDA's Arabian Peninsula Regional Program. ADOPT predicts the proportion of a target population that might adopt an innovation over time. ADOPT users respond to qualitative and quantitative questions regarding twenty-two variables that influence adoption. Going through this process also leads to increased knowledge about how the variables relate to each other, and how they influence adoption and diffusion. ADOPT is structured around four categories of influences on adoption:

Learnability of the population - concerns the characteristics of the population that affect their ability to learn about the innovation. There are four questions regarding this aspect of adoption, which focus on group involvement in the community relevant to the innovation, whether or not the populations uses advisors to get relevant advice about the innovation, the relevant existing skills or knowledge in the population, and the awareness of the innovation in the population.

Learnability of the Innovation - refers to the characteristics of the innovation itself that determine a group's ability to learn about it. Three factors are used to determine this aspect of the adoption process: the ability to run small trials of the innovation, whether or not the innovation requires complex changes to the farmland for implementation, and the level of observation of the innovation.

Relative Advantage for the Population - attempts to determine whether the advantage that the population could gain from the innovation is sufficient to encourage the population to adopt the innovation. To assess this aspect, the program asks six questions which review the following: the number of farmers that could benefit from the innovation, the extent to which farmers use long-term planning, how much the farmers' decisions are motivated by maximizing profits, how much the farmers' decisions are motivated by protecting the environment, the community's level of risk aversion, and short-term financial restraints.

Relative Advantage of the Innovation - looks at the objective advantages of the innovation without considering the community's perception of the innovation. This part of the process is assessed through eight questions, which deal with the following: the initial costs of implementation, whether or not implementation can be reversed to allow for other innovation options, overall change in profit to the farms from the innovation, how long it will take for the change in profit to take effect, whether or not the innovation decreases farmers' vulnerability to seasons with difficult conditions, the advantages and disadvantages to the environment as a result of implementation, how long until the environmental effects are noticeable, and the non-monetary benefits of the innovation to the farmer.

Data and sources of data

For the cost-benefit analysis, it is worth stating that the unit of analysis in this study was formed by Heads of Household who were farmers with or without each one of the technologies indicated above. In a first step, this analysis was conducted only for Yemen. A rapid agro-economic survey was conducted on selected farms. A survey questionnaire was administered (by the researcher and field assistance) to selected farmers in target areas. Data on the following farm level issues were elicited from smallholder farmers within the target sites: labor resources; farm land characteristics; crop yield and prices; and crop production (i.e. investments on crop production). This survey obtained the necessary quantitative data for the financial CBA. The financial CBA aided the discussion on the costs and benefits associated with the adoption of the following technologies: Sorghum forage vs Clitoloria forage; Local Lipid forage vs Gaynda Lipid forage; Soil vs Soilless technology; and IPPM technology. Data solicited from farmers were analyzed (for the financial cost benefit analysis) using Microsoft Excel.

We used a focus group discussion (FGD) methodology (Krueger, 2002) to apply ADOPT (Kuehne et al., 2013) with group farmers. The number of farmers in the focus groups vary between the countries, and for the improved/tested technologies. We streamlined 22 discussion questions around four categories of influences on adoption, such as (i) characteristics of the innovation; (ii) characteristics of the target population; (iii) relative advantage of using the innovation, and (iv)learning of the relative advantage of the innovation. The format of the discussion group consisted of both analytical questions (i.e., they discuss and collectively decide what they believe the answer is), and clarifying questions (i.e., questions that help to clear up confusion and explain why they had chosen this answer). Farmers were asked to think about problems and challenges related to implementing water harvesting

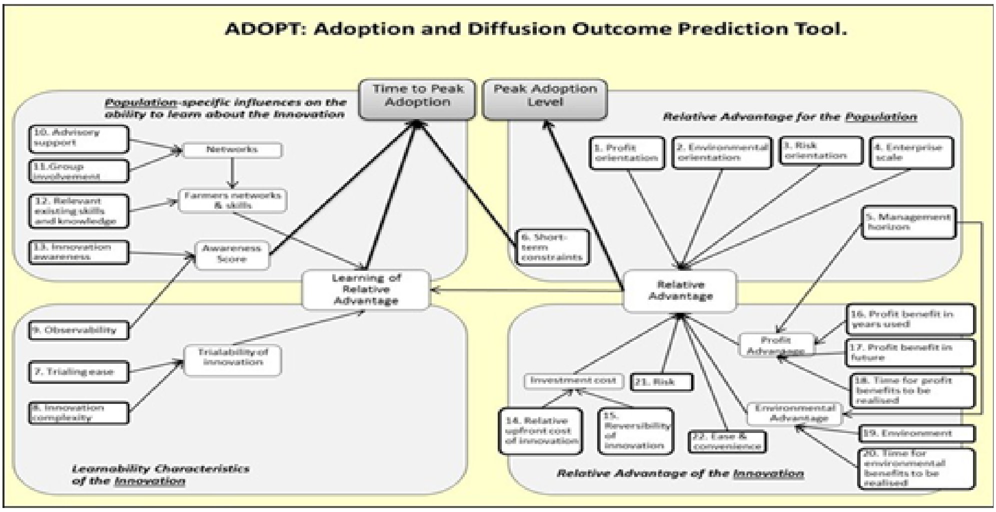


Figure 1 - Adoption and diffusion outcome prediction tool.
Source: http://aciar.gov.au/files/node/13992/adopt_a_tool_for_evaluating_adoptability_of_agric_94588.pdf.

Results and discussion

Cost Benefit Analysis (CBA) of the Adoption of the ICARDA's Arabian Peninsula Regional Program Improved Technologies

The results of the CBA for technologies implemented in Yemen are discussed in this subsection. The comparison between the costs and benefits between the sorghum and the improved forage named Clitoria indicates a clear profitability for the latter. Results indicate that, on average, the adoption of Clitoria implies a reduction of about 39% in total costs (Figure 2). The results also demonstrate an increase of about 207% and 479% on the revenue and the net return respectively. These findings are confirmed by the high Cost Benefit Ratio (CBR) when adopting Clitoria (7.97), in comparison with the farming of Sorghum (1.86). The major perceptible benefit, in addition to reducing total costs and increasing total revenue, is the amount of water saved when adopting this technology (reduction of about 48%). The visibility of these benefits could help public extension services enhance the adoption of this technology and encourage farmers to adopt it. This technology could be also scaled-up to other regions with similar socio environmental contexts across the AP region.

The empirical findings on the disaggregated costs and benefits assessment between the local libid (buffel grass, *Cenchrus ciliaris*) forage and an improved variety called gaynda are presented in Figure 3. The main appraisal indictors: net revenue, CBR and the Internal Rate of Return (IRR) indicated the high profitability when adopting the improved variety, libid. The corresponding CBR is around 22.32 among farmers who adopted gaynda against 18.35 among farmers adopting libid. Findings indicate that although we noted a slight increase in the total costs for the adopters of such technology, the net returns increased by approximately 126%. The major benefit of adopting this technology is the high level of revenue resulting from an increase in yield. Therefore, the tangible benefit from this technology is the high amount of forage produced per hectare, multiplied by its unit price during the period of analysis.

The third new technology evaluated is the soilless production system against the soil production system in protected agriculture. This technology was introduced to soil production system in protected agriculture. This technology was introduced to farmers in order to enhance the sustainability of their farming systems through an efficient use of resources, mainly water. The empirical findings indicate that CBR for the adopters of the soilless system for the cucumber crop is an average

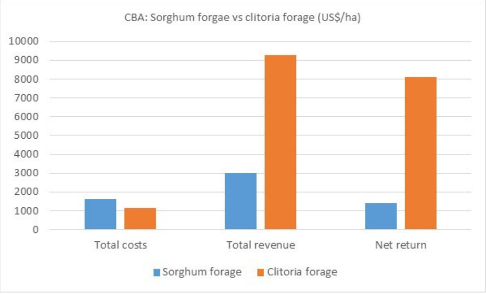


Figure 2: CBA – sorghum vs clitoria forage (US$/ha)

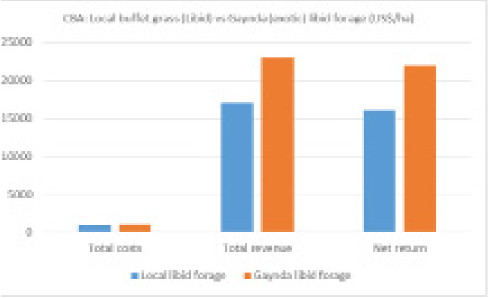


Figure 3: CBA – local buffel grass vs gaynda (exotic) libid forage (US$/ha)

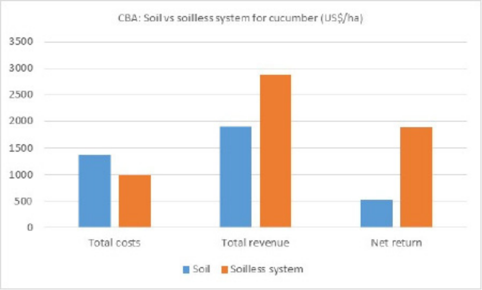


Figure 4: CBA – soil vs soilless system for cucumber (US$/ha)

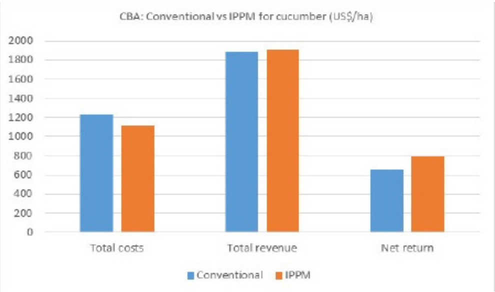


Figure 5: CBA – conventional vs IPPM for cucumber (US$/ha)

2.91, whereas this ratio is almost 1.4 for the farmers maintaining the soil production system. The tangible benefit gained from the adoption of this technology is, in addition to the high level of productivity and production, the conserved amount of water (around 200% saving in comparison with the soil production system). By applying this technology, the net return per hectare increased by 260% (Figure 4). This increase in income, in addition to the considerable amount of water savings that could accrue by adopting the soilless technology, highlighted the need to enhance the awareness of farmers regarding the profitability of using this technology (both economically and environmentally), in comparison to the soil system manual through an effective extension service to provide know-how and to facilitate the technology transfer on the use of this technology.

The interventions introduced by the project in using an integrated production and pest management (IPPM) production system were subjected to partial budgeting analysis, by comparing the adoption of the IPPM production system with the common practices of chemical pesticides or no pest control. The analysis showed that using IPPM increased yields by 15% per ha compared to yields with chemical

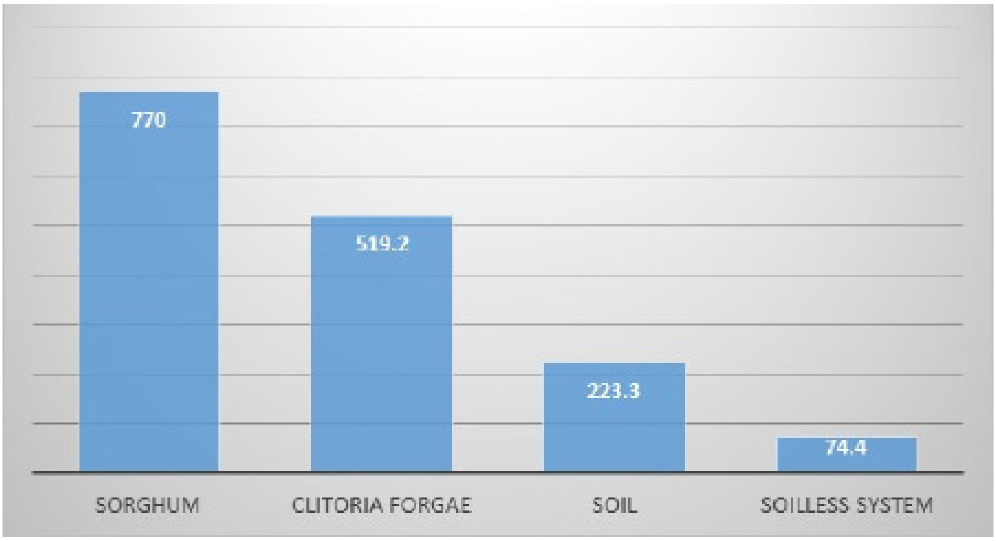


Figure 6: Water use efficiency by applying improved technologies (Clitoria forage and soilless system). The histogram represent the water used in m^3/ha

pest control, and gave a reduction in total costs of about 11% (Figure 5). Economic analysis showed that the net benefit to cucumber growers by applying IPPM technology was 1903 USD. These results are confirmed by the BCR indicators. BCR is around 1.72 among farmers who practiced the IPPM against 1.53 among farmers who did not practice it. The adoption of such technology offers an opportunity for arresting and reversing the downward spiral of resource degradation, protecting the environment (less chemical use), decreasing cultivation costs and making agriculture more efficient in terms of irrigation water-use (Figure 6).

In summary, there is clear evidence on the economic profitability of the four technologies. The project results suggested that sustainable increases in productivity of crops and forages can be achieved, the environment better protected, and a significant quantity of water can be saved if farmers/growers are encouraged to adopt the improved technology packages. The benefits of this technology must be clearly perceived by farmers, given their own socioeconomic conditions. However, the adoption of such technology needs to be accompanied by a supporting extension system and an enabling political environment to ensure the scaling-up and widespread use of this promising and profitable technology. In AP areas, increasing farmers' knowledge and perception of the merits of such technologies through better access to technical information, extension, and training will help them to develop a positive economic and environmental assessment of the proven technologies.

