Improving agricultural production systems and conserving natural resources under climate change in the Arabian Peninsula

ICARDA-APRP

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Ministry of Municipality and Environment, Qatar

Ministry of Environment, Water and Agriculture, Saudi Arabia

Ministry of Climate Change and Environment, UAE

Agricultural Research and Extension Authority, Yemen

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List of abbreviations

AP	Arabian Peninsula
AFESD	Arab Fund for Economic and Social Development
ANOVA	Analysis of variance
APRP	Arabian Peninsula Regional Program
AURAK	American University of Ras Al-Khaima
MOCCE	Ministry of Climate Change and Environment, UAE
ETo	Evapotranspiration
GAP	Good Agricultural Practices
GCC	Gulf Cooperation Council
ICARDA	International Center for Agricultural Research in the Dry Areas
IPPM	Integrated Production and Pest Management
NARS	National Agricultural Research System
KFAED	Kuwait Fund for Arab Economic Development
NAES	National Agricultural Extension System
NARS	National Agricultural Research System
PAAFR	Public Authority for Agricultural Affaires and Fish Resources
TWW	Threated Waist Water
UAE	United Arab Emirates
WP	Water productivity

Executive summary

The present project "Improving agricultural production systems and conserving natural resources under climate change in the Arabian Peninsula" is funded by the Arab Fund for Economic and Social Development (AFESD), and the Kuwait Fund for Arab Economic Development (KFAED). It aims at improving agricultural productivity without depleting water and soil resources while increasing the resilience of farmers and farming systems to climatic change and enhancing the capacity of these systems to sequester carbon and mitigate climate change. The project consists of four major components:

1. Enhance National Agricultural Extension Systems (NAES) and Transfer of Technology Packages
2. Problem-solving Research and Impact Assessment
3. Capacity Building and Institutional Strengthening
4. Socio-economic benefits and impact assessments of the project's targeted technologies

This progress report highlights ICARDA and NARS joint activities and achievements between 1 January – 31 December 2019.

Under the technology transfer component, 75 new pilot growers adopted the project targeted technologies, which consisted of 33 pilots for Irrigated forages and spineless cactus, 30 pilot sites on Soilless and IPPM packages under Protected Agriculture and 12 pilots for utilizing agricultural and agro-industrial by-products as an alternative animal feed resources during the reporting period. Considering the unsecure conditions and the related economic crisis, the use of feed blocks as an alternative feed resource and supplementation is considered appropriate for smallholder farmers, mainly women in Yemen. The activities related to the soilless production system and IPPM in Kuwait, where 8 new pilot growers adopt the technologies, is showing good results. The tomato and cucumber crop yield recorded at 12.66 and 13.39 kg/m^2 during the reporting period respectively. Similarly, in Yemen, the water productivity of cucumber in pilot farms reached 140 kg/m^3. The soilless production system showed a significant increase in net return compared to the soil-based production. The project also covered more than 20,500 ha of rangelands for rehabilitation and management activities compared to freely grazed areas (Control) in Kuwait (Al Wafra), Saudi Arabia (Doumet Al-Jandal, Tabarjal, and Bsita) and Yemen (Lahej). In Saudi Arabia, eleven new pilot growers rehabilitated their degraded rangelands by introducing native species recommended by the project team. The total area is about 400 ha. The range species include: *Salsola tetranda, Traganum, Salsola villosa, Artiplex Leucoclada, Haloxylon salicornicum,* and *Anabasis stifera.* In Kuwait, monitoring-assessing the dynamics of plant cover attributes in a rehabilitated degraded rangeland site at Al-Warf was developed in close collaboration between ICARDA and Public Authority for Agricultural Affair and Fish Resources (PAAF) and aims at monitoring the changes in the vegetation cover during several seasons through testing different techniques. In Yemen,

To improve the adoption of the project targeted technologies and the efficiency of extension systems in the AP countries, ICARDA and NARES have developed a survey to be conducted on October-November 2019. It consists of a questionnaire that will permit the assessment of the status of the current extension systems and develop a dissemination strategy for the transfer of knowledge from research to the end users via extension agents. This will be preceded by a training workshop on "Information and Communication Technology to Enhance Agricultural Extension Systems" to be held on 14-18 October 2019. Furthermore, the project conducts a survey on major factors affecting the decision to adopt ICARDA-APRP technologies implemented in the GCC Countries and Yemen.

The project conducted a number of research activities under component 2. Field trials on grass varieties (exotic and indigenous) assessed their water productivity under AP conditions. Clitoria, shows promising results in Qatar, UAE and Yemen. In UAE, some (5) drought and heat tolerant barley genotypes have shown very promoting performances regarding their production and adaptation to the very harsh environmental conditions. Buffel grass and Rhodes grass production were tested under Treated Wastewater (TWW) in Oman where results clearly show the higher yield and water productivity of Buffel grass. Data analysis related to chemical and heavy metal residue in plant and soil is in progress. In Kuwait, research activities were carried out on identifying indigenous medicinal and aromatic plant species. The five most desirable varieties of tomatoes identified by the farmers in UAE tested under soilless production system in cooled greenhouse and net house. The overall results showed that Marinza was the best in term of production, followed by SV4129. A study on a newly-designed greenhouse cooling system continued in collaboration with the American University of Ras Al-Khaima (AURAK). The water consumed for the cooling system during September and October was recorded at about 4 liters/day/m^2 which is about 60% less than the water consumed in the standard pad and fan system during the same period. A study will be conducted in Kuwait, which focus on different organic mulches that can be locally obtained. The organic mulches include shredded paper from offices, recycled cardboard, wood chips, shredded palm fronds, and palm fronds. In Yemen, a survey was conducted on the availability of agricultural by-products in Abyan and Lahej area. The total agricultural crop residues in Lahej and Abyan reached 46,192 tons/year, which constitutes about 11.5% of the total production of crops grown. Sorghum occupies the first place in terms of quantity of residues, i.e. 36.9% of total residues followed by bananas with 18.1%. Research activities on rangeland rehabilitation and water harvesting techniques have been continued in Yemen, Kuwait, and Saudi Arabia. Different water harvesting techniques and shape are under investigation.

Under component 3, ICARDA and its partners during this reporting period organized 18 field days, workshops and seminars throughout the visits of ICARDA scientists to the different Arabian Peninsula countries. During these events, ICARDA scientists provided technical backstopping and hands-on training to more than 250 researchers, extension agents and growers from the region. The program also organized 2 regional workshops on Use of Renewable Energy in the Management and Cooling of Hydroponics Nutrient Solution 17-20 March 2019, Oman; and Information and Communication Technology to Enhance Agricultural Extension Systems, Hammamet, Tunisia: 14-18 October 2019 where in total 44 participants attended.

The project also held its second regional technical coordination meeting (RTCM) and steering committee meeting (RSCM) in Kuwait from 9 to 12 December in close collaboration with the Public Authority for Agricultural Affaires and Fish Resources. Thirty-seven (37) participants from seven AP countries NARS, ICARDA and donor organizations attended this event.

1. Introduction

ICARDA's Arabian Peninsula Regional Program (APRP) was launched in 1995 with a goal of developing the agricultural sector and conserving the natural resources and the environment through scientific research and technology development. Furthermore, training and capacity building have received particular attention within the APRP. The joint efforts by ICARDA and the National Agricultural Research Systems (NARS) of the 7 Arabian Peninsula countries (6 GCC countries and Yemen) during the different implemented projects, resulted in developing and introducing more than six technology packages that address the major constraints to increasing water use efficiency to produce high-quality cash crops under protected agriculture, irrigated forages, and sustainable rangeland biomass.

The implementation of the present project "Improving agricultural production systems and conserving natural resources under climate change in the Arabian Peninsula" started in 2018 by a financial support from the Arab Fund for Economic and Social Development (AFESD). In 2019, the Kuwait Fund for Arab Economic Development (KFAED) has also approved, for the first time in the Arabian Peninsula Regional Program, co-funding the project proposal.

The project attempts to contribute to the national goals of the Arabian Peninsula countries through the development of more sustainable and resilient agricultural production systems, adapted to climate change, that enhance food security and reduce demands for imports.

The project efforts are to improve agricultural productivity without depleting water and soil resources while increasing the resilience of farmers and farming systems to climatic change and enhancing the capacity of these systems to sequester carbon and mitigate climate change.

This project consists of three major components:

1. Enhance National Agricultural Extension Systems (NAES) and Transfer of Technology Packages
2. Problem-solving Research and Impact Assessment
3. Capacity Building and Institutional Strengthening
4. Socio-economic benefits and impact assessments of the project targeted technologies

The present annual report highlights ICARDA and NARS joint activities and achievements during the period 1st January – 31st December 2019.

2. Enhance national agricultural extension system and Introduce and adoption the project technology packages

A major achievement of APRP are the proven technology packages for rangeland rehabilitation, irrigated forages, on-farm water management, and protected agriculture developed by ICARDA and its partners in the Arabian Peninsula (AP). These technology packages have positive impacts on the income and welfare of farmers in the region, and the management of natural resources, mainly water.

ICARDA and NARS in the seven AP countries agreed to out-scale four major technology packages, namely:

- Rehabilitation of rangeland through appropriate management techniques, water harvesting, re-seeding and controlled grazing along with monitoring techniques;
- Indigenous forage species with high water use efficiency and spineless cactus;
- Utilizing agricultural and agro-industrial by-products as alternative feed resources for livestock
- Soilless and Integrated Production and Protection Management (IPPM) under protected agriculture.