Adoption Levels and Factors Affecting the Adoption ICARDA's Arabian Peninsula Regional Program Improved Technologies

The use of new agricultural technologies has generally been found to be a function of farm and farmer characteristics and specific features of the particular technology (Feder et al., 1985; Marra and Carlson, 1987; Rahm and Huffman, 1984). A considerable set of literature has developed regarding factors that influence the adoption of new technologies by farmers through use of innovation theory (Feder et al., 1985; Griliches, 1957, and Rogers, 1995). Adoption and diffusion theory has also been widely used to identify the factors that influence an individual's decision to adopt or reject an innovation. Rogers (1995) defined an innovation as "…an idea, practice or object that is perceived as new by an individual or other unit of adoption. The perceived newness of the idea for the individual determines his or her reaction to it." The assessment of the adoption levels including the factors affecting the adoption of the outlined technologies implemented by the project are discussed in the following section. The analysis will be based on the following five characteristics of an innovation that affect an individual's adoption decision such as: (i) relative advantage on how the innovation is better than existing technology; (ii) the degree to which an innovation is seen as consistent with existing experiences, needs, and beliefs of adopters (compatibility); (iii) how difficult the innovation is to understand and use (complexity); (iv) the degree to which the innovation may be used on a limited basis (trialability), and (v) the degree to which the results of an innovation are visible to others (observability).

Predicted Adoption Levels and Factors Affecting the Adoption of Soilless Production System (SS) Technology

The results of the Focus group with farmers in Bahrain, KSA, Qatar and Yemen with respect to the adoption of soilless production system showed that the peak

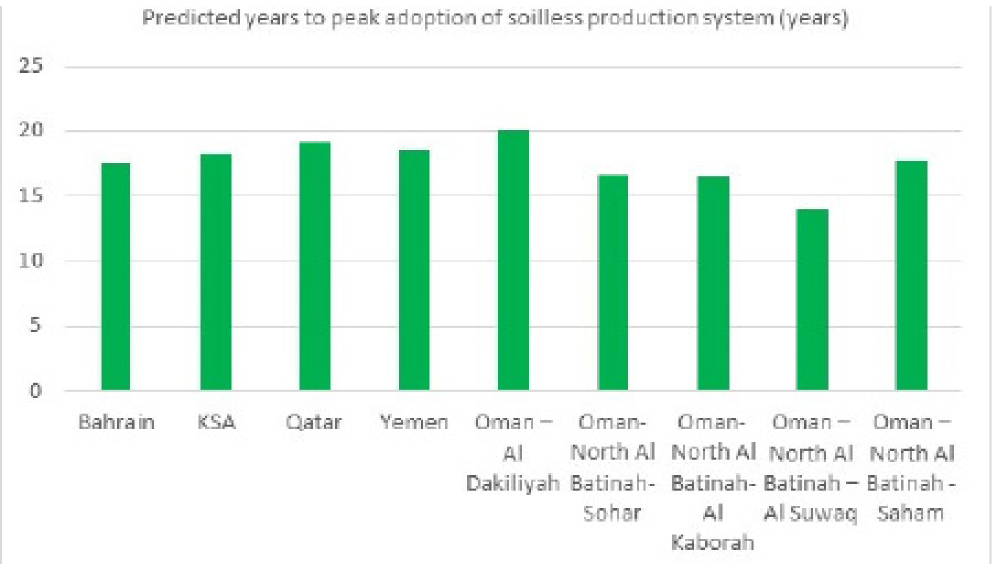


Figure 7: Predicted years to peak adoption of soilless production system (years)

adoption rate for this technology is predicted to be 95%, 91%, 8% and 86% after a period of 17.5, 18.3, 19.2 and 18.5 years, respectively (Figure 7). With respect to Oman, the findings indicate a slight difference between the regions on the predicted level of soilless production system. This difference is due to the socio demographic and economic conditions of the growers and to the farming system practiced in each region (Figure 8)

According to factors affecting both the peak of adoption and the time to reach this peak, results from the sensitivity analysis indicate that trialability of the technology in addition to its complexity where the effects of its use cannot be observed easily. In Bahrain, the adoption of the soilless system is affected negatively by the fact that it is not observable by the farmers who are yet to adopt it when it is used in their area.

In Yemen, in addition to the factors mentioned above, three factors are specific to the Yemeni growers that affect the technology of the considered technology. Such factors are the risk and investment cost and its profitability in the years that it is used. In Qatar, additional factors such as the need to develop substantial new skills and knowledge to use the innovation, are affecting adoption. This factor also influences the peak

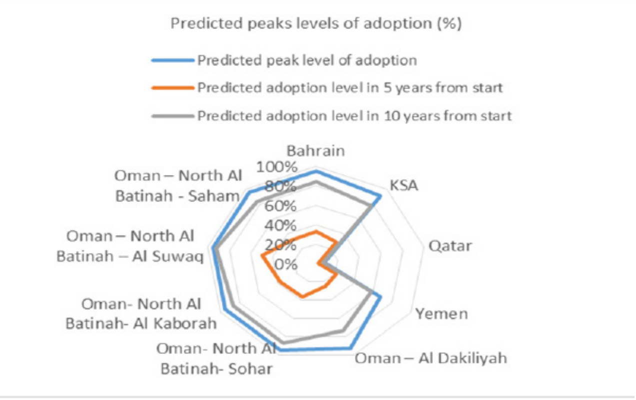


Figure 8: Predicted peaks levels of adoption of soilless production system (%)

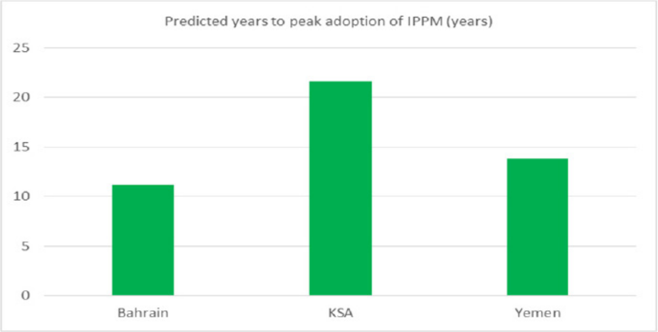


Figure 9: Predicted years to peak adoption of IPPM (years)

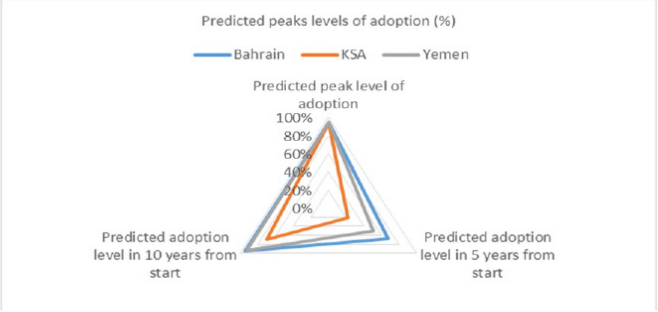


Figure 10: Predicted peaks levels of adoption of IPPM (%)

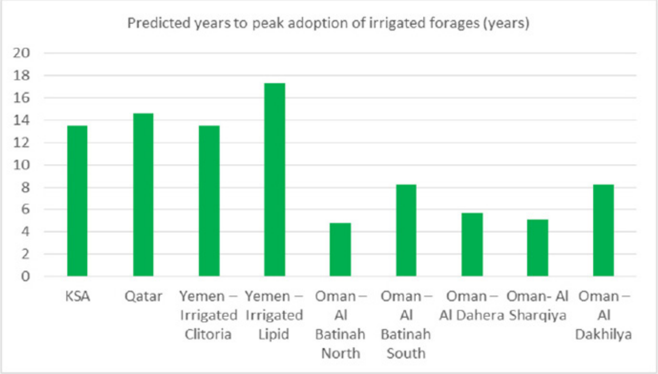


Figure 11: Predicted years to peak adoption of irrigated forages (years)

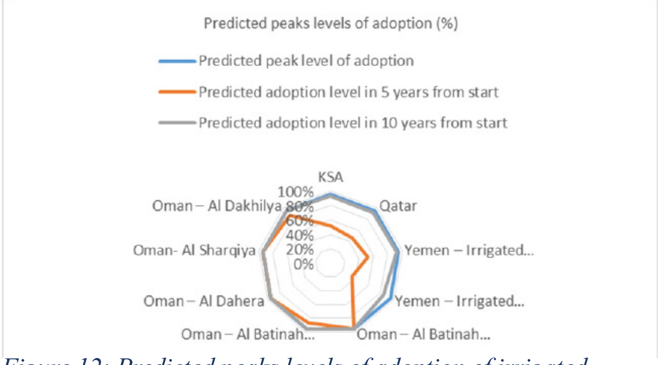


Figure 12: Predicted peaks levels of adoption of irrigated forages (%)

adoption time of soilless production in Oman (including the regional adoption across AP). This result highlighted the need to enhance the agriculture system to provide technical assistance for the users of this technology in all regions.

Predicted Adoption Levels and Factors Affecting the Adoption of Integrated Production and Pest Management (IPPM) System Technology

One of the major objectives of the ARPR is to include the IPPM technology. This technology aims to reduce costs, increase the productivity of small farmers, and protect the environment. The assessment results of the adoption of this technology with special emphasis on the main constraining factors affecting its adoption are displayed in the Figure 9. Results showed the peak adoption rate for Bahrain, KSA, and Yemen for this technology is predicted to be 95%, 94% and 85% after a period of 11.2, 21.6 and 13.8 years, respectively. After 5 years from the start, the predicted adoption level is quite acceptable for Bahrain and Qatar against KSA where this predicted level is very low. Furthermore, this level remains low after 10 years from the start of the adoption. This could be explained by the fact that many constraints are prohibiting the adoption and affects mainly the time to peak adoption level (Figure 10).

The discussion with farmers reveal that short term financial constraints of the farmers, the trialability of the technology, its complexity, lack of an effective advisory service, lack of know-how on the use of the technology and the up-front cost relative to the potential annual benefit from using this IPPM technology are the major constraints to adopt and widespread it. The outlined factors are also raised by the Yemeni farmers. Thus, for further expansion of this technology, there is a need for an enabling environment policy enhancing the use of organic sources and reducing the use of chemical in the indicated countries.

Predicted Adoption Levels and Factors Affecting the Adoption of Irrigated Forages (IF) Technology

The irrigated foraged and on-farm water management is an integrated technology introduced by the project and it is considered as a proven technology given its profitability both economically and environmentally. The aim is to reduce the quantity of water used for irrigation and to increase the profitability for the small farmers. Empirical findings from the identification and the analysis of the factors leading to the adoption of this technology, with emphasis to the predicted level of adoption and the time to peak such adoption after 5 and 10 years from the start are presented in the Figure 12. These results show a similarity in the years to peak adoption in KSA, Qatar and Yemen (for clitoria forage) where this peak (95%) is expected to be after 13.5, 14.6 and 13.2 years, respectively. In the case of Yemen (libid forage), this peak is predicted to be after 17.3 years (Figure 11).

In Oman, we note that this peak is very short in comparison with the rest of AP countries. It is expected to be around 5 years for the northern region and between 6 and 8 years for the southern region. This variability is due to the fact that environment of the northern region of Oman is characterized by availability of water and animal resources which enhance the adoption of this technology.

The results indicate that there are number of factors that influence the extent of adoption of technology such as characteristics or attributes of technology; financial factors, the change agent (extension system, professional, etc.); and the socio-economic and physical environment in which the technology take place. Thus, it is imperative to create favourable conditions so that a greater number of farmers can take advantage of these technologies. Furthermore, on the most important steps towards this goal is to identify the factors encouraging the adoption of high water efficiency irrigated forages. The results displayed in Figure 4 confirm that action should take into consideration only the factors that can step change only in time to peak adoption level. Factors such as severe short-term financial constraints, trialability of the technology before a decision is made to adopt it, complexity of the technology, observability to farmers who are yet to adopt it when it is used in their area, paid advisors capable of providing advice relevant to the innovation, need to develop substantial new skills and knowledge to use the innovation, and the size of the up-front cost of the technology relative to the potential annual benefit from using it.

Thus, farmers skill and networks, the trialability of the innovations, combined with the relative advantage of the innovations make up the population's ability to learn about the innovations, and this, combined with the factor of short-term financial constraints determines the time to peak adoption. In these countries, increasing farmers' knowledge and perception of the merits of irrigated less water consuming forages technology through better access to technical information, extension, and training. However, any intervention should take into consideration the most important factors influencing adoption, region specificities and farmers' preference.

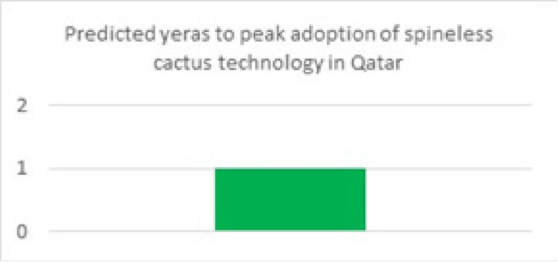


Figure 13: Predicted years to peak adoption of spineless cactus in Qatar (years)

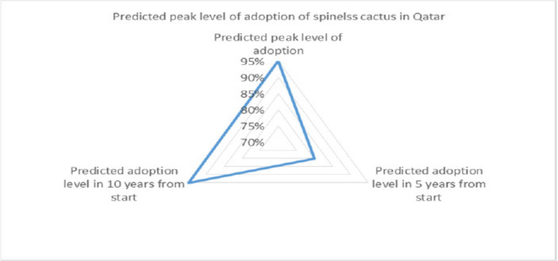


Figure 14: Predicted peak level of adoption of spineless cactus

Predicted Adoption Levels and Factors Affecting the Adoption of Spineless Cactus (SC) Technology

The peak adoption rate for spineless cactus technology in Qatar is predicted to be 95% after a period of 9.4 years (Figure 13). The predicted adoption level in 5 and 10 years from the starting period on the adoption of this technology is 80 and 90%, respectively (Figure 14). According to factors such as farmers' profit, and environmental and risk orientations, the number of farmers expected to benefit from the innovations, the environmental and profit advantages, the ease and convenience of implementation and use, and therefore, the level of peak adoption of the innovations is quite high. The farmer's skills and networks, the trialability of the innovations, combined with the relative advantage of the innovations make up the population's ability to learn about the innovations, and these factors determine the time to peak adoption. These results suggest that the expected adoption of this technology in the future is quite promising and therefore, its scaling-up should be accompanied by an effective and specialized extension system and an enabling policy environment, in addition to a financial supporting system given the high cost of rehabilitation.