During the reporting period, ICARDA in collaboration with seven Arabian Peninsula (AP) countries developed 75 new pilot sites including 33 sites on irrigated forages and spineless cactus, 30 pilots on soilless production system and IPPM and 12 new pilot sites on utilizing agricultural and agro-industrial by products as alternative feed resources for livestock. The project also covered about 20,500 ha of rangelands for rehabilitation and management activities without considering the freely grazed areas (considered as controls) in Kuwait (Al Wafra), Saudi Arabia (Doumet Al-Jandal, Tabarjal, and Bsita) and Yemen (Al-Sudah, Al-Hajar, Al-Taimira, Lesagan and Al-Ruwaid in Lahej). Table 1 presents the number of new pilot farms, adopted APRP targeted technologies, during the reporting period.

Table 1- Project technology transfer Achievements in AP countries during January-December 2019

Countries*	Targeted technology packages											
	Irrigated forages and spineless cactus			Soilless and IPPM packages			Feed block production			Rangeland Rehabilitation and management		
	2019	2018	Total	2019	2018	Total	2019	2018	Total	2019	2018	Total
Bahrain	-	-	-	-	-	-	-	-	-	-	-	-
Kuwait	-	-	-	8	5	13	-	-	-	1 site (40 ha)	1 site (40 ha)	1 site (40 ha)
Oman	6	2	8	5	3	8	-	-	-	-	-	-
Qatar	6	8	14	1	1	2	-	-	-	-	-	-
KSA	11	-	11	6	-	6	-	-	-	11 sites (more than 400 ha)	3 site (more than 100 ha)	11 sites (more than 400 ha)
UAE	2	-	2	2	-	2	-	-	-	-	-	-
Yemen	8	10	18	8	12	20	12	8	20	5 sites (20,000 ha)	5 sites (20,000 ha)	5 sites (20,000 ha)
Total	33	20	53	30	21	51	12	8	20	17 sites	9 sites	17

**Data concerning Bahrain for 2019 are missing*

2.1. Promote an integrated production system for indigenous forage species with high water use efficiency and spineless cactus to farmers

In **Yemen**, despite the insecure situation and energy generation problems, five new pilot farmers introduced indigenous irrigated forages including buffel grass (*Cenchrus ciliaris*) and a perennial herbaceous legume, the butterfly pea (*Clitoria ternatea*). The production records of Clitoria are very promising at the pilot farms. The fodder is considered suitable for growing under the irrigated system in the southern coastal plain of Yemen condition, where the water productivity reached to 11.6 - 12 kg/m^3. Moreover, three new pilot growers adopted spineless cactus as a forage crop. In each pilot site, six different cactus accessions were planted to investigate their adaptability to the farmers' situation in Yemen (table 2).

Table 2- Spineless cactus sites developed during 2019 in Yemen

No.	Name of the Farmer	Location	Date of Planting	Irrigation Method
1	Ameen Qais	Hamadan, Sana'a	12 February	Surface
2	Ahmed Othreb	Bani Alhareth, Sana'a	24 February	Surface
3	Abdullah Al-Hagawai	Alqabel, Thahaban	4 April	Drip
4	Livestock Res. farm	Lahej	30 June	Surface

Figure 1- Clitoria field in a pilot farm in Lahej, Yemen

In **Oman**, six new pilot growers adopted Buffel grass and hence the total number reached 50 growers. Despite the problem of seed availability of this species, it is being adopted by neighboring growers through farmer-to-farmer extension system thanks to its higher water productivity compared to Rhodes grass. The estimated dry matter yield data showed encouraging results with the yield varying from 16.0 to 23.1 t/ha/year with an average of 19.0 t/ha/year among the pilot growers. The number of cuts ranged between 10 and 11 per year. Good Agricultural Practices (**GAP)** for *Cenchrus ciliaris* were demonstrated to the surrounding farmers through farmers' field trials during periodic visits with regard to sowing, planting, irrigation, and harvesting for forage and seed during the year. *Cenchrus ciliaris* has been recommended for fodder cultivation in Oman since 2008 instead of Rhodes grass. The only problem is the very low rate of germination which constitute a major constraint to upscale its cultivation. Study continued on seed production and germination in Oman with ICARDA support. Two seed production scientists from ICARDA have visited Oman and UAE on March 2019 and collected buffel grass seeds to test and improve their germination capacity.

Figure 2- Pilot growers adopt Buffel grass in Oman

In **Qatar**, three (3) new pilot growers adopted the irrigated forages while spineless cactus accepted in another 3 pilot farms. A total of 20 growers adopted spineless cactus so far.

Figure 3- Two pilot growers in Qatar

2.2. Rehabilitation of rangeland through appropriate management techniques, water harvesting, re-seeding, grazing along with monitoring techniques

Following the great success of the rehabilitation operation conducted in Yemen during the previous phase (2014-2017) at a pilot rangeland site both on the density and productivity of the native plants as well as on the survival and growth of the introduced plant species, during 2019 this technology has been transferred to five new rangeland sites covering about 4,000 ha area each. These five sites (Al-Sudah area in the west, Al-Hajar in the south, Al-Taimira in the east, Lesagan in the north and Al-Ruwaid area in the middle) are in two districts of Al-Mallah and Al-Habeelin in Lahej Governorate. At each site, two different water harvesting shapes (crescent and furrows), depending on the land slope, were established. *Panicum turgidum* and *Cenchrus ciliaris* are two native grass species planted in May 2019 within these management structures. These sites will be subjected to appropriate rangeland management strategies on the basis of the site carrying capacity and the period of grazing. Table 3 shows the improvement of the plant density in five different rangeland sites with two water harvesting techniques between June (just after establishing the water harvesting techniques) and September 2019. The number of plant species in crescents and furrows increased by 45% and 39% respectively.

Table 3- Evolution of the plant density (individuals/m^2) between 25 September and 25 June 2019 in relation to the shape of the water harvesting technique in the 5 rangeland sites.

Rangeland site	Furrows		Crescents	
	25 June	**25 September**	**25 June**	**25 September**
Al Rowid	1.57	2.34	2.13	3.50
Lasjan	2.24	2.65	2.73	3.40
Al Soda	6.6	1.08	1.08	1.42
Al Hajar	2.65	3.79	3.46	5.10
AL Saimara	9.6	1.42	1.49	2.41

Figure 4- Rehabilitation activities in Yemen

In **Saudi Arabia**, 11 new pilot private degraded rangeland sites, of a total area of 240 ha, were subject to rehabilitation by setting up crescent and furrow water harvesting techniques and introducing several native range species selected based on the adaptive performances they show in the previous rehabilitation trials. The range species include: *Artiplex leucoclada, Haloxylon salicornicum, Anabasis stifera*, *Salsola tetranda, Traganum nudatum* and *Salsola villosa.*Farmers were fully involved in the rehabilitation operations and the protection of the sites. Only species seeds have been provided by the project.

As it was the case of Mr. Hamdan Al-Hassan rangeland site in Saudi Arabia in 2018, considerable emergence and growth of annual species was observed within the crescent shape in the spring of 2019 compared to the control (no water harvesting structure). This is explained by the role of these crescents in collecting these seeds and in their emergence due the higher soil moisture once rains occur. However, very low rates (about 10%) of establishment of seedlings of *Salsola tetranda and Traganum nudatum* have been registered compared to the other species that reached about 72% in average.

2.3. Establish demonstration sites for feed block production

In **Yemen**, a manual press prototype was developed for producing feed blocks from agricultural by-products. The feed block techniques adopted by 12 pilot farmers during the reporting period and reached 28 pilot farmers in total who adopted this technology since the beginning of the project in 2018. Four on-the-job training courses and field schools were held on 9 April, 13 April, 2 May and 15 July in Lahej Governorate where more than 146 livestock breeders, including large number of women attended these events. A technical field guide was developed and disseminated.

Figure 5- On the job training course for farmers on feed block in Yemen using local by-products and manual press

During the training programs, participants, composed mainly of women, produced more than 100 feed blocks with four different formulas. The analysis of the chemical composition of these formulas shows that the protein content varies between 13 and 36 %. The cost of production of each feed block calculated between 0.5 to 0.7 US$ based on different composition.

2.4. Introduction and adoption of soilless and IPPM packages

In 2019, more than 30 new pilot growers adopted the soilless production system and IPPM packages all around the Arabian Peninsula countries. In **Oman**, five new pilot growers adopted the IPPM and soilless production techniques for cucumber during the reporting period. This included one pilot on Root Zone Area (RZA) cooling. After the successful research on cooling of the nutrient solution the system will now be transferred to farmers. The pilot farmer was assisted with cooling materials and seeds, fertilizers and pesticides. The plantation of cucumber took place in July 2019. The yield and water productivity recorded as high as 19.9 kg/m^2 and 142.8 kg/m^3 respectively.

Figure 6- Pilot growers' fields in Oman

In **Yemen**, four new farmers adopted IPPM techniques during the reporting period. NARS in collaboration with ICARDA scientist provided technical backstopping. Also, in Yemen, the soilless production system was adopted by three new pilot growers. This could be explained by the benefits of this technology compared to control units since an increase of the net income by three times was recorded in 2018 in the 25 pilot farms that adopted soilless production system.