Predicted Adoption Levels and Factors Affecting the Adoption of Rangeland Rehabilitation (RR) Technology

The analysis of the empirical findings presented in Figure 15 related to the predicted level of adoption for the rangeland rehabilitation technology indicates a huge difference between KSA and Qatar on the predicted peak of adoption of this technology. Although, the predicted years to peak adoption are around 18 years, the peak of adoption is expected to be 92% for KSA and 11% for Qatar (Figure 16). This predicted peak remains very low even during the first five to ten years in the case of Qatar.

The sensitivity analysis reveals that many factors are contributing/constraining the peak level of adoption, mainly for Qatar. These factors are the complexity of the

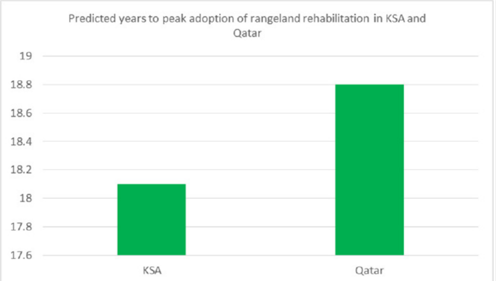


Figure 15: Predicted years to peak adoption of rangeland rehabilitation in KSA and Qatar (years)

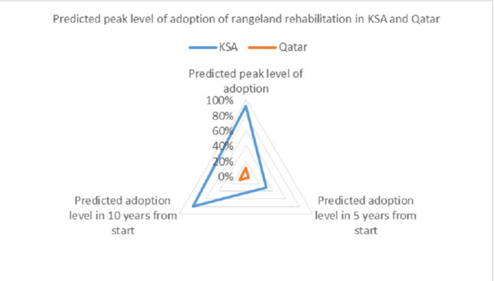


Figure 16: Predicted peak level of adoption of rangeland rehabilitation in KSA and Qatar (%)

innovation, its trialability, and the need for farmers to develop substantial new skills and knowledge to use the innovation. In addition, there are problems linked to the up-front costs of the investment relative to the potential annual benefit from using this technology. This implies that decision makers should take this into consideration when developing extension programs and effective extension services in Qatar.

Concluding remarks and policy implications

The economic evaluation and the identification and analysis of factors affecting ICARDA's Arabian Peninsula Regional Program (APRP) technologies implemented in the frame of improving food security and sustainable natural resources management through enhanced integrated agricultural production systems in the Arabian Peninsula project leads to the following results:

- There is a clear evidence on the economic profitability (reducing production costs and increasing =net return) if these technologies are applied appropriately (in the case of Yemen). Indeed, farmers are encouraged to adopt these proven and promising technologies.
- The project results suggest that sustainable increases in vegetable crops and irrigated forages productivity can be achieved.
- The project results suggest also that adopting integrated production and pest management and soilless production systems will contribute to a better protected environment (reduction of chemical products) and more efficiency in water-resources use.
- Although the adoption of some technologies is complex (case of rangeland management system), there is still interest from farmers/growers.
- The predicted level to peak adoption of these technologies is different between the AP countries and within the same country (case of Oman).
- The characteristics of the technology are a determinant on its level to peak The characteristics of the technology determine the peak adoption level and the time to peak adoption level (results suggest a low predicted level of adoption for the irrigated forages and high predicted level of adoption for the IPPM and rangeland rehabilitation).
- Technical assistance, substantial new skills and knowledge, up-front cost of

investment, financial resources and effective extension advisory services are considered the main factors influencing the adoption of these technologies.

- The action on these factors will affect only the time to peak adoption levels of the technologies.

The results from the present research study suggest the following:

- Given these technologies meet the technical, economic, and socioeconomic requirements, there is a need for a greater political and institutional input into these technologies. In particular, there is a need to design and develop alternative policy instruments (other than subsidies) and institutions for a well-developed agricultural extension system that will facilitate adoption of APRP technologies. There is a need also to create a new price policy that gives higher prices for the IPPM products (or organic products). Furthermore, raising awareness of farmers and decision makers on the environmental benefits of applying these technologies is needed to gain their support and confidence.
- The benefits (economic and environmental) of these technologies must be clearly perceived by farmers, given their own socioeconomic, cultural and economic conditions. In AP areas, increasing farmers' knowledge and perception of the merits of these technologies through better access to technical information, know-how, effective extension delivery system, credit services, and training will help them to develop a positive assessment of these technologies. This will ensure their scaling-up and widespread use.
- To accelerate the adoption process of these technologies, it is imperative to create favorable conditions so that a greater number of farmers can take advantage of the benefits of such technologies. The creation of a strong network among different institutions related to applying ICARDA-APRP technologies and the involvement of public and private financial institutions and support services could be an example of mechanisms to enhance adoption. More specifically, linking mechanisms between research and extension and extension education on ICARDA-APRP technologies would further extend the adoption of such resource-saving technologies to the farm level.
- Finally, there is a clear disparity at the regional scale on the level of adoption and on the factors affecting and encouraging the adoption of a specified technology (i,e. the case of soilless production systems and irrigated forage in Oman). Thus, scaling-up to other regions within the same country could be facilitated with interactive similarity maps that identify similar socio-economic and environmental contexts. Hence, only technologies with a high financial feasibility should be promoted, and therefore farmers should be encouraged to join established and strengthened associations through which training, technical assistance and help with access to extension information can be provided.

Training & Capacity Building

Training and Capacity building

The human resource development program included general training of members at ICARDA HQ and specialized training programs in different regions or countries. The APRP specialized training program included:

1. Regional training courses based on the participating country needs;
2. Field days and on the job training courses;
3. Workshops, seminars and conferences.

During the period between 1995 and December 2016 APRP conducted 50 specialized training courses from which 17, 21 and 12 are, respectively, related to irrigated forages/rangeland rehabilitation; Protected agriculture and cross cutting issues (statistics, proposal development, socio-economics, etc.). A total number of 735 researchers, extension agents and growers participated in these training courses.

This is in addition to more than 40 regional/national workshops in all seven participating countries.

Farmer Field Schools and Field days

During the different seasons and stages of crop growth and development, Farmer Field Schools (FFS) were organized to train farmers on their fields. The trainings were facilitated by ICARDA scientists in collaboration with NARES researchers and extension agents. The FFS approach is an effective approach to technical education and capacity building. Farmers generate knowledge that is functional and necessary to improve their production and livelihood potential.

FFS sessions were conducted at the pilot farmers' sites and the subjects were selected based on the crop or site situation. The main focus was analyzing the field management status and best practices to develop the situation. Discussions were in both directions and the farmers also provided some inputs based on their experience and knowledge. On the job training is considered the best method to provide practical knowledge in a relatively short time at minimum cost, as it is planned, organized, and conducted directly on the field and worksite.

Workshops & Expert Consultation Meetings (ECM)

Project activities, achievements and constraints were discussed and studied during a number of seminars conducted by ICARDA scientists during their visits to AP countries. However, specific subjects and constraints which needed more detailed discussions, were covered by ECM during the annual Regional Technical Coordination Meetings (RTCM). The international experts and consultants in related fields of the programme were invited to share their knowledge and ideas with local and regional experts.

Travelling Workshop for Regional Researcher & Extension Agents

To increase the regional networking and cooperation between NARS & NAES in different AP countries, several workshops and field visits to the research and extension institutes in the region were organized during the RTCM. During these workshops, researchers and extension agents of the Arabian Peninsula visited the leading NARS & NAES organizations in the region.

Training courses on Rangeland and Forages:

1. Training Course on Seed Production and Technology, 16 – 26 February 1998, Rumais, Oman, 16 participants.
2. Training on Germplasm Collection and Maintenance, 28 Februrary – 4 March, 1998, UAE, 12 participants.
3. Training Course on Collecting and Utilizing of Local Plant Genetic Resources, 24-26 March, 2001, Dhamar, 13 participants.
4. Training Course on Forage and Range Germplasm Collection in Dhofar, 8-18 November 2001, Oman, 10 participants.
5. Training course on Seed Production and Processing of Indigenous Forage Species, 14-17 July 2002, Sharjah, 15 participants.
6. Training on Maintenance and Operation of a Seed Technology Unit, September 2004, Al-Dhaid, 1 participant.
7. Field propagation and management of forage cactus, 28 September-1 October, 2005, Oman, 15 participants.
8. Improved seed production and quality control of the targeted range shrub species , 20-24 June,2010, Al Jouf, Saudi Arabia, 11 participants.
9. Modern Techniques for Rangelands Management and Monitoring in Arid Areas, 18-19 December 2010, Kuwait, 15 participants.
10. Rangeland Rehabilitation, Monitoring and Management, 2-5 October 2011, Oman, 15 participants.
11. Installation, Operation and Adjustment of Seed Processing Machines, 19-21 Februrary 2012, Doha, 10 participants.
12. Spineless cactus and feed blocks: Production techniques and animal feeding, 1-3 April 2012, Oman, 22 participants.
13. Management of Seed Health Units, 6-10 April 2012, Oman & KSA, 10 participants.
14. Management of Seed Health Units, 23-26 September 2012, UAE, 18 participants.
15. Participatory Improvement of Landraces, 06-11 December2012, Sanaa, Yemen, 14 participants.
16. Management of Seed Health Units, 6-10 April 2013, Oman, 22 participants.
17. Modern techniques for seed production , 27 -29 October 2014, Kuwait, 10 participants.

Training courses on Protected Agriculture:

1. Greenhouse high value vegetable crops post-harvest, 27 to 29 April 2014, Dubai, UAE, 35 Participants.
2. Insect Taxonomy and IPM of Insect Pests, 21 March-1 April 1998, Rumais, Oman, 21 Participants.
3. Water Use and Fertigation (Irrigation and Fertigation), 15-25 November, 1998, Saudi Arabia, 15 Participants.
4. Training Program on Protected Agriculture (Integrated Management of Greenhouses), 19 – 24 April, 1999, Qatar, 20 Participants.
5. Training Course on Greenhouse Management, 29 Nov 2000 -26 Feb 2001, Dubai, 1 Participants
6. Training Course on Greenhouse Management, 18Feb – 17 May, 2001, Dubai, 1 Participants
7. Training course on Solarization & Integrated Management of

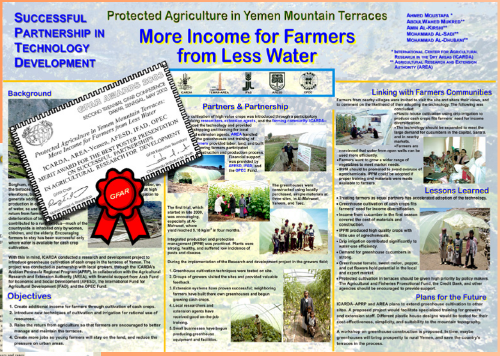
Greenhouses, 23-28 June 2001, Muscat, 22 Participants

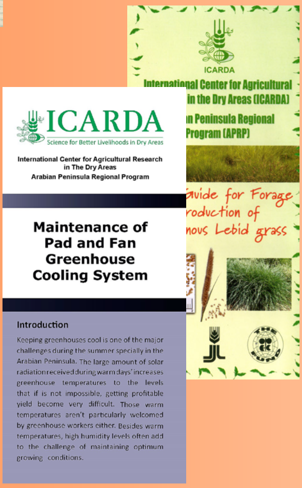
8. Training Course on Greenhouse Management, 4 March -3 May 2002, Dubai, 2 Participants
9. Training Course on Greenhouse Management, 1June- 30August 2003, Doha, 2 Participants.
10. Vertical Soilless Growing System for Production of Strawberry, 9-14 October, 2004, Muscat, Oman, 5 Participants.
11. Soilless Culture, Irrigation & Fertigation Management in Protected Agriculture, 25 - 29 January 2005, Cairo, 12 Participants.
12. Training Course on Greenhouse Management, 24 April - 13 June 2005, Muscat, 3 Participants.
13. Modern Techniques for Protected Agriculture, 31 Oct - 4 Nov 2010, Doha, 30 Participants.
14. Good Agricultural Practices (GAP) for protected agriculture, 28 Nov - 1 Dec 2011, Qatar, 22 Participants.
15. In Situ Conservation of Landraces, 08-13 December 2012, Sanaa, Yemen, 14 Participants.
16. Surveillance Methods of Date Palm Pests, 27-31 January, 2013, UAE, 20 Participants.
17. Proper Management of Soilless Production Systems Under Protected Agriculture, 19-21 April, 2013, Sanaa, Yemen, 10 Participants.
18. Operation and Management of Soilless Production Systems, 28-30 April 2013, Oman, 17 Participants.
19. Greenhouse IPPM and Good Agricultural Practices, 19-21 May 2013, Dubai, 15 Participants.
20. 20. Soilless production system for high value crops, 8 – 9 December, 2014, UAE, 10 Participants.
21. 21. Soilless production system and automatic fertigation, 6 Jan, 2014, Kuwait, 10 Participants

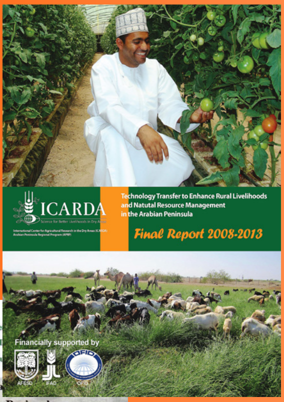
Training courses on Cross Cutting issues

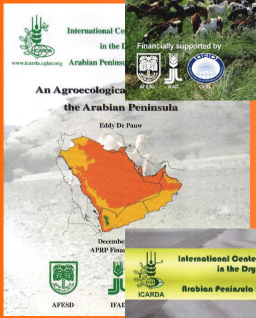
1. Training Program on Field Plot techniques, data analysis and presentation and scientific writing 25 April - 6 May 1998, Qatar, 21 Participants.
2. Information Technology for Natural Resource Management in the Arabian Peninsula (ITAP) Weather Station Network and Expert Systems, 22-27 June 2002, Cairo, Egypt, 14 Participants.
3. Specialized Training Course on On-line Bio-computing, 9-10 December 2003, Syria, 3 Participants.
4. Development of Project Proposals, Scientific Writing And Data Presentation, 8-11 January, 2005, Sharjah, UAE, 16 Participants.
5. Advanced Biotechnology and statistical Analysis for Biotechnology/BIGM, 9-13 May, 2009, Oman, 20 Participants.
6. In-Situ Conservation of Agrobiodiversity, 9-10 January2010, Yemen, 9 Participants.
7. Date Palm Project Experiments Data Analysis, 2-6 October, 2011, UAE, 24 Participants.
8. Project Proposal Development, 27- 29 November, 2012, UAE, 16 Participants.
9. Agricultural Extension and Technology, 1-3October, 2012, Oman, 26 Participants.
10. SNP Genotyping in Date Palm, 2-5 December, 2013, Qatar, 20 Participants.
11. Treated Wastewater Irrigation Date Palm Irrigation, 9-13 February, 2013, Oman, 26 Participants.
12. Economic Assessment of Agricultural Technologies, 24-28 April 2016, Oman, 23 Participants

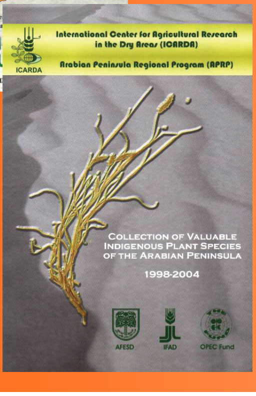

Successful partnership in developing indigenous forage production that use less water in the Arabian Peninsula
Introduction
The Challenge
Partners and Approach
Outputs
Lessons Learned
What's Next


Successful Partnership in Technology Development
Protected Agriculture in Yemen Mountain Terraces
More Income for Farmers from Less Water
Background
Partners & Partnership
Objectives
Linking with Farmers Communities
Lessons Learned
Plans for the Future


ICARDA
Science for Better Livelihoods in Dry Areas
International Center for Agricultural Research in The Dry Areas
Arabian Peninsula Regional Program
Maintenance of Pad and Fan Greenhouse Cooling System
Introduction
Keeping greenhouses cool is one of the major challenges during the summer specially in the Arabian Peninsula. The large amount of solar radiation received during warm days' increases greenhouse temperatures to the levels that if is not impossible, getting profitable yield become very difficult. Those warm temperatures aren't particularly welcomed by greenhouse workers either. Besides warm temperatures, high humidity levels often add to the challenge of maintaining optimum growing conditions.


ICARDA
Technology Transfer to Enhance Rural Livelihoods and Natutal Resource Management in the Arabian Peninsula
Final Report 2008-2013
Financially supported by


An Agroecologica
the Arabian Peninsula
Eddy De Pauw


International Center for Agricultural Research in the Dry Areas (ICARDA)
Arabian Peninsula Regional Program (APRP)
Collection of Valuable Indigenous Plant Species of the Arabian Peninsula
1998-2004
AFESD
IFAD
OPEC Fund

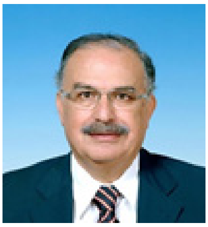
Annexes

Annex I

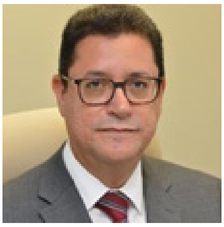
ICARDA APRP Personnel 1988-2016

ICARDA Director Generals

Prof. Dr. Adel El Beltagy
1995-2006



Dr. Mahmoud El Solh
2006-2016



Mr Aly Abousabaa
2016 to date

ICARDA Assistant Director Generals – International Cooperation

Dr. Mahmoud El Solh
up to 2002

Dr Mohan Saxina
ADG at large
2002-2006

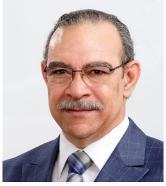
Prof. Dr. Magdy
Madkour
2004-2006

Dr. Kamel Shideed
2010 to Date

Regional Coordinators:

1. Azaiez Ouled Belgacem, Regional Coordinator 2014 to date

2. Faisal Awadeh, Regional Coordinator, 2012-2014



3. Ahmed Moustafa, Regional Coordinator, 2001-2012

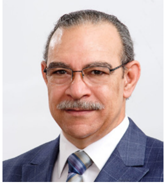
4. John Peacock, Regional Coordinator, 1996-2001

5. Samir Al Sebae Ahmed, Regional Coordinator, 1988-1995

Researchers and Specialists:

1. Azaiez Ouled Belgacem, Rangeland and irrigated forage specialist, 2011 to date

2. Naem Mazahrih, on farm water management specialist, 2012-2015



3. Ahmed Moustafa, Protected Agriculture Specialist, 1998-2012

4. Abdullah Al Shankiti, on farm water management specialist, 2009-2011

5. Abdul Wahed Jessra, Rangeland and Irrigated Forage Specialist, 2009-2010

6. Ahmed Osman, Pasture and Rangeland Specialist, 2001-2006

7. Assadullah Al Ajmi, Water and Irrigation specialist, 2002-2002

8. Ian McCann, Water and Irrigation Specialist, 1998-2001

9. John Peacock, Regional Coordinator, 1996-2001

Support Staff:

1. Arash Nejatian, Activities Coordinator Officer, 2001- date

2. Wael Mahmoud, Secretary, 2005-date

3. Saad Samuel, Driver, 2009-date

4. Arashad Mahmoud, accountant, 2010-2013

5. Serejit Alambilayi, accountant, 2007-2010

6. Robelinda Perviz, accountant, 2003-2006

7. Iman Adel Zaki, Secretary, 2004-2005

8. Hakim Khodabakhsh, Driver, 2000-2005

9. Thuraia Al-Bitar Secretary, 2003

10. Kouther Ben Ouaghram, Secretary, 2001-2002

11. Fatimah, Secretary, 1997-1999

Annex II

NARS Participants at ICARDA-APRP regional steering committee meeting (RSCM)

RTCM 29 February 1996
Seddik S. Al-Alawi, Bahrain
Shiek Mohamed Abdul Wahab Al-Khalifa, Bahrain
Amir Al-Zalzalah, Kuwait
Saoud Bin Salem Al-Harthy, Oman
Abdul Rahman Mohamed Youssef Al-Mahmoud, Qatar
Abdulrahman Saleh Al-Muhammadi, Qatar
Abdulkarim Bin Mohamed Al-Ghamdi, KSA
Mohamed Sakar Al-Assam, UAE
Rashed Khalfan Al-Shariqi, UAE
Abdulrahman M.Bamatraf, Yemen
Ali Mkred, Yemen

RSCM, 15-16 May 2000, Doha Qatar
Jaffar Habib Ahmed, Bahrain
Sheikh Mohamed Al Khalifa, Bahrain
Afaf Al Nasser, Kuwait
Adbul Khudur Al Mazeedi, Kuwait
Abdul Aziz Al Harthy, Oman
Ali Al Lawati, Oman
Abdullah Jasim Al Buainain, Qatar
Abdulrahman Al Mahmoud, Qatar
Abdulrahman Al Mohammadi, Qatar
Abdullah Al Ghamdhi, KSA
Abdulah H. Aboudi, UAE
Mohamed Sagar Al-Asam, UAE
Mohamed Al Nasseri, Yemen

RSCM, 15 October 2000, Dubai, UAE
Jaffar Habib, Bahrain
Shiekh Mohamed Abdul Wahab, Bahrain
Abdulharim Al Ghamdi, KSA
Abdulla Al Hajoj, KSA
Abdulla Al Shankiti, KSA
Abdula Khuder Al Mazeedi, Kuwait
Afaf Al Nasser, Kuwait
Samira Omar, Kuwait
Abdul Aziz Al Harthy, Oman
Ali Al Lawati, Oman
Mohamed Hashim El-Deeb, Qatar
Yaqoub Al Haja, Qatar
Abdulah H Abboudi, UAE
Mohamed Sager Al Asam, UAE
Abdul Wahed Mukred, Yemen

RSCM, 26 January 2002, AFESD, Kuwait
Jaffar Habib, Bahrain
Sheikh Mohamed Al-Khalifa, Bahrain
Khalid J. Al-Masbahi, Kuwait
Salwa Sultan Al-Orifan, Kuwait
Abdelaziz Al Harthy, Oman
Ahmed Al-Bakri, Oman
Abdullah Jasim Albou Ainain, Qatar
Abdulrahman Al-Mohammadi, Qatar
Abdullah Al-Shankiti, KSA
Mohammad Al Mazroe, KSA
Mohamed Sager Al-Asam, UAE
Abdul Wahed Mukred, Yemen
Hady Shobaihi, Yemen

RSCM, 3 October 2002, Sana'a, Yemen
Isam Mustafa A-Razaq, Bahrain
Khalid Jasem Al-Masbahi, KUWAIT
Salwa Al-Oraifan, Kuwait
Abdul Aziz Al Harthy, Oman
Ahmed Nasser A.Al-Bakry, Oman
Abdul Rahman S.Al-Mohamadi, Qatar
Abdullah Jasim Albou Ainain, Qatar
Abdullah Shankiti, KSA
Mohammed Al-Mazroui, KSA
Abdullah H. Abboudi, UAE
Abdul W. Mukred, Yemen
Ismail Muharram, Yemen

RSCM, 26 Feb 2004, Aleppo, Syria

Hussain Jawad Al-Laith, Bahrain
Adel Shehab, Kuwait
Khaled Jasem Al-Musbahi, Kuwait
Moaied Ebrahim Gamal, Kuwait
Abdul Aziz Al-Harthi, Oman
Ahmad Naser Al-Bakri, Oman
Hamad Saad Al- Saad, Qatar
Mr Yaqoub Abdullah Al-haj, Qatar
Abdullah Al Hinidi, KSA
Abdullah Al-Shankiti, KSA
Saeid Al Baggam, UAE
Saif Abdullah Al-Shar, UAE

RSCM, 17 Feb 2005, Muscat, Oman
Sheikh Abdul Wahab Khalifa, Bahrain
Khaled Nasser Al Thany, Kuwait
Saad Naby Al Rashidi, Kuwait
Abdul Aziz Al Harthi, Oman
Ahmed Al Bakri, Oman
Abdullah Jassin Al Boainin, Qatar
Mohamed Bin Zaid Al Julaifi, KSA
Abdullah H Aboudi, UAE
Ismail Muharram, Yemen
Khadir Atroosh, Yemen

RSCM, 19 December 2005, Muscat, Oman
Abdel Aziz M Abdelkarim , Bahrain
Isam Mustafa Abdelrazaq, Bahrain
Mrs Salwa Sultan Al Oraifan, Kuwait
Abdul Aziz Al Harthi, Oman
Ahmed Al Bakri, Oman
Hamad Al-Saad, Qatar
Ali Zaid Al-Dosari, Qatqr
Abdullah Al Shankiti, KSA
Mohamed Zaid Al- Julaifi, KSA
Ahmed Al-Hammodi, UAE
Saeed Al -Bagham, UAE
Ismail Muharram, Yemen
Khadir Atroosh, Yemen

RSCM, 2 July 2008, ICARDA-HQ, Aleppo
Essam Abdel Razak , Bahrain
Hussain Al Laith , Bahrain
Salwa Al-Orifan , Kuwait
Ali Al-Lawati , Oman
Salim Al Kindi , Oman
Tariq Al-Zidjali , Qatar
Abdullah Al-Hajoj , KSA
Abdullah Al-Hindi , KSA
Mansour Ibrahim Mansour , UAE
Saed Al Bagham , UAE
Khader Atroosh , Yemen
Khalil Al-Sharjabi , Yemen

RSCM, 10 December 2009, Dubai, UAE
Abdul Aziz Abdul Kareem , Bahrain
Essam Mustafa Abdel Razak , Bahrain
Amal Abdul Kareem Abdullah Redha, Kuwait
Salwa Sultan Al-Orifan , Kuwait
Ahmed Nasser Al-Bakri , Oman
Ali Hussein Al-Lawati , Oman
Abdulla J. B. Al-Buainain , Qatar
Abdullah Al-Hajoj , KSA
Abdullah Ali Al Hindi , KSA
Saud A. Aleyyed , KSA
Ali Hassan Al Hamoudi , UAE
Mansour Ibrahim Mansour, UAE
Ismail Abdullah Muharram , Yemen
Amin Abdo Hassan Al-Krishi, Yemen