Figure 7 - Field days on IPPM techniques in Yemen

Figure 8- Simple soilless production system in Yemen using available materials

Comparing to conventional soil system, the soilless (hydroponics) production system is generating more income for the growers. The following figure shows and compares the income of tomato crop in two growing systems per square meter of greenhouse at the 12 pilot farms in Yemen. Soilless system increased income by 40% compared to soil-based production system

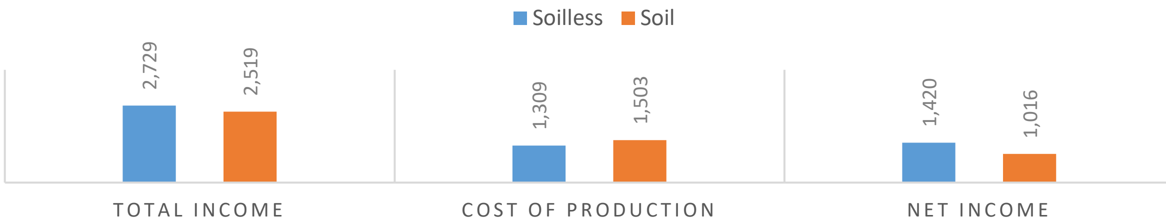

Figure 9- Comparing total income, cost of production and net income (YR/m^2) between soil and soilless system in Yemen 2019

In Kuwait, 8 new pilot growers adopted the soilless production system. The recorded mean yields of tomato and cucumber crops were 12.66 and 13.39 kg/m^2 respectively during the reporting period, an increase of about 52 and 63% compared to the yields, the same growers recorded before adopting hydroponics.

Figure 10- Pilot farms in Kuwait

In Qatar, one new pilot growers adopted the soilless production techniques using closed system with perlite as media for cucumber crop.

Figure 11- High quality tomato crop with soilless production system at farmers field in Qatar

In UAE, 2 new pilot growers adopted the IPPM and soilless growing techniques. Thanks to the fruitful collaboration between the Ministry of Climate Change and Environment (MOCCAE) and ICARDA-APRP, the actual number of growers, who adopted the technology through farmers to farmers extension and MOCCAE supports (subsidies) exceeds 1,500 farmers since the establishment of the program.

Figure 12- Appling IPPM and Soilless culture techniques in private farms in UAE trough farmers to farmers extension system and support of MOCCAE

In **KSA**, 6 new pilot growers adopted the IPPM techniques. The growers benefited from NARS researchers' regular visits and recommendations related to irrigation and fertigation management, plant density, using dabble doors and covering greenhouse ventilations with insect-proof nets.

3. Problem-solving research

3.1. Collection mission for indigenous plant species

In **Oman**, previously two missions were conducted jointly with ICARDA: the first one in 1998 where 68 seed accessions of both forage and pasture species were collected from the northern governorates of Oman; and the second one in 2002, where 23 seed accessions of both forage and pasture species were collected from the mountains of southern (Dhofar) governorate. These accessions are conserved in the facilities of Seed and Plant Genetic Resources Lab. Due to the exceptional wet season, the activities of collection and conservation of indigenous rangeland species were also conducted during 2019.

Figure 13- Collection mission in Qatar

In **Qatar**, seeds of 6 promising grass species were collected. These seeds were cultivated in Rawdat Al Faras Research Station for multiplication.

In **Kuwait**, research activities were carried out on identifying indigenous medicinal and aromatic plant species. The study aims at developing a data base which will include:

- List of the native medicinal and aromatic plants (MAPs) in Kuwait

- Map of the geographical distribution of the most important MAPs
- Identifying the traditional use and the active compounds of the AMPs and their potential use to treat known diseases;
- Possibilities of promoting the valorization of the AMPs and linking to the markets.

3.2. Establish Buffel grass field for seed production

No agronomic evaluation studies have been conducted in **Oman** on Buffel grass (*Cenchrus ciliaris* L.) before ICARDA-APRP. Under ICARDA-APRP, more than 50 on-farm trials were conducted in the last five years. The on-farm productivity was found to range from 9 t/ha/cut to 12 t/ha/cut. In view of the above, a Buffel grass field for seed production was established in Oman to evaluate and select seed production methods to be recommended for expanding the adoption level. Within this framework, two ICARDA seed production scientists visited Oman and UAE in March 2019 and started working on improving the germination capacity of the buffel grass seeds in collaboration with national researchers. This aims at overcoming the constraints of adopting this native forage species by farmers and its cultivation at a larger scale.

3.3. Long term effect of treated wastewater on heavy metal accumulation in Buffel (*Cenchrus ciliaris*) and Rhodes (*Chloris gayana*) grasses and soil chemical properties.

This study started two years ago and is still being continued in **Oman**. Buffel grass (*Cenchrus ciliaris*), which is indigenous to AP, has been identified to have higher water productivity than other fodder crops grown in AP (MAF 2005/2006, ICARDA/ APRP, 2003-2005). In all previous studies, Buffel grass produced the highest dry matter under all tested irrigation levels and had the highest WUE compared to other indigenous grasses including Rhodes grass (Osman 1979, Osman et. al. 2008, and Mazahrih et al. 2016). Treated wastewater has become one of the most important non-traditional sources of water that can be utilized in agriculture, especially for fodder production. Previous studies indicated that irrigating seasonal fodder crops with tertiary treated wastewater increased production by 20 to 30% (MAF, 2009) without any accumulation of heavy metal in both fodders and soil. In this experiment, both Rhodes and Buffel grasses will be analyzed for long term effects of treated wastewater irrigation.

Plant and soil samples are being collected twice per year (June and December). Samples were collected from plants and soil on irrigated with tertiary treated wastewater (TWW) and non-irrigated fields on 15 May 2019. Samples of soil and water were analyzed for heavy metals accumulation in Buffel and Rhodes grasses and for soil chemical properties. The results compared with last year's analysis to determine the effects of using tertiary treated wastewater on the accumulation of heavy metals in water, soil and plant are presented in tables 4, 5 and 6 and figures 14 and 15.

The results indicated that heavy metals (Lead, Cadmium, Copper, Chromium, Nickel and Zinc) were not detected in the treated wastewater.

Table 4- Heavy metals concentration (ppm) in the treated wastewater used for irrigation in 2019.

Metal concentration (ppm)	Lead Pb	Cadmium Cd	Copper Cu	Chromium Cr	Nickel Ni	Zinc Zn
Water analysis	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Maximum Permissible Limit (MPL)	5.00	0.01	0.20	0.10	0.20	2.00

Soil Samples: The results showed that Lead, Cadmium and Copper, were not detected in the soil in 2017 and 2018, whereas Chromium and Zinc were found below Maximum Permissible Limit (MPL).

Table 5- Heavy metals concentration (ppm) in the soil at depths of 30cm and 60cm.

Season	Soil Depth	Lead Pb	Cadmium Cd	Copper Cu	Chromium Cr	Zinc Zn
2017	0-30cm	<0.01	<0.01	<0.01	<0.00	2.49
	30-60cm	<0.01	<0.01	<0.01	<0.01	5.38
	Control 0-30 cm	<0.01	<0.01	<0.01	<0.01	4.57
	Control 30-60 cm	<0.01	<0.01	<0.01	<0.01	2.97
2018	0-30cm	<0.01	<0.01	<0.01	<0.01	3.33
	30-60cm	<0.01	<0.01	<0.01	<0.01	2.85
	Control 0-30 cm	<0.01	<0.01	<0.01	<0.01	1.49
	Control 30-60 cm	<0.01	<0.01	<0.01	<0.01	1.62
Maximum Permissible Limit		100.0	3.0	100.0	100.0	300.0

Plant samples: The results indicated that Lead and Cadmium were not detected in both Buffel and Rhodes grasses in 2017, 2018 and 2019, whereas Nickel and Zinc were found below the Maximum Permissible Limits from human standard.

Table 6- Heavy metals concentration (ppm) Buffel and Rhodes grasses irrigated with tertiary treated wastewater. Control: Buffel and Rhodes grasses irrigated with fresh groundwater.

Season	Grass	Lead Pb	Cadmium Cd	Copper Cu	Nickel Ni	Zinc Zn
2017	Buffel	<0.01	<0.01	<0.01	5.47	2.60
	Rhodes	<0.01	<0.01	<0.01	5.90	4.10
2018	Buffel	<0.01	<0.01	<0.01	4.38	4.06
	Rhodes	<0.01	<0.01	<0.01	4.38	1.14
Mid 2019	Buffel	<0.01	<0.01	1.27	6.11	24.28
	Rhodes	<0.01	<0.01	1.10	4.27	23.63
Control	Buffel	<0.01	<0.01	2.22	3.54	15.53
Control	Rhodes	<0.01	<0.01	1.12	4.71	10.41
Maximum Permissible Limit		0.3	0.2	73.0	67.0	100.0

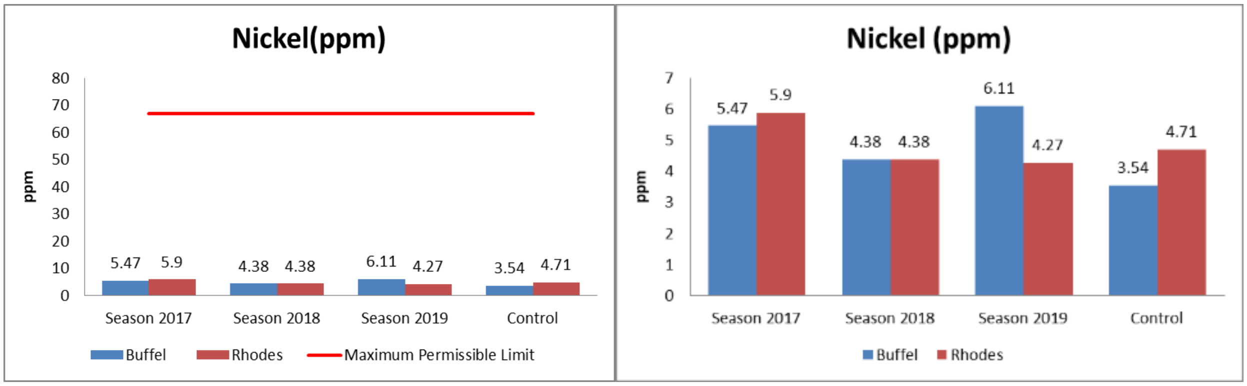

Figure 14- Nickel concentration (ppm) in both Buffel and Rhodes grasses in 2017, 2018 and 2019