RSCM, 23 December 2010, AFESD, Kuwait
Abdul Aziz Abdul Kareem , Bahrain
Amal Abdulkareem Abdullah Redha, Kuwait
Salwa Sultan Al-Orifan , Kuwait
Ahmed Nasser Al-Bakri , Oman
Ali Hussein Al-Lawati , Oman
Mohammed A.Wahab Al-Mohannadi, Qatar
Yousef Khalid Al-Khulaifi, Qatar
Saud A. Al-eyyed, KSA
Mansour Ibrahim Mansour, UAE
Rashid Khamis Borshid, UAE
Khader Balem Atroosh, Yemen

RSCM, 7 December 2011, Doha, Qatar
Abdul Aziz Abdul Kareem , Bahrain
Amal Abdul Kareem Abdullah Redha, Kuwait

Mohamed A. Jamal, Kuwait
Abdulaziz Salem Amer Al Harthi, Oman
Ahmed Nasser Al-Bakri , Oman
Mohammed A.Wahab Al-Mohannadi, Qatar
Yousef Khalid Al-Khulaifi, Qatar
Bander Mohammed Al-Otaibi, KSA
Saud A. Al-eyyed, KSA
Abdul Wahed Mukred, Yemen
Khader Balem Atroosh, Yemen

RSCM, 20 December 2012, Dubai, UAE

Abdul Aziz Abdul Kareem , Bahrain
Essam Mustafa Abdel Razak , Bahrain
Amal Abdul Kareem Abdullah Redha, Kuwait
Mohamed A. Jamal, Kuwait
Yousuf Mohammed Murad Al-Raisi, Oman
Nasser Al Kabbi, Qatar
Yousef Khalid Al-Khulaifi, Qatar
Bander Mohammed Al-Otaibi, KSA
Saud A. Al-eyyed, KSA
Mansour Ibrahim Mansour, UAE
Khader Balem Atroosh, Yemen
Mansour Mohammed AL Aqil, Yemen

RSCM, 19 December 2013, Muscat, Oman

Abdul Aziz Abdul Kareem , Bahrain
Essam Mustafa Abdel Razak , Bahrain
Amal Abdul Kareem Abdullah Redha, Kuwait
Mohamed A. Jamal, Kuwait
Ahmed Nasser Al-Bakri , Oman
Hamdan Salim Said Al-Wahaibi, Oman
Mohammed Salem H. Al-Bakri Al-Yafei, Qatar
Yousef Khalid Al-Khulaifi, Qatar
Bander Mohammed Al-Otaibi, KSA
Saud A. Al-eyyed, KSA
Ali Hareb Salem Albathra, UAE
Mohammed Mousa Abdullah Al Alameeri, UAE
Khader Balem Atroosh, Yemen
Mansour Mohammed AL Aqil, Yemen

RSCM, 8 January 2015, Dubai, UAE

Esam Mustafa Abdel Razag, Bahrain
Khalifa Ibrahim EL Elhaj, Bahrain
Mohamed A. Jamal, Kuwait
Hamdan Salim Said Al-Wahaibi, Oman
Hamoud Darwish Al-Hasani, Oman
Masoud Almarri, Qatar
Mohammed Salem H. Al-Bakri Al-Yafei, Qatar
Bander Mohammed Al-Otaibi, KSA
Saud A. Al-eyyed, KSA
Mohammed Mousa Abdullah Al Alameeri, UAE
Khader Balem Atroosh, Yemen
Mansour Mohammed AL Aqil, Yemen

RSCM, 9 December 2015, Bahrain

Esam Mustafa Abdel Razag, Bahrain
Khalifa Ibrahim EL Elhaj, Bahrain
Amal Abdulkareem Abdullah Redha, Kuwait
Mohamed A. Jamal, Kuwait
Saud Saif Ali Al Habsi, Oman
Mohammed Salem H. Al-Bakri Al-Yafei, Qatar
Bander Mohammed Al-Otaibi, KSA
Saud A. Al-eyyed, KSA
Mohammed Mousa Abdullah Al Alameeri, UAE
Khader Balem Atroosh, Yemen
Mansour Mohammed AL Aqil, Yemen

RSCM, 1 December 2016, Kuwait

Esam Mustafa Abdel Razag, Bahrain
Khalifa Ibrahim EL Elhaj, Bahrain
Amal Abdulkareem Abdullah Redha, Kuwait
Mohamed A. Jamal, Kuwait
Hamdan Salim Said Al-Wahaibi, Oman
Hamoud Darwish Al-Hasani, Oman
Saud A. Al-eyyed, KSA
Salah Abdulla Al Mousa, UAE
Khader Balem Atroosh, Yemen
Mansour Mohammed AL Aqil, Yemen

Annex III

Publications

A. Journal Articles:

Al Ajmi, A., S. Nortcliff and L. Simmonds. 2002. A Physically-Based One Dimensional Irrigation Management Model for Soil Salinity Control. Soil Use and Management 18 (3): 184-190.

Ghassali, F., A. E. Osman, Singh M., Norton B., Louhaichi M., Tiedeman J. 2011. Potential use of Mediterranean saltbush (Atriplex halimus L.) in alley cropping in the low rainfall-cropping zone of northwest Syria. Range Management and Agroforestry, 32 (1): 1-8.

Mazahreh, N., Arash Nejatian and Mohamed Mousa. 2015. Effect of different growing Medias on Cucumber Production and Water Productivity in Soilless Culture under UAE Conditions. Merit Research Journal of Agricultural Science and Soil Sciences Vol. 3(9): 131-138.

Mazahrih, N., Al-Wahaibi, H., Al-Farsi, S., and Ouled Belgacem, A. 2016. Yield and water productivity of Buffel and Rhodes grasses under different irrigation water regimes using the sprinkler line-source system. Grassland science. 62 (2): 112-118.

Nejatian, A. 2013. Review Arabian Peninsula different agro ecological zones (similarity studies) in terms of demography, economic and environmental development. International Journal of Geosciences and Geomatics. 1 (2): 77-85.

Nejatian, A., Ganan, A., and Ouled Belgacem, A. 2016. Factors affecting the adoption of soilless production systems in UAE. International Journal of Agricultural Extension. 4 (2): 119-131.

Osman, A.E., F. Bahhady, N. Hassan, F. Ghassali, T. Al Ibrahim. 2006. Livestock production and economic implications from augmenting degraded rangeland with Atriplex halimus and Salsola vermiculata in northwest Syria. Journal of Arid Environments. 65: 474-479.

Osman, A.E., M. Makawi and R. Ahmed 2008. Potential of the indigenous desert grasses of the Arabian Peninsula for forage production in a water-scarce region. Grass and Forage Science. 63: 495-503.

Ouled Belgacem, A., A. M. Tarhouni, and M. Louhaichi. 2013. Effect of protection on plant community dynamics in the Mediterranean arid zone of southern Tunisia: A case study from Bou Hedma national park. Land Degradation and Development 24: 57-62.

Ouled Belgacem, A., Al Kaabi, H. Al Wawi, and M. Louhaichi. 2013. Effect of livestock grazing on plant cover and species diversity in desert rangelands. Range Management and Agroforestry 34(1): 88-92

Ouled Belgacem, A., and M. Louhaichi. 2013. The vulnerability of native rangeland plant species to global climate change in the West Aisa and North Africa regions. Climate Change 119(2): 451-463.

B.Books and Book Chapters

Al Hariri, G. 2004. Evaluation and

Restructuring of Agricultural Research Systems in the GCC Countries. ICARDA-APRP, Dubai, UAE. 56 pages.

Awawdeh, F., and Nejatian, A. 2016. Water Resources and Agriculture in Arab Countries. In The Arab World and Latin America; Economic and Political Relations in the 21 Century (pages. 245-266). UK: I. B. TAURIS.

De Pauw, E. 2001. An Agro ecological Exploration of the Arabian Peninsula. December 2001, Dubai. UAE. 77 pages.

ICARDA. 1997. Strthening Agricultural Research and Human Resource Development in the Arabian Peninsula Phase II: Summary of Priority research Areas, Activities and training. ICARDA, Aleppo, 1-4 March 1997.

ICARDA. 2014. Technology Transfer to Enhance Rural Livelihoods and Natural Resource Management in the Arabian Peninsula. Final report, 2008-2013 ICARDA - Arabian Peninsula Regional Program. International Centre for Agricultural Research in the Dry Areas (ICARDA), Beirut, Lebanon, 72 pages.

ICARDA-APRP. 2002. Strthening Agricultural Research and Human Resource Development in the Arabian Peninsula 1995-2000 (Final Report) Aleppo, Syria. 87 pages.

ICARDA-APRP. 2002. Sustainable Management of Natural Resources and Improvement of Major Production Systems of the Arabian Peninsula (Annual Report 2000/01 season) Dubai, UAE. 206 pages.

ICARDA-APRP. 2003. Sustainable Management of Natural Resources and Improvement of Major Production Systems of the Arabian Peninsula (Annual Report 2001/02 season) Dubai, UAE. 182 pages

ICARDA-APRP. 2004. Sustainable Management of Natural Resources and Improvement of Major Production Systems of the Arabian Peninsula (Annual Report 2002/03 season) Dubai, UAE. 182 pages

ICARDA-APRP. 2005. Sustainable Management of Natural Resources and Improvement of Major Production Systems of the Arabian Peninsula (Annual Report 2003/04 season) Dubai, UAE. 240 pages.

ICARDA-APRP. 2006. Sustainable Management of Natural Resources and Improvement of Major Production Systems of the Arabian Peninsula (Annual Report 2004/05 season) Dubai, UAE. 148 pages.

ICARDA-APRP. 2007. Sustainable Management of Natural Resources and Improvement of Major Production Systems of the Arabian Peninsula, Final report 2000-2005. Arabian Peninsula Regional Program. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. 69+VI pages.

ICARDA-APRP. 2010. Technology Transfer to Enhance Rural Livelihoods and Natural resource management in the Arabian Peninsula. ICARDA-APRP Annual Report 2008-2009. Dubai, UAE, 124+IV pages.

ICARDA-APRP. 2011. Technology Transfer to Enhance Rural Livelihoods and Natural Resource Management in the Arabian Peninsula. ICARDA-APRP Annual Report 2009-2010, Dubai, UAE, 157+V pages.

ICARDA-APRP. 2012. Technology Transfer to Enhance Rural Livelihoods and Natural Resource Management in the Arabian Peninsula. ICARDA-APRP Annual Report 2010- 2011, Dubai, UAE, 172+IV pages.

ICARDA-APRP. 2013. Technology Transfer to Enhance Rural Livelihoods and Natural Resource Management in the Arabian Peninsula. ICARDA-APRP Final Report 2008-2013, Dubai, UAE, 72 pages.

ICARDA-APRP. 2013. Technology Transfer to Enhance Rural Livelihoods and Natural Resource Management in the Arabian Peninsula. ICARDA-APRP Annual Report 2011-2012, Dubai, UAE, 210+IV pages.

ICARDA-APRP. 2016. Improving food security and sustainable natural resources management through enhancing integrated agricultural production systems in the Arabian Peninsula. ICARDAAPRP Annual Report 2015, Dubai, UAE, 42+IV pages (including CD for country reports)

Moustafa, A. T., A.T. A. Al Mohammadi, A. Abou Hadid and J.M. Peacock.1998. Protected Agriculture in the Arabian Peninsula. Summary Proceedings of an International Workshop, 15-18 February 1998. Doha, Qatar. ICARDA, Aleppo, Syria. x + 104 pages.

Osman, A. E. 2005. Collection of Valuable Indigenous Plant Species of the Arabian Peninsula, 1998-2004. 144 pages.

C. Conference papers

Abu Hadid, A. F. 1998. Overview of Protected Agriculture in the Arabian Peninsula Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Al Khalifa, M. A., and Mohammed T. Al-Shaikh.1998. Protected Agriculture in the State of Bahrain Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Al Kirshi, A. A. H. and Taher A.M. Abbas.1998. Protected Agriculture in the Republic of Yemen, Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Al Mohammadi, A., and Ahmed T. Moustafa.1998. Protected Agriculture in the State of Qatar, Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Al Nasser, A. Y., and N.R. Bhat .1998. Protected Agriculture in the State of Kuwait, Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Al Shanqiti, A., Ahmed T. Moustafa & Ian MacCan, 2003. Development of information technology system for agriculture and natural resource development in the Arabian Peninsula. In Proceedings of the VII International Conference on Development of Dry Lands, Tehran, Iran 14-17 September 2003.

Al Zeir, K. 1998. Protected Agriculture in the Kingdom of Saudi Arabia, Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Atroosh, K. B. and Ahmed T. Moustafa.

2008.Interventions to enhance the use efficiency of water harvested from dams and reservoirs in the mountains of Yemen, 9th International Conference on Dry land Development (IDDC), 7 to 10 November 2008, Alexandria, Egypt

Awawdeh, F., A. Ouled Belgacem, A. Nejatian, N. Mazahrih ,M. Moussa, A. Al Bakri and K. Atroosh. 2013. Improving the livelihood of small farmers in the Arabian Peninsula through increasing land and water productivity: A transition towards green economy. 2014 Green Economy in the Gulf Region workshop 25-28 August 2014 at the University of Cambridge, UK.

Dakheel, A., M.E.Ferguson, G. Al-Hardami, A.Saleh, I.R. McCann, J.M.Peacook. 2000. Desert forages of the Arabian Peninsula - the sustainable use of salt affected soils through conservation and evaluation. Desert International Seminar on prospects for saline agriculture. April 10-12 2000, Islamabad.

Ferguson, M. E., A. Saleh, A. Hassan, G. Al-Hadrami, I. R. McCann and John M Peacock. 1999. Desert forages of the Arabian Peninsula-- solution for sustainable rangeland production in the 21st Century? Presented at “Sixth International conference on the Development of Dry Lands”, August 22-27, 1999,Cairo, Egypt,

Ferguson, M. E., G. Al-Hadrami S. L. R. Al-Rowaily, A. Al Hajoj, John M. Peacock. 1999. Desert forages of the Arabian Peninsula-a solution for enhancing conservation and combating desertification Presented at “Third International Conference Desertification and Environmental Studies-Beyond the Year 2000”, held at the Center for Desert Studies, , 30 November-4 December, 1999, King Saud University, Riyadh, Saudi Arabia

Hash, C. T., R.E. Schaffert , J.M. Peacock..1999. Prospects for using conventional techniques and molecular biological tools to enhance efficiency of crop plants in low-nutrient environments Presented at International Workshop on Food Security in nutrient stressed environments: exploiting plants genetic capabilities» held 27- 30 September, 1999, ICRISAT, Patancheru, India

Louhaichi, M., and Ouled Belgacem A. 2014. Understanding the vulnerability of rangeland ecosystems to global climate change in the dryland areas of MENA region. Proceeding of 3rd UNCCD scientific conference.

McCann, I. 1999. Water resources in the Arabian Peninsula and their impact on greenery and beautification. Presented at First International Conference. on Greenery and Environmental Beautification in Arid Zones” 20-24 November, Kuwait,

McCann, I. 2001. Water Management in Protected Agriculture in Yemen. ICARDA, Arabian Peninsula Regional Program. Workshop on Protected Agriculture in Yemen – Current Status and Future Challes, 2 April 2001, Sana’a, Yemen.

McCann, I., and Ahmed T. Moustafa. 1999. Water resources in the Arabian Peninsula. Water Resources Management, Use and Policy in Dry Areas”, 1-3 December in Amman, Jordan

Moustafa, A. T. 1998. ICARDA activities relating to environment protection and management of natural resources in the Arabian Peninsula. Presentation at the Coordination Meeting for the GCC countries and the Regional & International Organizations involved in Environmental Protection activities & issues in the Gulf States. Secretariat General of the Gulf Cooperation Council (GCC). 2-4 June 1998. Bahrain

Moustafa, A. T. 1998. Protected Agriculture in the Arabian Peninsula: A Strategy and Workplan for Research and Transfer of Technology, Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Moustafa, A. T. 2001. Integrated Production and Protection Management for the Development of Protected Agriculture in Yemen Workshop on Protected Agriculture in Yemen – Current Status and Future Challes, 2 April 2001, Sana'a, Yemen.

Moustafa, A. T. 2001. Integrated Production and Protection Management for the Green Houses Al Morshed November 2001, Abu Dhabi, UAE

Moustafa, A. T. 2001. Soilless culture in the Arabian Peninsula, Research and Implementation. Paper presented at the Expert Consultation Meeting for Soilless Culture in the Arab World. November 2001 Amman, Jordan.

Moustafa, A. T. 2003. Development of soilless systems for the production of high value crops in dry areas. Presented at Untraditional methods for production and improvement of agricultural crops conference, Cairo, Egypt 1st to 3rd December 2003

Moustafa, A. T. 2004. Hydroponics Techniques offer More Crops per Drop. In: proceedings of the International Conference on Water Resources and Arid Environment, King Saud University, 4-8 December 2004, Riyadh, KSA.

Moustafa, A. T. 2006. Economic perspectives of protected cultivation in the Arab Peninsula. Paper presented to First Workshop on Investment in Protected Cultivation in GCC countries, Abu Dhabi, UAE, 15 May 2006.

Moustafa, A. T. 2007. ICARDA's activities (R4D) for livelihood enhancement of the resource poor farmers through the production of high value horticultural crops. Presented at ICARDA-IFAD expert consultation/workshop on "The Role of Domestic and Export Marketing of Horticultural Commodities in Poverty Alleviation in the Near East and North Africa (NENA) Region 13-15 MARCH 2007, ICARDA, Aleppo, Syria"

Moustafa, A. T. 2007. Protected Agriculture as a Sustainable Technology for cash crop production to enhance farmers' livelihood. Presented to International workshop on Horticulture Technology for Sustainable Development and Biodiversity, Aleppo University 2 to 4 December 2007.

Moustafa, A. T. 2010. Sustainable Production Techniques for High Value Crops under Protected Cultivation in the Arid Region, Protected Cultivation - Present Status and Future Trends, Towards food and water security 06-08 April 2010. Riyadh, Saudi Arabia.

Moustafa, A. T., A. Al Farsi, A. Al Bakry, M. Al Rawahi, and S. Al Makhmary. 2008. Sustainable soil-less technique to combat soil-borne diseases and salinity for greenhouse growers – a success story of an Omani grower. 9th IDDC, 7 to 10 November 2008, Alexandria, Egypt

Moustafa, A. T., A. Al Shankiti & A. Nejatian. 2010. Economic Prospective of Protected Cultivation in the Arabian Peninsula, Protected Cultivation - Present Status and Future Trends, Towards food and water security 06-08 April 2010. Riyadh, Saudi Arabia.

Moustafa, A. T., A. Al Shankiti, A. Nejatian. 2010. Potential of protected agriculture to enhance water and food security in the Arabian Peninsula, 10th IDDC, Cairo Dec 2010.

Moustafa, A. T., A.W. Jasra, and A. Al Shankiti. 2010. Water and Food Security in the Arabian Peninsula: Struggling for More Actions. International symposium on Water Issues in the Middle East and Asia 6-8 March 2010, Japan.

Moustafa, A. T., Ian McCann, John M, Peacock. 2000. Biological and Natural Resources and Development System to Meet the Challes of new Era. Presented at"Scientific Research Outlook in the Arab world and the new Millennium: Science and Technology" Symposium, 24-26 April 2000, Sharjah University, UAE.

Moustafa, A. T., K. Amegbeto; M. Wadid, S. El-Abd, and A. Nejatian. 2006. Improving rural livelihood in Afghanistan through the promotion of sustainable production technologies for high value crops". Paper presented to 8th IDDC China, Feb 2006.

Moustafa, A.T., and Ian McCann. 1999 Agricultural water management in the Arabian Peninsula. Presented at "Sixth International conference on the Development of Dry Lands", August 22-27, 1999,Cairo, Egypt,

Nejatian, A., and Ouled Belgacem, A. 2014, Technical, Environmental and Economic Review of ICARDA Targeted Technology Packages For Adoption In The Present Arabian Peninsula Farming Systems: The Case Of UAE. Proceeding of 3rd UNCCD scientific conference.

Osman, A. E. 2002. The Role of ICARDA in Combating Desertification and in the Rehabilitation of Degraded Rangelands in the Arabian Peninsula. Proceedings of Conference on Combating Desertification (25-27 March, 2002, Salalah, Sultanate of Oman), ICARDA-APRP. 2002.

Osman, A. E. 2013. Range management options for sustainable improvement of fodder and livestock production in the dry areas. Proceedings of the XI International Conference on the Development of Drylands, 18-23 March 2013, Beijing, China.

Osman, A. E. and A.M. Al Hajoj 2005. Arabian Peninsula rangeland status and development. In: El Beltagy, A. and Saxena, M. C. (eds.), Sustainable Development and Management of Drylands in the Twenty-first Century. Proceedings of the Seventh International Conference on the Development of Drylands, 14-17 September 2003, Tehran, Iran. ICARDA, Aleppo, Syria, xvi + 517pp.

Osman, A. E. and W. Tsuji 2010. Root development and carbohydrate reserves as related to persistence of some desert grasses. Proceedings of the tenth International Conference on the Development of Drylands, 12-15 December 2010, Cairo, Egypt.

Osman, A. E., F. Bahhady and F. Ghassali 2002. The role of edible shrubs in rehabilitation of degraded rangelands-case study from north Syria. Proceedings: Second Saudi Symposium on Halophytes Plantation, 17-20 March 2002. Riyadh, Saudi Arabia

Osman, A. E., M. Makawi and R. Ahmed 2010. Productivity and water use efficiency of five grasses in United Arab Emirates. Proceedings of the tenth International Conference on the Development of Drylands, 12-15 December 2010, Cairo, Egypt.

Osman, A. E., Ahmed T. Moustafa, Arash Nejatian, and Mehdi Layth. 2004. In: proceedings of Organic Farming. Organic Farming Systems Seminar, 4-5 October 2004, Abu Dhabi, UAE.

Peacock, J. M. 1998. A strategic planning process and problems of implementation. APRP, Paper presented at Workshop on Needs Assessment in Agricultural Research Management and Capacity Building, .30 November 2 December 1998.Beirut, Lebanon

Peacock, J. M., G. A. Al-Hadrami, M. E. Ferguson, R. Karnik, Ian McCann, A. Saleh.2000. Desert forages of the Arabian Peninsula - the conservation and utilization of biodiversity for sustainable animal production in the UAE. Dubai International Conference on Desertification, 12-16 Feb 2000. Dubai, UAE

Peacock, J. M., M.E. Ferguson, G.A. Alhadrami, Ian McCann, A.Al Hajoj, A. Saleh , R. Karnik. 2000. Conservation through utilization – a case study of the indigenous forage grasses of the Arabian Peninsula. International conference on the Conservation of Biodiversity in Arid Regions, 27-28 March 2000, Kuwait.

Peacock, J.M. 1997. The Arabian Peninsula Regional Program (APRP). Paper presented at the International Seminar on “Regionalisation of Agricultural Research in the Mediterranean and Near East countries” 5- 7 May 1997.Florence, Italy

Peacock, J.M. 1997. The search for Salt Tolerant Forages. APRP, Paper presented at the International Symposium on “Sustainable Management of Salt Affected Soils in the Arid Ecosystem”.22-28 September 1997. Cairo, Egypt

Pengelly, B. C., J.P. Muir, A.E. Osman and J.D. Berdahl. 2003. Integration of improved forages and their role in the supplementation of natural range vegetation. Proceedings VII International Rangeland Congress, 26 July-1 August 2003, Durban, South Africa.

Sager Al Asam, M. 1998. Protected Agriculture in the United Arab Emirates, Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

Sidahmed, O. A., Muthir S. Al Rawahy , Fatma S. Al Raisy .1998. Protected Agriculture in the Sultanate of Oman, Presented at International Protected Agriculture Workshop, 15-18 February 1998, Doha, Qatar

D. Posters

Al-Oraifan, S., and A. T. Moustafa. 2003. Agro-economic assessment of a hydroponics production system in the Arabian Peninsula: Sustainable production system of cash crops using less water (Poster). 7th IDDC, Tehran 14-17 Sep.

Al Farsi, S., A. Al Bakri, A. Alshankiti and A. Osman. 2010. Optimum water application for buffel and rhodes grass in Oman, 10th IDDC, Cairo Dec 2010.

Belgacem, A. O., and M. Louhaichi, F. Awawdeh, A. Nejatian. 2013. The vulnerability of native reland plant species to global climate change in the West Aisa and North Africa regions.

Moustafa, A. T., Ahmed Bakri, M. Al Rawahi, Abdul Rahman Al Mohammadi and Rashed Ahmed. 2003. Development of soilless growing techniques (hydroponics) in the Arabian Peninsula: More crop per drop (Poster). Dubai, UAE.

Moustafa, A. T., Ahmed Al Bakry, Muthir Al Ra-wahi, Abdul Rahman Al Mohammadi and Ras-hed Ahmed, 2003. Development of soilless growing techniques for production of high quality cash crops with less water in the Arabian Peninsula (Poster). 7th IDDC, Tehran 14-17 Sep 2003.

Moustafa, A. T., Salwa Al Oraifan, Ahmed Al Bakri and Arash Nejatian. 2006. High density cropping system for cash crop production in marginal land with less water: successful partnership in technology development. 8th IDDC China, Feb 2006.

ICARDA-APRP. 2011. Soilless (Hydroponics) production systems

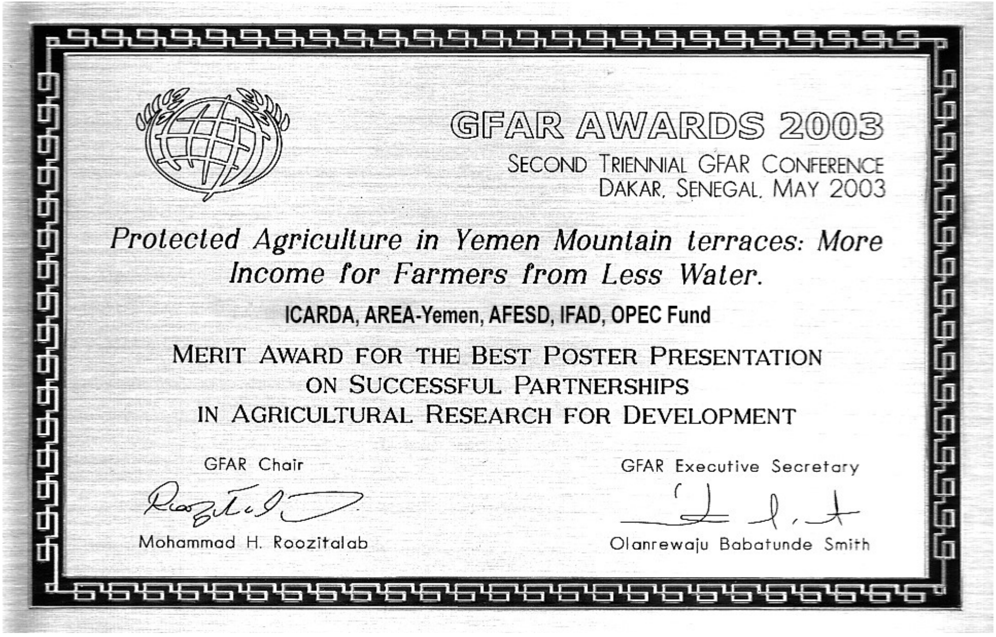
ICARDA-APRP. 2012. Spinless cactus as fodder bank.