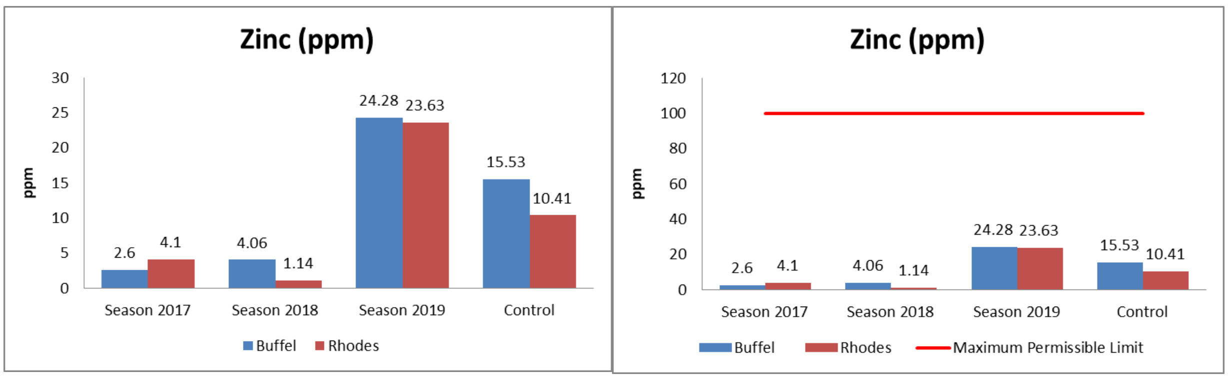

Figure 15- Zinc concentration (ppm) in both Buffel and Rhodes grasses in 2017, 2018 and 2019

3.4. On-farm trial on rangeland rehabilitation in Saudi Arabia

An area of 2 hectares (100 x 200 m) within the farm was selected. Contour lines were made 30 cm high and 8 m between the line. The site was planted with a mixture of grass seeds suitable for animal feed. At seedlings stage, an additional irrigation rate of 30 liters per seedling was provided. The project team contributes only by seeds and provides technical assistance to the farmer regarding the management including the carrying capacity and the period of grazing.

In another site, a drip irrigation network was established in an area of 2 hectares (100 x 200 m) to accommodate about 2,222 shrubs. Shrubs (*Atriplex leucoclada, A. halimus and Salsola villosa*) were planted with 3m distance between individuals. The shrub ponds were designed in the form of an open crescent perpendicular to the tilt to take advantage of the rainwater. Supplementary irrigation was provided during the dry seasons. All the fees related to this operation are covered by the farmer. Growth of shrubs was very good during the spring and summer of 2019 with a success rate of 80% establishment but was affected by the end of summer drought. The mean biomass production was estimated at 2,000 kg/ha dry matter, would be considered good under these conditions.

The aim of this experiment is to obtain cheap animal feed at the lowest cost, either by direct grazing of the cultivated range plants combined with the use of agricultural farm residues or cutting wild plants and animal feed. Al-Naimi sheep were introduced for direct grazing in the fields of the experiment (April 1st to July 30th) each year.

3.5. Rangeland rehabilitation and water harvesting techniques

In Yemen, on-farm rainwater harvesting techniques were demonstrated and monitored in degraded rangelands at Al-Mallah and Al-Habailin-Lahj. The aim of this activity is to disseminate the on-farm water harvesting technique using two geometric shapes (crescent and furrow) to rehabilitate the degraded rangeland by reintroducing native palatable grass species. This activity was carried out in in five rangeland sites (Al-Sudah area in the west, Al-Hajar in the south, Al-Taimira in the east, Lesagan in the north and Al-Ruwaid area in the middle). The activities include:

- Five pastoral sites were selected in the entire area (Al-Sudah area in the west, Al-Hajar in the south, Al-Taimira in the east, Lesagan in the north and Al-Ruwaid area in the middle.)
- The two treatments were randomly distributed, and some urgent interventions were carried out for the purpose of rehabilitating the pasture by cultivationg *Panicum turgidum* and *Cenchrus ciliaris*.
- Conducting periodic field visits every 15 days for data collection by monitoring the emergence of seedlings and their survival.

3.6. Evaluation of Clitoria production and water productivity under different irrigation levels in the Arabian Peninsula

Clitoria (*Clitoria ternatea L.*) is known as a drought tolerant fodder crop that has good nutritional value, high dry matter yield, and high-water use efficiency (ICARDA, 2016). It is an herbaceous perennial legume. It is also a multi-purpose species since different parts of the plant are also utilized in medicinal and culinary purposes. Clitoria is mostly recommended to replace alfalfa as a source of protein with higher water use efficiency. Due to the small size of most of fields in the AP, herbs were cut and carry.

In **Qatar** and **UAE**, fields for the cultivation of Clitoria (butterfly pea) were established at Rawdhat Al-Faras (Qatar) and Al-Dhaid (UAE) Research Stations for two seasons. Both experiments aim at evaluating the productivity and nutritive value of Clitoria and studying the possibility of success of Clitoria as alternative source of protein forage under the environmental conditions of the region. The preliminary results, under analysis, are very promising.

In **UAE**, water productivity of Clitoria is i being studied in a randomized complete block design with 60%, 80% and 100% Et_0 irrigation level. The primary results of forage yields show that 80% Et_0 showed the highest water productivity of 1 kg DM/m^3 with 10 cuts per year.

Figure 16- Clitoria experimental field in UAE

In **Qatar**, a field for the cultivation of butterfly peas (Clitoria) was established at Rawdhat Al-Faras Research Station. The preliminary results indicate about 7 cuts per year and 0.575kg DM/m^2 per cut, about 40 t/ha/year.

Figure 17- Clitoria experimental field in Qatar

In **Oman**, an experiment started in September 2019 in order to evaluate water productivity of Clitoria as compared to Alfalfa, the most widely grown perennial legume in Oman. This experiment is conducted in a factorial randomized complete block design with four replications (Blocks). It consists of two forage legume species (Clitoria and Alfalfa) subject to four irrigation levels (40, 60, 80, 100% of ET_0). Evapotranspiration (ET_0) is calculated using CROPWAT program using local climatic data and FAO crop factor (Kc). Both fodders will be irrigated using drip system. Yield parameters is collected at each harvest for both fodders. Soil moisture is monitored using sensors located at three depths.

3.7. Study on 13 varieties of heat tolerance barley genotypes

In **UAE**, the study of 13 barley heat tolerant genotypes was completed. Five (5) varieties showed better adaptation to the harsh environmental conditions and high performances in most scored parameters including seed production (figure 18). These genotypes have been selected to test their tolerance to irrigation water salinity. The study started in 20 November 2019 and results will be presented in the next annual report (figure 20).

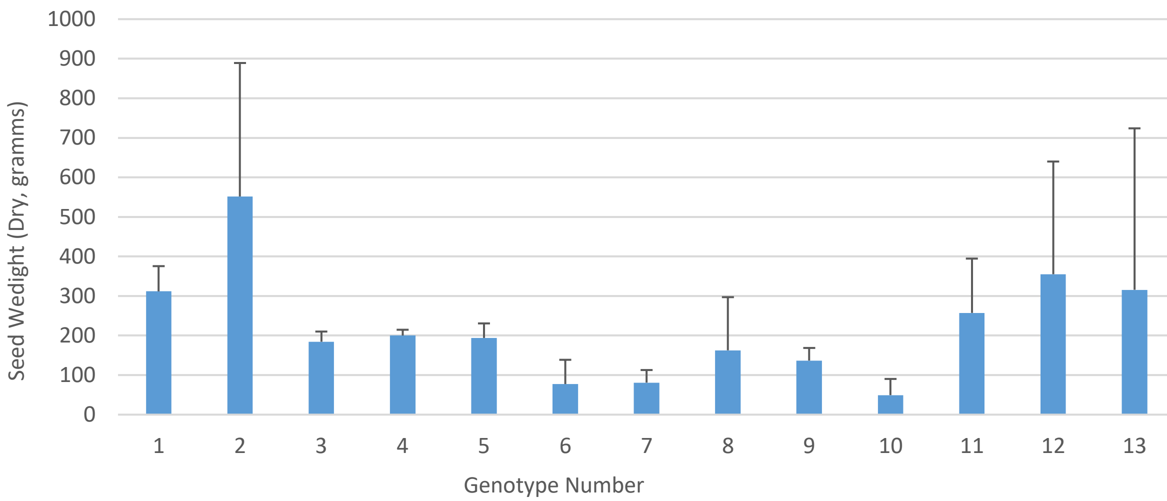

Figure 18- Seed Yield (Dry, grams) of 13 barley varities in UAE

Figure 19- Study on 13 heat tolerant barley genotypes in UAE

Figure 20- Study the effect of salinity level on five Barley varities with the highest yield (Nov 2019)

3.8. Comparative study of the productivity of local and exotic Buffel grass in Riyadh, KSA

The study aims to compare the productivity of local and exotic Buffel grass under the environmental conditions of Riyadh region in **KSA.** At the start, the chemical and physical properties of the soil were analyzed in addition to a sample of irrigation water. On 31st March 2019, the first field was planted with exotic (African) seeds obtained from ICARDA, while the second field was planted with local seeds, which were collected from the seed multiplication site in Bsita originally collected from natural environments in the Al-Jouf region. An area of 110 m^2 was allocated to each field. Drip irrigation was installed with 10 lines of 20 m each and 50 cm distance between both lines and plants. The field was irrigated at a rate of 10,000 m^3/ha/year. The following characteristics will be studied: number of cuts, biomass, plant length, spike length, dry and protein content. The study is in progress and Table 3 presents some results from the first harvest in June 2019.