ICARDA-APRP. 2013. A success story on adopting buffel grass in Emirates, Mr. Rashid Bin Yaroof.

ICARDA-APRP. 2013. A success story on adopting buffel grass in Qatar, Mr. Manik Miah.

ICARDA-APRP. 2013. A success story on adopting buffel grass in Yemen, Mr. Ali Nasser Taisir.

ICARDA-APRP. 2013. A success story on adopting soilless production system in Bahrain. Mr. Sadeg Mirza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ICARDA-APRP. 2013. A success story on adopting soilless production system in Oman. Mr. Ali Abri

ICARDA-APRP. 2013. A success story on adopting soilless production system in Emirates. Mr. Saeed Mohamed Bin Nahileh

ICARDA-APRP. 2013. A success story on adopting soilless production system in Kuwait. Mr. Abdulrahman Alawdiy

ICARDA-APRP 2013. A success story on adopting soilless production system in Oman. Mr. Salem Al Zekaiti

ICARDA-APRP. 2013. A success story on adopting soilless production system in Oman. Mr. Saad Al Magbali

ICARDA-APRP. 2013. A success story on adopting soilless production system in Oman. Mr. Saud Al Magbali

ICARDA-APRP. 2013. A success story on adopting soilless production system in Emirates. Mr. Rashid Al Naeemi

ICARDA-APRP. 2013. Enhance soilless production systems.

Khader B. A., and Ahmed T. Moustafa. 2010. An estimation of the probability distribution of Wadi Bana flow in the delta Abyan of Yemen, Poster presented at 10th IDDC, Cairo Dec 2010.

Moustafa, A.T., A. Nejatian, H. Abu Al Kabash, 2010. Improving water productivity for high value crops under protected agriculture in Emirates, 10th IDDC, Cairo Dec 2010.

Moustafa, A.T., Abdul Wahed Mukred, Amin Al Kirshi, Mohamed Al Sadi, Mohamed Al Dhobani. 2003. Protected Agriculture in Yemen Mountain Terraces: More income for farmers from less water. GFAR conference Dakar,May 2003

Osman, A.E., J. M Pea-cock, M.E. Ferguson, I.R. McCann, Abdul Karim Ashour, Ahmad Al-Karim, Rashid Al-Shariqi, Ali Saleh, Galeb Al Hadrami, R. Karnik, Saleem K. Nadaf, Safaa Al-Farsi, Mohamed Ali Hassan, Abdullah Al Hajoj. 2003. Successful partnership in developing indigenous forage production systems that use less water in the Arabian Peninsula (Poster). 7th IDDC, Tehran 14-17 Sep.2003.

E. Technical Advisory Notes, Training Manuals, Magazines & Leaflets:

Al Shafi, E. M., 2009. Communication and extension methodology, Training workshop on Agricultural Extension and Technology Transfer. 21-24 Nov 2009. ICARDA-CRDRS. Cairo.

Ferguson, M., Ian McCann and Guy Manners. 1998. Less water, more grazing. Caravan 8: 9-11

Ferguson, M., Ian McCann and Guy Manners. 1998. Seeds: the Starting Point for Plant Research Caravan 8: 23

Ferguson. M., 1998. Photographic Flora of Important Indigenous Forage Species of UAE & Oman (Vol. I, II, & III) . Dubai, UAE.

ICARDA. 2015. Enhance Rural Livelihoods and Efficient Use of Scarce Water Resources in the Arabian Peninsula. Beirut, Lebanon.

ICARDA-APRP. 2001. APRP brochure.2001, Dubai, UAE

ICARDA-APRP. 2001. Highlights of Achievements of the NARS and ICARDA in the Arabian Peninsula

(Arabic & lish).

ICARDA-APRP. 2001. Soil Solarization for Protected Agriculture, Technical Booklet.

ICARDA-APRP. 2002. Arabian Peninsula Regional Program - ICARDA. Ghars Zaied Magazine, April 2002.

ICARDA-APRP. 2002. Expert System for Protected Agriculture in Arabian Peninsula , Al-Morshed Magazine, November 2002.

ICARDA-APRP. 2002. International Center for Agricultural Research in Dry Areas (ICARDA). Ghars Zaied Magazine, January 2002.

ICARDA-APRP. 2002. Introductory Technical Note on Expert System for Protected Agriculture in the Arabian Peninsula.

ICARDA-APRP. 2004. Cucumber production in the GH (Arabic)

ICARDA-APRP. 2004. GH installation and preparation (Arabic)

ICARDA-APRP. 2004. Soil preparation, Irrigation and Fertigation in GHs (Arabic)

ICARDA-APRP. 2006. Field Guide for Forage Production of Indigenous Lebid Grass (Arabic/lish)

ICARDA-APRP. 2010. Farm management strategies to improve crop-water productivity using AquaCrop, Training course handout 26-30 September 2010, ICARDA-HQ, Allepo.

ICARDA-APRP. 2010. Indigenous forages with high water productivity (Buffel grass) Arabic Leaflet, Dubai, UAE, 2010

ICARDA-APRP. 2010. Modern techniques for protected agriculture. Training course hand out. Modern Techniques for Protected Agriculture. 31Oct to 4Nov 2010, Doha, Qatar.

ICARDA-APRP. 2010. Soilless Culture (Hydroponics) Arabic leaflet, Dubai, UAE, 2010

ICARDA-APRP. 2012. Irrigated forages and Feed Blocks. Field day handout, June 2012, UAE

ICARDA-APRP. 2013. Establishment of soilless production system under protected agriculture. Training course hand out. Operation and Management of Soilless Production Systems, Muscat, 28-30 April 2013

ICARDA-APRP. 2015. Bahrain and ICARDA, working together for enhancing food security and improve natural resources management while conserving the environment in the Arabian Peninsula. Dubai, UAE.

Louhaichi, M. 2010. Modern Techniques for Rangeland Management and Monitoring in Arid Areas, Training Manual. First edition. Modern Techniques for Rangeland Management and Monitoring in Arid Areas Kuwait, December 2010.

Moustafa, A. T. 2002. Soilless Culture, Al-Morshed Magazine, May, 2002

Moustafa, A. T., and Walid Abu Gharbieh, 2002. Soil Solarization for Protected Agriculture, Al-Morshed Magazine, February 2002.

Ouled Belgacem, A., and Dr Hichem Ben Salem, 2012. Spineless cactus and feed blocks: Production techniques and animal feeding. Training course handout, Spineless cactus and feed blocks: Production techniques and animal feeding. Muscat, Oman 1-3 April 2012

Ouled Belgacem, A., and M. Louhaichi. 2011. Rangeland Rehabilitation, Monitoring and Management. Training course on Rangeland Rehabilitation, Monitoring and Management. Muscat, Oman 2-5 October 2011.

Peacock, J. 1997. Into the driest areas. Caravan 5: 8-9; 23

Qaryouti, M. M., 2013. Greenhouses Integrated Production and Protection Management (IPPM) and Good Agricultural Practices, Trainig handout. Greenhouses Integrated Production and Protection Management (IPPM) and Good Agricultural Practices 19-21 May 2013, Dubai, United Arab Emirates.

Shazli, F., 2009. Technology transfer and development, Training workshop on Agricultural Extension and Technology Transfer. 21-24 Nov 2009. ICARDA-CRDRS. Cairo.

Suolo E Salute Arabian. 2011. Good Agricultural Practices (GAP) for protected agriculture. Training handout. Good Agricultural Practices (GAP) for protected agriculture, Doha, Qatar, 28 Nov to 1 Dec 2011

Zahran, Y. A., 2009. Organizing agricultural extension, Training workshop on Agricultural Extension and Technology Transfer. 21-24 Nov 2009. ICARDA-CRDRS. Cairo.

Zahran, Y. A., 2012. Modern techniques in agricultural extension and technology transfer. Training workshop on Agricultural Extension and Technology Transfer 3-6 Oct 2012, Musact, Oman.

F. Consultants' reports:

Abou Hadid, A. 1998. State of the art of protected cultivation in the Arab peninsula. Report prepared for APRP, Central Laboratory for Agricultural Climates. (ARC), 1998. Egypt

Abou Hadid, A. 1999. Executive Summery Report, Kuwait mission, April 1999. Report prepared for the Regional Technical Coordination Meeting, 13-16 June 1999. Muscat, Oman.

Abou Hadid, A. 2000. The use of climate data for integrated crop management in protected agriculture. Presented at Expert Consultation Meeting (ECM) on Integrated Production and Protection Management (IPPM) for Protected Agriculture in the Arabian Peninsula 16-17 October 2000 Dubai, UAE

Abou Hadid, A. 2003. The utilization of IT for water use efficiency, presented at APRP-RTCM Aleppo 7-9 December 2003.

Abu Gharbieh, W. 2000. Integrated management of phytonematodes and soil-borne diseases in protected agriculture. Presented at Expert Consultation Meeting on Integrated Production and Protection Management (IPPM) for Protected Agriculture in the Arabian Peninsula 16-17 October 2000, Dubai, UAE

Abu Gharbieh, W. 2000. Practical applications of soil solarization. Presented at Expert Consultation Meeting on Integrated Production and Protection Management (IPPM) for Protected Agriculture in the Arabian Peninsula 16-17 October 2000, Dubai, UAE

Al Baiz, A. A. 2002. Importance of fingerprinting genomes using PCR with arbitrary primers as genetic markers for genetic analysis in field crops. Third APRP-RTCM, Sana'a, Yemen, 28 September – 2 October 2002.

Al Hadrami, G. 2001. Evaluation of priority indigenous rangeland species & forages (nutritive feed value). Presented at Second Regional Technical coordination meeting (rangeland), 15-16 May 2001, Al-Jouf, Saudi Arabia

Almasoum, A. A. 2000. Plastic mulch as part of protected cultivation, for higher yield and safer environment. Presented at Expert Consultation Meeting on Integrated Production and Protection Management (IPPM) for Protected Agriculture in the Arabian Peninsula 16-17 October 2000 Dubai, UAE

Almasoum, A. A. 2002. Greenhouse cooling and ventilation Presented at Second Protected Agriculture Regional Technical Coordination Meeting, 20-23 January 2002 Kuwait

Almasoum, A. A. 2003. Application of IPPM in greenhouse for production of organic produce. Presented at APRP-RTCM Aleppo 7-9 December 2003

Almasoum, A. A. 2005, Summary of recommendation for APRP RTCM, Muscat, Feb 2005.

Baily, B. J. 2002. Ventilation and new methods of cooling greenhouses. Presented at2nd Regional Technical Coordination Meeting (PA), 20-23 January 2002, Kuwait

Baily, B. J. 2002. Ventilation and new methods of cooling greenhouses. Presented at Second Protected Agriculture Regional Technical Coordination Meeting, 20-23 January 2002 Kuwait

Baudoin, W. 2000. FAO's program on Integrated Greenhouse Production and Protection Management (IGPP). Presented at Expert Consultation Meeting on Integrated Production and Protection Management (IPPM) for Protected Agriculture in the Arabian Peninsula, 16-17 October 2000 Dubai, UAE

Baudoin, W. 2002. HORTIVAR, FAO'S database on the performance of horticulture cultivars. Third APRP-RTCM, 28 September – 2 October 2002, Sana'a, Yemen

Baudoin, W. 2002. Integrated Greenhouse Production and Protection (IGPP) for improved quality of horticulture produce Presented at 2ndProtected Agriculture Regional Technical Coordination Meeting, 20-23 January 2002, Kuwait.

Baudoin, W. 2002. Recent developments in greenhouse technology for arid & semi arid regions Third APRP-RTCM, Sana'a, Yemen, 28 September – 2 October 2002

Baudoin, W. 2005. Establishment of regional network on greenhouse crops production in the Arabian Peninsula. Presented at APRP-RTCM, Muscat, Feb 2005.

Contant, R. B.1998. The Strategic Planning Process for the Arabian Peninsula Regional Program (APRP). May 1998. ISNAR Haque , The Netherlands.

De Pauw, E. 1998. Status of

Agroecological Characterization in The Arabian Peninsula. Report prepared for the Regional Technical Coordination Meeting .May 1998.Manama, Bahrain

De Pauw, E. 2003. Agro ecological characterization studies in the Arabian Peninsula. Past and Future Needs, presented at APRP-RTCM Aleppo, 7-9 December 2003.

El Behairy, U. A. 2012. Report on soilless culture in Arabian Peninsula countries. Dubai, United Arab Emirates 2012.

Hanafi, A. 2000. Integrated Pest Management in greenhouse vegetable production. Presented at Expert Consultation Meeting on Integrated Production and Protection Management (IPPM) for Protected Agriculture in the Arabian Peninsula 16-17 October 2000 Dubai, UAE

Humeid, B. 1998. Trip Report on the Mission to Sultanate of Oman. March 30, to April 5, 1998, ICARDA (GRU)

Ibrahim, F. 2000. Biological control of agricultural pests. Presented at: Expert Consultation Meeting (ECM) on Integrated Production and Protection Management (IPPM) for Protected Agriculture in the Arabian Peninsula, 16-17 October 2000, Dubai, UAE

ICARDA. 1999. Characterization of Breeds of Small Ruminants. Report prepared for the Regional Technical Coordination Meeting, 13-16 June 1999. Muscat, Oman

ICARDA. 2000. Rangeland ecosystem restoration and conservation – a feasibility study for Ahfara, Fujairah, UAE. June 2000. Aleppo, Syria

Le Houérou, H. N.1998. Outline of a Strategy for Rangeland and Feed Resource Development in the Arabian Peninsula. Report to the Arabian Peninsula Regional Programme (APRP). March 1998, Dubai

Mahmoud, M. 2002. Expert System for the management of greenhouse crops. Presented at 2nd Protected Agriculture Regional Technical Coordination Meeting, 20-23 January 2002, Kuwait

Makkouk, K., and Ahmed T. Moustafa. 1997. IPP management program for PA in the Arabian Peninsula. Program prepared for APRP. 1997.Dubai, UAE.

Moustafa, A. T. 1997. Status of Protected Agriculture in the Arabian Peninsula Countries. Questionnaire prepared for APRP. 1997.Doha, Qatar.

Mukred, A. W. 2005. Summary of recommendation for APRP RTCM, Muscat, Feb 2005

Oweis, T. 2003. Managing water in agriculture under extreme scarcity. Presented at APRP-RTCM Aleppo, 7-9 December 2003

Salama, A. 2013. ICARDA-APRP 2008-2013 External Complision Recview Mission Report. Dubai, United Arab Emirates 2013.

Singh, M. 2003. On-line biocomputing: a research solution tool. Presented at APRP-RTCM Aleppo, 7-9 December 2003

Tantawi, S., and Aymen F.Abou Hadid. 2002. Information technology for the Arabian Peninsula Presented at 2nd Regional Technical Coordination Meeting, 20-23 January 2002, Kuwait

Turner, M., and J.Valkoun. 2001. Movement of forage and rangeland seeds within Arabian Peninsula. Presented at Second Regional Technical coordination meeting (rangeland), 15-16 May 2001, Al-Jouf, Saudi Arabia

Turner, M., Mohammed Makkawi & Lahcen Grass, .1999. Report on Seed Studies of Indigenous Forage Species. Report prepared for the Regional Technical Coordination Meeting, 13-16 June 1999. Muscat, Oman.

Von Zabeltitz, C. 1999. Greenhouse Structure, Covering Materials and Climate Control Institute for Horticulture ineering, University of Hanover, Germany

Von Zabeltitz, C. 2002. Ventilation and cooling of greenhouses in hot arid climate. Presented at 2nd Regional Technical Coordination Meeting (PA), 20-23 January 2002 Kuwait.

Von Zabeltitz, C. 2002.Ventilation and cooling of greenhouses in hot arid climate. Presented at Second Protected Agriculture Regional Technical Coordination Meeting, 20-23 January 2002, Kuwait.

Annex IV

Comments from farmers/growers and senior AP countries administrators

Mr. Mohamed Al Naeemi, Grower, Ajman, UAE

"With hydroponics, water consumption is far less for cucumber production compared to soil cultivation"

Standing in the middle of one of his own greenhouses equipped with a hydroponics system, Mr. Al Naeemi claimed that in his farm the hydroponics was very successful, significantly reducing water and pesticide application. One of the successful cases recorded in UAE is Mr. Rashid Al Naeemi. He was selected as a progressive farmer to adopt soilless prodcution sysetms. After the first growing season he started to expand the hydroponics systems in his farm, where the cucumber yield increased from 5kg/m2 to above 12kg/m2 for a single crop. Furthermore, he opened his farm to ICARDA and NARS scientists for on-farm research activities, as well as a demonstration site for other growers. ICARDA organized a number of Farmer Field School (FFS) sessions in this farm. After four years, the rapid appraisals and interviews revealed that a virtual network of growers were established, where Mr. Naeemi acts as a local technical leader and a bridge between ICARDA scientists and other growers who clearly start to test and adopt the new technology after observing its benefits at Mr Naeemi's farm. This network covers about 20 farmers and is expanding.

Mr Ali Al Abri, Grower, Oman.

I adopted soilless production because in soil production I:

- Face many fungal diseases
- Use a lot of fertilizers and pesticides
- Lose a large number of plants because of pests.

According to my experience, the advantages of hydroponics over soil system include:

- Easier work;
- Shorter time for preparation and sterilization between two crops;
- Higher yields; 3 to 4 crops per year can be achieved in hydroponics;
- Hydroponics use less water, fertilizers and pesticides compared with the soil
- growing system.

Mr Ali Nasser Taisir, Grower, Yemen.

"I am very happy with Buffel grass as it increases the production of meat and milk"

"I own cows and camels and I would like to increase planting of the Buffel grass as it is very good and important for animal nutrition."

Mr Sadeg Mirza, Grower, Bahrain.

"I need to start using more hydroponics in my greenhouses"

After 10 years of growing vegetables, the soil salinity made it almost impossible to grow crops in my farm anymore. But since last year, with the hydroponics production system my farm comes back to life. I need to see and learn more about this new system.

Mr. Mohamed Al Adway, Bahla, Al Dakhlia Region, Oman.

I used to grow cucumber in soil where the yield was very low due to soil and water salinity. But after adopting the hydroponics systems the situation changed. I harvested about 3000 to 3300 kg of cucumber from my single greenhouse while plants were about two months old and I am expecting them to continue production for at least another month. From the same greenhouse I used to harvest only about 2000 kg per crop in soil.

Saif Bin Hamid Al Badi, Buffel grass grower, Butaineh, Oman.

"This new grass has higher yield and needs less water"

While comparing the Buffel grass with Rhodes grass at his farm, Mr. Al Badi explained that the new grass (Buffel grass) needs less water. "I use 30-45 min irrigation for my Rhodes grass but for this new one I only use 15-20 min daily." He continued: "Buffel grass grew faster than Rhodes, particularly after the third cut, and gave me very good yield from 10 cuts." Furthermore, the Rhodes grass regenerated poorly after direct grazing, whereas the Buffel grass was excellent.

Mr. Faisal Alawi, Grower from Bahrain.

"I see a huge difference with hydroponics, which is the reason why we want to adopt it. All the results are positive – reduced water, fertilizer use and less area used with more yield produced."

"In Bahrain, the obstacles are the lack of water and the limited land area. This is a problem because, if you do not have enough land and water, you cannot grow. But, with hydroponics, we can take a small area and grow anything."

Mr, Saeed bin Khalid Al Hanai, Grower, Oman.

Mr. Al Hanai produces strawberries in a vertical hydroponics system. His success story started when he heard about the technology and got acquainted with the vertical production system in one of the project pilot sites and research stations in Rumais. He then developed the system at his own cost on his farm using two greenhouses. He also established a mother nursery for strawberries in another greenhouse which enabled him to produce his own seedlings. Mr. Hanai is very enthusiastic about the vertical production system for which he made some modification in the irrigation system. "I have installed", said Mr. Al Hanai, "the lateral irrigation pipes on the top, not on the ground, which makes the irrigation process easier." Although this modification has been installed and tested before in Qatar, ICARDA and MAF would support and conduct a technical and economical analysis study on this farmers' initiative.

Mr. Rashed Bin Yaroof Al Suwaidi, Grower, Emirates.

"I used to grow Rhodes grass, but it is consuming too much water. For that reason, I am adopting Buffel grass on my farm."

I have a little water on my farm. So I dug another well and brought water from 5 km distance. Therefore I can only grow very high water efficient crops such as Ghaf trees.I am adopting Buffel grass in my farm. But first I need to compare its production and palatability with other grasses.

Mr. Salim Saied Al Eisai, Grower, Oman.

"I recommend the Hydroponics to all producers, and I am planning to expand this system into all my greenhouses."

Based on my experience,

Hydroponics require less cost for production compared with the conventional soil production system.

Fertilizer use in hydroponics is less than in the soil system.

Hydroponics also use less water and the production is higher. In Hydroponics I am losing fewer plants.

Mr. Abdualrahman Alawdiy, Grower, Kuwait.

I started production of vegetables, cut flowers, and medicinal plants under greenhouses 10 years ago. In the beginning, I used to plant in soil, but five years ago, when I heard about the benefits of soilless culture, I changed all my greenhouses to soilless. The soilless production system enhanced my yield and saved:

- more than 67% of irrigation water
- 60% of fertilizer application
- more than 50% of labor cost.

Dr. Mansour Al-Aqil, Chairman, Agricultural Research and Extension Authority (AREA), Yemen, December 2013.

"The Arabian Peninsula Program has played a definite role in transferring efficient and applicable technologies to the region. These technologies certainly helped resource poor growers to enhance their livelihoods." Soilless system doubled the net income of Yemeni farmers compared to soil based conventional systems.

Dr. Ahmed Al Bakri, Under Secretary of Agriculture, Minister of Agriculture and Fisheries, Oman, December 2013.

The project is important to the region, as growers in Oman have substantially benefited from its technologies such as those for protected agriculture and the use of water efficient users' "indigenous forage species."

Salman Abdul Nabi, undersecretary for Agricultural Affairs, Ministry of Municipality Affairs and Urban Planning (MMAUP), Bahrain, December 2015.

While addressing the ICARDA-APRP annual regional meetings, Bahrain, he expressed gratitude towards the joint venture with ICARDA, which he said has increased crop production up to five times at pilot sites as a result of the adoption of the soilless production system.

Faisal Al Seddiqi, Assistant Undersecretary, Deputy Director General of Plant Wealth.

While addressing the ICARDA-APRP annual regional meetings held in Kuwait, December 2016, he praised the program efforts, which enabled Kuwait to consolidate efforts to demonstrate the technology of soilless culture to farmers through the establishment of pilot farms.

Dr. Thani Bin Ahmed Al-Zeyoudi, Minister of Climate Change & Environment (MoCCE), UAE.

regional coordinator at his office on June 2016, H.E. expressed the willingness of his ministry to expand the collaboration with ICARDA-APRP on technology transfer focusing on enhancing Food security and Climate Change management. He praised the excellent cooperation with the program during the past years, and he hoped for more efforts in supporting the advanced scientific research in UAE, as well as disseminating the technology packages developed within the framework of the program to farmers.

Dr. Bandar Al-Odhiani, GCC Secretariat Representative and Former Director General of National Center for Agriculture and Animal Research, Riyadh, Saudi Arabia.

While addressing the ICARDA-APRP annual meeting in Kuwait, December 2016; he highlighted the importance of these annual technical meetings which bring together ICARDA scientists and researchers, extension agents, and growers from different AP countries to evaluate the joint projects. He also emphasized the importance of technology packages developed within this program and their dissemination to farmers and producers. This process has resulted in a good farmer-to- farmer extension system.

H.E. Mr. Ahmad Amer Alhemaidi, Qatar Minister of Environment (MoE), May 2015.

While receiving ICARDA Director General at his office, May 2015; H.E. the Minister emphasized the necessity of taking advantage of ICARDA experiences for Qatar. His Excellency expressed the priority areas of cooperation between MoE and ICARDA that included the preservation of genetic resources; development of livestock and animal feed resources; soilless production systems; and the use of treated wastewater, as well as training farmers in developing knowledge and adopting new techniques.

Annex V

List of spineless cactus accessions imported by ICARDA-APRP in 2005 from Tunisia, grown in Oman and later distributed among AP countries.

Accession Number	Accession ID (ecotype/variety)	Country of origin
4321	-	-
68247	O.F.I DJ. BARGOU 68247	Tunisia
69199	MAXIMA V. LANCEOLATO 69199	Algeria
69210	O. TOMENTOSA 69210	Algeria
69217	O. MAXIMA 69217	Algeria
69220	O.F.I VAR LISSIMA 69220	Algeria
69223	UNARMUS BURBAN 69223	Algeria
69223	O.F.I HETAPENTICA 69233	Catania ITALY
69234	O.F.I NOSTRALE FEMENIANA 69234	Catania ITALY
69236	O. SANGUINEA 69236	Sicily Italy
73056	O.F.I CHICO 73056	South Africa
73058	CARTHA 73058	Tunisia
73060	TUMONTOSA 73060	Tunisia
73062	MAXIMA 73062	Tunisia
73952	O.F.I 73952	Tunisia
74071	O.F.I 74071	Tunisia
74083	O.F.I SEFROU 74083	Morocco
74110	O. LAEVIS SP3 74110	New Mexico
74111	O. LAEVIS SP4 74111	New Mexico
74112	O. LAEVIS SP5 74112	Mexico
69241	O.F.I THALA 69241	Tunisia
69242	O.F.I SBEITLA 69242	Tunisia
69245	AIN – BOUDER- IESS 69245	Tunisia
69246	O.F.I AIN AMARA 69246	Tunisia
69248	O.F.I BORJ EL FARAG 69248	Tunisia
69219	O.F.I GRASSA CAREF–68 69219	Algeria
69198	CAREFIN – 1 69198	Algeria
73049	O.F.I VIB FP 2 73049	Mexico
73054	O. FAUSICALIS 73054	South Africa
75012	DJ – SOLAH 75012	Tunisia

Accession Number	Accession ID (ecotype/variety)	Country of origin
75018	EL BOROUJ 75018	Morocco
75019	AIN JIMAA 75019	Morocco
75032	O.SP. 75032	Madagascar
CONLEA-L19	O.F.I CONLEA RUBESCENS	Algeria
-	R-14	Unknown
-	Nil-I	Unknown
-	Nil-II	Unknown
74112 (29)	O. LAEVIS SP5 74112	Mexico