Table 7- Comparison of exotic and local Buffel grass in Riyadh, KSA (first harvest at June 2019)

Variety	Yield (kg DM/m^2)	Plant length (cm)	Spike length (cm)
Local	0.664	68.2	9.0
Exotic	0.890	69.8	9.6

3.9. Effect of salinity of soil and irrigation water on the growth of five spineless cactus accessions in Yemen

The aim of this study is to test the effect of soil and water salinity on the growth and productivity of five spineless cactus accessions in **Yemen** (table **8**).

Table 8- The spineless cactus varieties used in the salinity study in Yemen

The spineless cactus varieties are the following:	Country of origin	Genetic number
29	N/A	74112
28	New Mexico	74111
26	Morocco	74054
21	Tunisia	73062
8	Italy	69233

To implement this study, three fields with different levels of salinity content in soil and irrigation water, were selected. Two fields were located in Bir Jaber and the other field in Bir Fadl in Lahj Governorate. Soil and irrigation water samples from these fields were collected and analyzed at Nasser College of Agricultural Sciences at Aden University. Table 9 shows salinity levels in soil and irrigation water in the studied fields.

Table 9- Salinity levels in soil and irrigation water in the studied fields.

Field	Samples	Ec, mS/cm	pH	Level of Salinity
North of Beir Gaber	Irrigation Water	4.628	7.54	Very high
	Soil: 0-30 cm	8.5	7.72	Very high
	Soil: 30-60 cm	2.219	8.07	High
South of Beir Gaber	Soil: 0-30 cm	9.8	8.18	Very high
	Soil: 30-60 cm	3.004	8.04	High
Beir Fadhel (Control)	Irrigation Water	1.96	6.74	Low
	Soil: 0-30 cm	0.33	8.23	Low
	Soil: 30-60 cm	0.323	8.35	Low

During the month of April, the land was prepared for planting. The first and second fields were planted on 1st May and the third field was planted in 20 May. Irrigation water was added for 8-10 days. In this experiment, split-plot design with three replications was used. The data clearly show that the growth of the spineless cactus' pads in experimental sites 1 and 2 with high salinity was negatively affected.

Figure 21- (left) Cactus field with high salinity 40 days after plantation and (right) spineless cactus growth in lower salinity field 32 days after plantation.

3.10. Study of Selected Native Medicinal plants of Kuwait

Kuwait is characterized by an extreme desert climate with extremely hot temperatures and scarcity of rain. In winter the temperature reaches below zero degrees while its over 50 degrees during summer period. Native plants have the ability to adapt to this desert environment, they can withstand drought and high salinity as well as extreme temperatures. This study aims at establishing Kuwaiti Medical Native Plants Database.

Objectives include:

- Start building a Data base of Kuwait Medical Native plants.
- Prepare a map of native plants of Kuwait.
- Analyze a selection (5-10 species) of medicinal plants to determine their chemical composition, effectiveness and treatment for specific diseases.
- Medical uses of the selected plants.

Activities have started and will continue throughout 2020.

3.11. Use of Coffee Grounds residue as an Organic Method to Help Increase the Yield of Lettuce (Latuca spp.)

In **Kuwait** a study is being carried out on the use of coffee residue as organic fertilizer. Kuwait imported 6,213 tons of unroasted and not decaffeinated coffee beans in 2017 (Factfish 2017). Most of the coffee residues were wasted in garbage bags and sent to landfills. The amount of nitrogen from residue of coffee grounds lost to landfills is estimated to be about 93,000 kg N. This is a major loss of a resource that not only can provide additional nutrients to poor soils in Kuwait but also increase water holding capacity and help reduce the pH (Hardgrove, 2016). The focus of the study is to test different concentrations of coffee grounds on lettuce crops and utilize different methods of application by mixing coffee grounds in the soil as a liquid fertilizer. The growth, yield and change in soil chemical properties are the main variables to measure the benefits of coffee grounds on lettuce plants. The preliminary results show promising improvement of lettuce growth. The study will continue in 2020.

3.12. Comparative study of the productivity of 5 commercial tomato varieties under hydroponics production system between cooled greenhouse and net house

In UAE, five commercial varieties of tomato were selected to study yield and water productivity under cooled greenhouse and net house. The selection was completed after interview with about 60 growers and commercial seed companied.

- Two greenhouse structures, one with polycarbonate (pad and fan cooling) and another with insect-proof net covers, were selected at Al Dhaid research station
- 5 x 5 Latin square factorial design was applied
- 20 plants per block, in total 100 plants for each variety in each greenhouse
- Tomatoes were transplanted in both greenhouses on 24 October 2018
- First harvest in both greenhouses was on 8 January 2019 ast harvest in the net house was on 30 March 2019
- Last harvest in the cooled greenhouse on 15 April 2019

The results show that there was no significant difference in tomato yield between the greenhouses This testifies that economically, it will be better for farmer to use the net house since it produced almost similar yield without using water and electricity for cooling, compared to the cooled plastic greenhouse with pads (figures 22, 23 and 24).

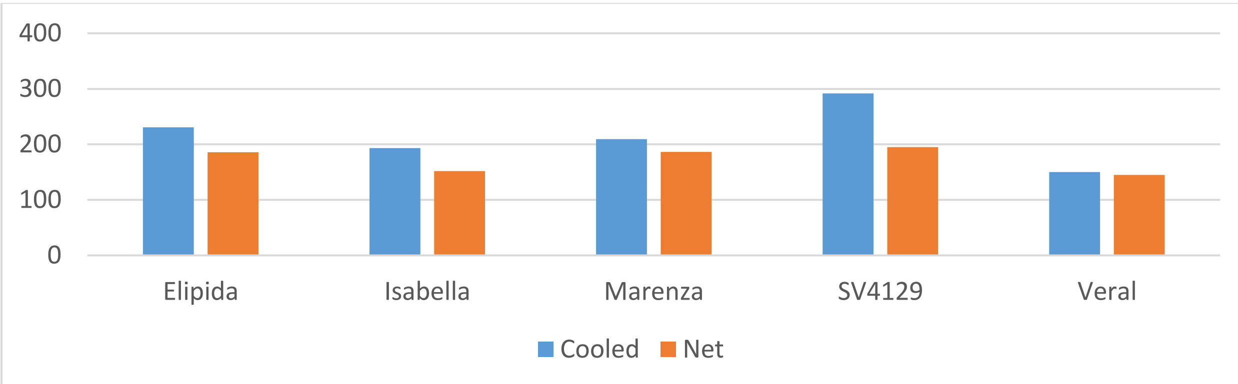

Figure 22- Total Yield (kg) of Tomato by tested commercial varieties in cooled greenhouse (pan and fan) and net house (January-April 2019)

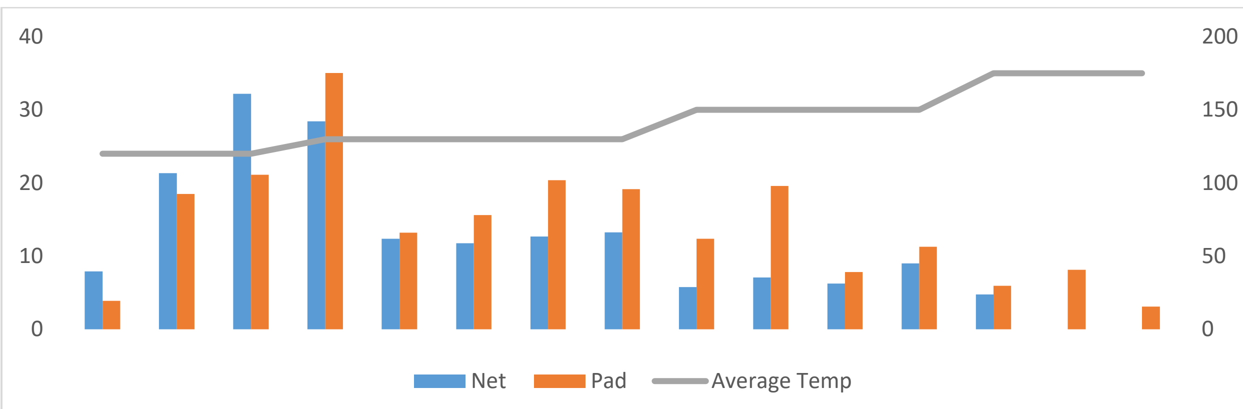

Figure 23- Variation of the total yield per harvest in cooled greenhouse and net house in relation to the daily average temperature

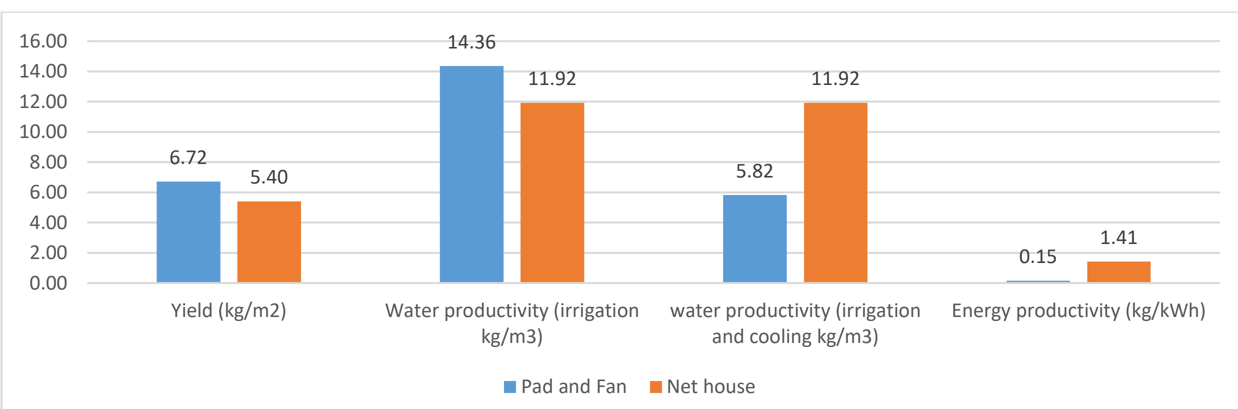

Figure 24- Variation of yield, water and energy productivity between cooled greenhouse and net house.

3.13. Comparative study of pepper, tomato and cucumber varieties under soilless production system in Qatar

In **Qatar**, different experiments were conducted to identify the best adapted and productive commercial varieties of pepper, tomato and cucumber available in the local market,.

Four varieties of pepper called Nice, Majester, Carina and Lido were planted on 25 October 2018 and the last harvest was at 22 May 2019. Figure 25 shows the average production of each variety. The ANOVA shows no significant difference between the varieties.

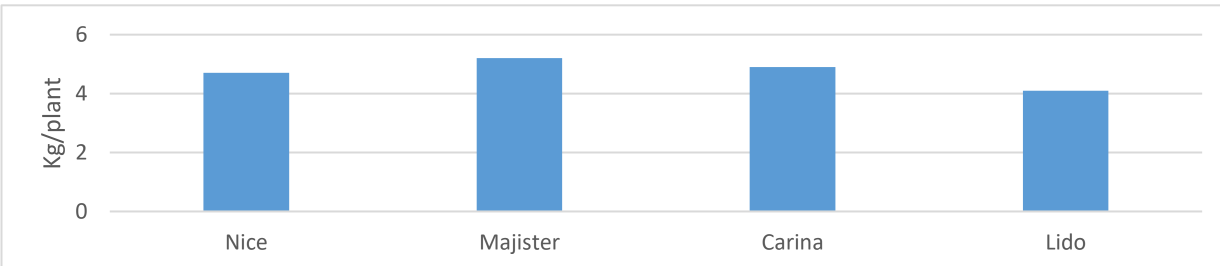

Figure 25- Average yield (kg) per plant for 4 pepper varieties in Qatar

Similar studies were conducted in Qatar on three varieties of tomato and four varieties of cucumber. The result is presented in figure 26. The ANOVA analysis shows that there is no significant difference between Barkat, Amle and SV129. However, the variety Tansim produced a significantly lower yield per plant (figure 26).

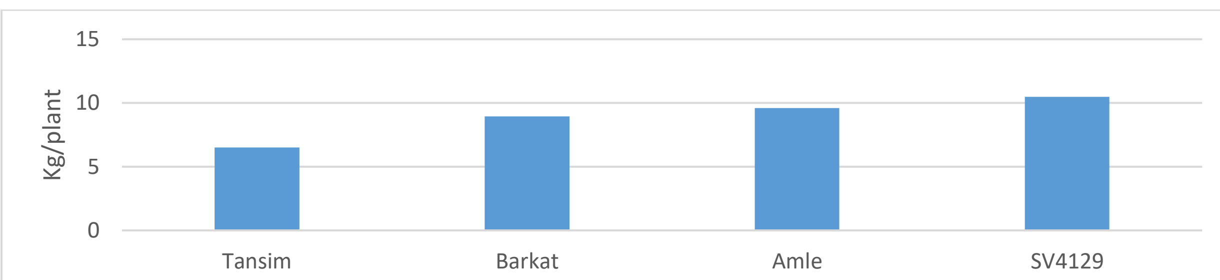

Figure 26- Average yield (kg) per plant for 4 tomato varieties in Qatar

Figure 27- Tomato and pepper crops in a greenhouse with soilless production system (Qatar)

The four cucumber varieties also showed no significant difference in yield. Figure 28 shows the average production (kg/plant) for the four cucumber varieties.

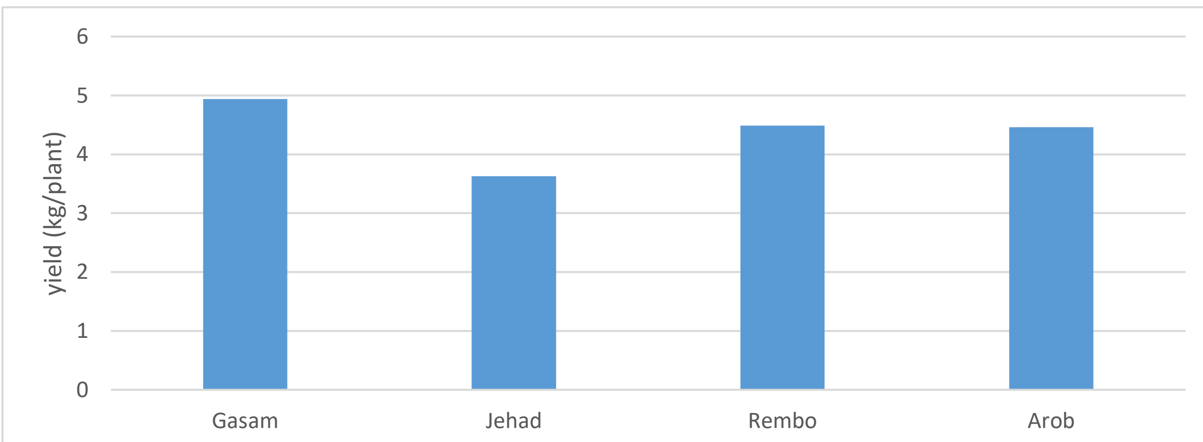

Figure 27- Average yield (kg/plant) cucumber varieties in soilless culture (Qatar)

Figure 28- Cucumber production with soilless production system in Qatar

3.14. Influence of different organic mulch on the growth of Zucchini (*Cucurbita pepo*)

The Arabian Peninsula is characterized by its high temperature throughout the year and low amounts of water available to plants. The use of techniques such as applying mulch has shown to be beneficial to help increase yield and water productivity of crops while also reducing salinity hazards inside and outside the greenhouse. Furthermore, the addition of organic mulch is crucial in controlling weeds in organic production systems. An experiment was conducted late 2019 in **Kuwait**, which uses different organic mulches that can be locally obtained. The organic mulches include shredded paper from offices, recycled cardboard, wood chips, shredded palm fronds, and palm fronds. Results will be presented in the next report.

3.15. Study of cooled nutrition for reducing plant root zone temperature in hydroponics production

In **Oman, Kuwait, Saudi Arabia** and **UAE** studies are being carried out on the effect of cooling the Root Zone Area (RZA) of plants under hydroponics production system through cooling the nutrient solution. This is a new development in the region as a result of a PhD student's study in Oman that was supported by ICARDA-APRP. Preliminary results are very promising for high quality production in the summer with less water when the RZA temperature remain at 25 degrees (figure30). The nutrient solution in the irrigation tank is chilled with an Air Condition compressor. The study was also conducted in Kuwait at three pilot sites on private farms.

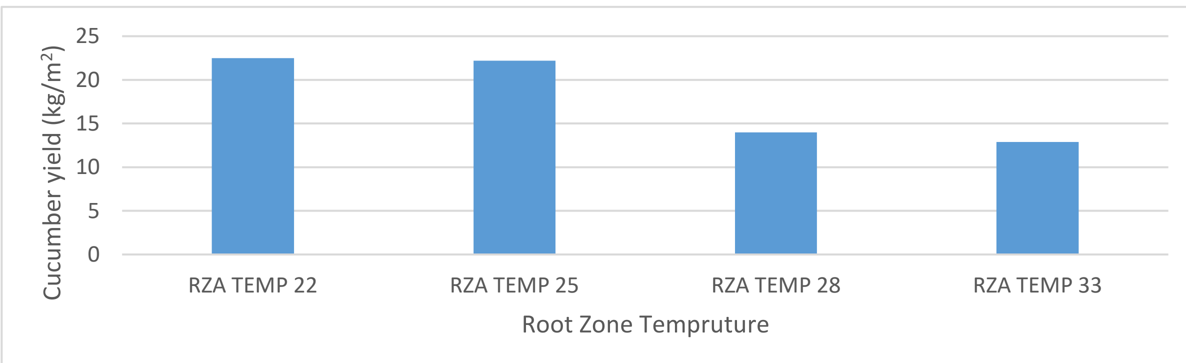

Figure 30- Summary production (June 2019) in Oman

In KSA, the study was conducted in one single span cooled greenhouse where two lines out of four were irrigated with cooled nutrient solution. For cooling the solution, the tank was placed inside the greenhouse beside cooling pad (figure 31). The average temperature in cooled and non-cooled solution during the study was recorded at 29 and 34 degrees, respectively. The study showed that irrigation with a cooled tank compared to a tank outside the greenhouse:

- reduced fungal infection.
- reduced water consumtion by 6% .
- increased production by 3%.
- increased total vegetative growth and crop quality. Dats on cost benefit are being coected for further study.

Figure 29- KSA study with irrigation tank outside and inside the greenhouse

3.16. Response of Ozone treatment on dissolved oxygen levels, growth and yield of cucumber crop grown under hydroponics in a cooled green house

The experiment was conducted in a cooled greenhouse (270 m^2) to study the response of ozone treatment and dissolved oxygen levels on cucumber production using soilless growing techniques (closed system) during February 2019 in Oman. Two feeding nutrient solution tanks were used, one with ozone treatment and without ozone treatment. One variety of cucumber was used, namely Kirton F1. Seedlings were transplanted on 11 March 2019. The treatments were arranged in complete randomized design with four replications. The medium used was perlite, which was filled in white polystyrene pots size (23 x 23 x 20 cm). The number of pots per plot was 25 and the number of plants in each pot were two resulting in 50 plants per plot. Plot size was 8.4 m^2 (1.2 m x 7 m). Automatic irrigation controller system was used to irrigate the plants, which was set to two minutes every five minutes from 7.00 am to 6.00 pm afternoon during the whole period of experiment. Three stock solutions, namely (SS1) containing Calcium nitrate 12 kg with iron chilate 50 g diluted in 40 liter of water, (SS2) NPK (12:12:36+TE) 12.5 kg and magnesium sulfate 6 kg diluted in 40 liter of water and (SS3) acid for balancing PH, were prepared to feed the plants through the feeding solution tank (400 gallon). The plants were fed by measuring the EC and pH of the solution in the feeding tanks, which started at EC 2ds/m and pH of 5.8. Through automatic intelligent hydroponic doser the EC of nutrient solution was increased as the plants were growing and reached to 3 ds/m at the end of the experiment. Harvest started after 20 days from the date of transplantation and fruits from both treatments were harvested every two days. Dissolved oxygen levels in feeding tanks, water uptake, first harvest, picking period (days), number of fruits/plots, and fruit weight kg/plot were taken and recorded.

The results presented in figure 32, emphasize the effect of treated nutrient solution with ozone on the dissolved oxygen levels with significant ($p<0.05$) differences between untreated nutrient solution. High levels of dissolved oxygen (DO) was with ozone treated nutrient solution at both time 8am and 12pm

6.4 mg/l and 5.8mg/l, while untreated nutrient solution gave less (DO) which was 5.8mg/l and 5.6mg/l .

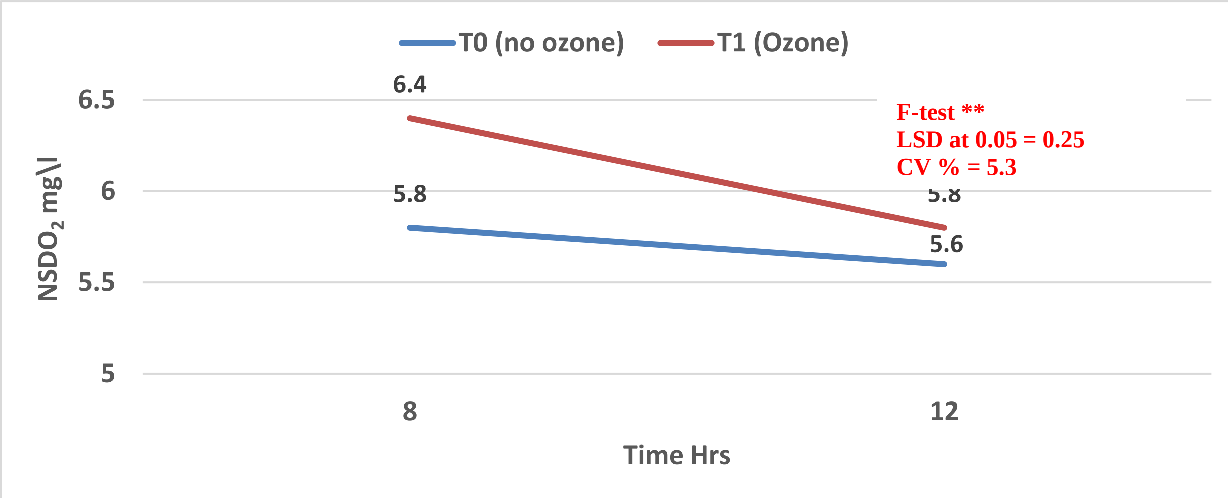

Figure 30- Effect of ozone treated and untreated nutrient solution on dissolved oxygen levels on cucumber crop grown hydroponically during spring period (February-May 2019) in greenhouse.

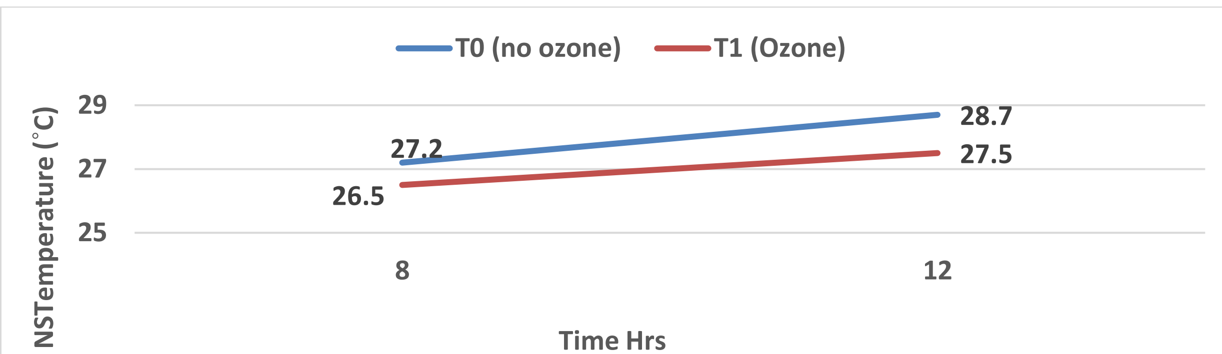

Figure 31. Temperature of ozone treated and untreated nutrient solution on cucumber crop grown hydroponically during spring period (February-May 2019) in greenhouse.

3.17. Evaluate the new cooling system and utilizing renewable energy

In **UAE**, ICARDA and the American University of Ras Al-Khaima (AURAK) continued research on a new cooling system for greenhouses during the hottest period of summer season (from August to September 2019). In this study, a spot (zone) cooling system was tested to reduce air temperature inside a model-sized greenhouse during the summer. A spot cooler duct provided cold air developed by a compact desert cooling using water evaporation and blown into the plant layer in the greenhouse. The air duct was flexible and raised gradually with the plant's growth (figure 34). The cooling system was designed to use 100% solar-based electricity, which is generated by the six panels beside the greenhouse. The study objectives were to reduce freshwater consumption for a greenhouse cooling system that can generate more than eight liters/day/m^2 of the greenhouse. Results showed that the cooling system could reduce the maximum air temperature at the cooled spot and lower layers to about 25-30°C while outside the cooled spots in the greenhouse the temperature reached to about 45-50°C (figure 35). First harvest was after 28 days with about 2.5 liter/day/m^2 of Greenhouse water use for cooling. This is about 60% less than what is used in a conventional cooling system of pad and fan.

Level 1 | **Level 2** | **Level 3**

Figure 34- Cooled air flexible duct on three levels; the duct moves up with plant growth

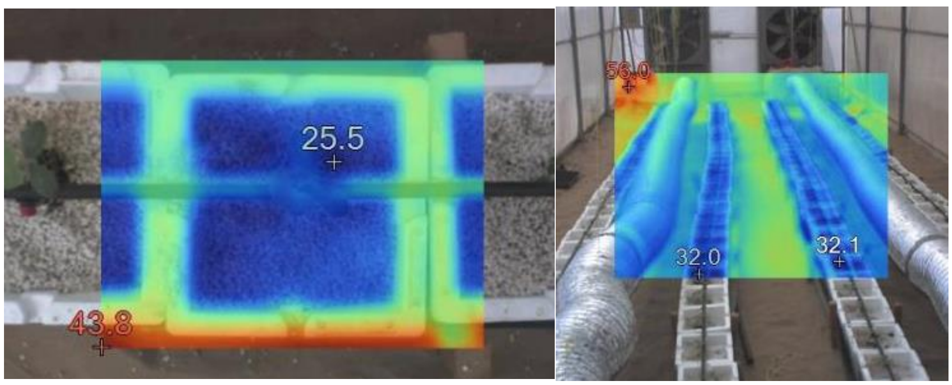

Figure 32- Temperature difference inside and outside the cooled spot

3.18. Inventory of crop residues in the southern coastal plain of Yemen

The aim of this study is to create an inventory of crop residues in Abyan Governorate in **Yemen** permitting to develop different formulas of alternative rations for livestock. This survey was carried out during 2019 in the Abyan Delta, which included 39 farms.The results showed that the total crop residues in Abyan are 55,076 tons/year. Bananas and sorghum provide the highest quantity of residues with 30.8% and 24.9% of the total crop residues, respectively.

4. Capacity Building

During 2019, ICARDA and its partners organized the project annual meetings of the technical and steering committee in Kuwait on 9-12 December. Furthermore, two regional training courses and a number of field days, workshops and seminars were held and moderated by ICARDA scientists in the different Arabian Peninsula countries. During these events, ICARDA scientists provided technical backstopping and hands-on training to more than 100 researchers, extension agents and growers from the region. The main events are described below.

Figure 33- Field day on Valorizing the agricultural by-products as alternative animal feed resources in UAE

4.1. Field days and workshops

During 2019, ICARDA scientists in collaboration with NARS organized 22 on-the-job practical training including workshop and field days for researchers, extension agents and growers in various AP countries where more than 250 participants attended this events. Table 11 presents the on the job, field days and workshop during 2019.

Table 11- Field days, workshops and on-the-job training courses in 2019

	Name	Subject	Date	Country
1	Dr. Azaiez Ouled Belgacem	Irrigated forage and rangeland rehabilitation	28-Feb	KSA
2	Dr. Ahmed Amri	Genetic resources management	23-Feb	Oman
3	Dr. Ahmed Moustafa	Protected Agriculture and its associated techniques	15-Mar	Oman
4	Dr. Azaiez Ouled Belgacem	Irrigated forage and rangeland rehabilitation	16-Mar	Oman
5	Dr. Abdulaziz Niane	Seed production unit and process	16-Mar	UAE
6	Dr. Ali Shehadeh	Seed production unit and process	16-Mar	Oman
7	Dr.Faouzi Chokri	Solar energy	16-Mar	Oman
8	Dr. Azaiez Ouled Belgacem	Irrigated forage and rangeland rehabilitation	18-Mar	Qatar
9	Dr.Abdulaziz Niane	Seed production unit and process	20-Mar	Oman
10	Dr.Ali Shehadeh	Seed production unit and process	20-Mar	UAE
11	Dr.Abdulaziz Niane	Seed production unit and process	9-Apr	KSA
12	Dr. Azaiez Ouled Belgacem	Irrigated forage and rangeland rehabilitation	21-Apr	KSA
13	Dr. Ahmed Moustafa	Protected Agriculture and its associated techniques	14-Jul	Kuwait
14	Dr. Azaiez Ouled Belgacem	Irrigated forage and rangeland rehabilitation	20-Jul	Kuwait
15	Dr. Ahmed Moustafa	Protected Agriculture and its associated techniques	18-Sep	Kuwait
16	Dr. Ahmed Moustafa	Protected Agriculture and its associated techniques	8-Oct	UAE
17	Dr. Muhi Eldin Hilali	Alternative feed resources and feed block	28-Oct	Kuwait
18	Dr. Azaiez Ouled Belgacem	Irrigated forage and rangeland rehabilitation	12-Nov	Kuwait

	Name	Subject	Date	Country
19	Dr. Azaiez Ouled Belgacem	Indigenous plant species	25-Nov	UAE
20	Dr. Azaiez Ouled Belgacem	Heat tolerance barley	25-Nov	UAE
21	Dr. Muhi Eldin Hilali	Alternative feed resources and feed block	17-Nov	UAE
22	Dr. Ahmed Moustafa	Protected Agriculture and its associated techniques	7-Dec	Kuwait

4.2. Regional training course on "Use of Renewable Energy in the Management and Cooling of Hydroponics Nutrient Solution ", Muscat, Oman: 17-20 March 2019.

Figure 34- A view from the opening ceremony of the regional training course on "Use of Renewable Energy in the Management and Cooling of Hydroponics Nutrient Solution", 17-20 March 2019.

ICARDA-APRP held a regional training workshop on the "Use of Renewable Energy in the Management and Cooling of Hydroponics Nutrient Solution" on 17-20 March 2019 which was attended by 28 participants from all AP countries and ICARDA. The workshop took place in City Season Hotel in Muscat, Oman.

4.3. Regional training course on "Information and Communication Technology to Enhance Agricultural Extension Systems", Hammamet, Tunisia, 14-18 October 2019

The main objective of the current project "*Improving agricultural production systems and conserving natural resources under climate change in the Arabian Peninsula (AP)*," is to address the challenges farmers arefacing in adopting these technology packages at a larger scale. To achieve this goal the current extension systems needs to be reviewed and improved. Introducing modern ICT techniques permitting to develop a Smart Extension Diary (SED) is one option to support the agrarian extension system for the dissemination of the project targeted technologies in the AP. The SED is an innovative and interactive extension system that is intended to provide the information required by extension staff during farm visits in an easily accessible format. The approach embodies three components:

- SMART stands for Specific, Measurable, Attainable, Relevant and Time-bound activities and objectives;
- The extension includes technology transfer and advisory assistance and

- Diary is an interactive digital system that provides access to a wide range of end-users.

This training workshop was a step forward to introduce different ICT models used in the world for agricultural extension and knowledge dissemination. Twenty (20) researchers and extension agents from seven AP countries and ICARDA participated in this event.

Figure 38- Participants at Information and Communication Technology to Enhance Agricultural Extension Systems workshop, Hammamet, Tunisia: 14-18 October 2019

4.4. ICARDA APRP annual regional meetings on December 9-12, Kuwait.

The 2nd regional annual Technical Coordination (TC) and Steering Committee (SC) meetings of the project "Improving agricultural production systems and conserving natural resources under climate change in the AP" were held in Kuwait during 9-12 December 2019.

Figure 35- A view from ICARDA-APRP annual meetings opening ceremony, front row from left: Mr. Abdullah Kh. Al-Musaibeeh, Regional Manager for Arab Countries Operation Department, KFAED; Dr. Jacques Wery, Deputy Director General-Research, ICARDA; Dr. Bandar Al Odaiani, Head of Consultancy office, GCC general secretariat; H.E. Sheikh Mohammad Al-Yousef Al-Sabah, Chairman and Director of PAAFR; Eng. Aly Abousabaa, Director General, ICARDA; Dr. Mansour Al Aqil, Chairman of Agricultural Research and Extension Authority, Yemen; Mr. Ahmed Eid Al Hadhoud, Senior Financial Officer, Agricultural Financial Portfolio, The Industrial Bank of Kuwait; and Dr. Abdul Aziz Abdul Kareem, Assistant Under Secretary for Agricultural Affaires, Ministry of Municipal Affaires and Urban Planning, Bahrain.

The meeting inaugurated under patronage of H.E. Sheikh Mohammad Al-Yousef Al-Sabah, Chairman and Director of PAAFR and started by Dr. Jacques Wery, ICARDA DDG-Research opening state when he welcomed all participants.

Figure 36- Two of the project pilot growers in Kuwait received certificates of appreciation from ICARDA-DG

Dr. Wery also delivered a presentation on ICARDA and desert farming which focused on science-based solutions for thriving, and resilient livelihoods in the dry areas. The next speaker was Dr. Azaiez Ouled Belgacem, ICARDA-APRP regional coordinator, who presented highlights of the project activities and achievements during 2019. Dr. Amal Abdul Karim, Agricultural Research and Experiment supervisor also presented a summary achievement of the project in Kuwait. Two of the project pilot growers in Kuwait were acknowledged and received certificatesof appreciation for their participation in the project's targeted technology dissemination.

Figure 37- Participants of ICARDA-APRP annual RTCM and RTCM opening, Kuwait 9-12 December 2019

More than 30 scientists, researchers, and growers from ICARDA, and seven (7) AP countries came together to exchange of information and ideas on the sustainable development of AP. The participants made about 20 presentations where they discussed and reviewed the research for development activities and experiences as well as state-of-the-art new technologies on rangeland rehabilitation, irrigated forages, water use efficiency, and protected agriculture. They also developed a work plan for 2020. The meeting also included a field visit to ICARDA-APRP project activities and pilot sites in Kuwait.

Figure 38- Field visit

Then later, on 12 December, the participants in SC meeting discussed the overall project progress, financial status, and research activities. SC members commended actions for the next season and approved a detailed work plan for the assigned activities for each country participating in the project. The meeting was attended by Mr. Abdullah Kh. Al-Musaibeeh and Dr. Abdulredha Bahman from Kuwait Fund for Arab Economic Development, as one of the project's donor representatives.

Figure 39- APRP SCM participants, 12 December 2019, PAAFR, Kuwait

5. Enhancing of ICARDA-APRP Technology Transfer and Technology Transfer Models in the Arabian Peninsula: Towards an Effective Technology Transfer Methods

This study examined the sources of information on improved agricultural technologies introduced by the ICARDA Arabian Peninsula (AP) regional program in the AP farming systems as well as the assessment of various agricultural technology transfer methods introduced used to enhance the adoption and widespread of these technologies. The research uses primary data collected from 87 extension agents from the Arabian Peninsula extension system. A descriptive statistic supported by Kendall's W-test and chi-squared distribution test is employed to identify and assess the effectiveness of the different technology transfer methods used by the AP extension system. To address AP extension agents perceived opinions and classify the changes from the use of the improved technologies, a qualitative approach based on the Likert scale was used.

Results show that mass media (video, posters, newspapers, mobile phone, radio, and video), farmers filed schools (FFS's) and neighboring farmers were perceived as the most effective agricultural extension methods to enhance the adoption of ICARDA-APRP introduced technologies, in particular, and the new agricultural innovations, in general. The assessment of the potential influential factors affecting the effectiveness of these transfer methods reveals also that each AP has its own context and both technology transfer methods and its affecting factors differ within countries. In summary, number of farmers per extension officer and categories of farmers; cost of extension methods; geographic location and the target farmers; age of extension officers; location and availability of extension offices; and leadership and supervision are found the most important factors. The study recommends empowering the national extension system through both conventional and technology-led approaches using ICT technologies and mass media (video and mobile phones) given the cost-effectiveness and their impact on the farmers adoption decisions.

For making the extension system more efficient in the AP region, the study recommends also the following: (i) Development of private advisory services to serve medium to large farmers or farmers association against direct payment; (ii) changing the extension policy toward more market orientated approaches; (iii) fostering farmers' organizations involvement in extension activities and financing and improving extension infrastructure and equipment; and (iv) Increasing number of extension agents, experts and subject matter specialist working in extension

6. Publications

- Dhehibi B., Nejatian A., Ouled Belgacem A. 2019. Adoption and Economic Assessment of Improved Technologies in ICARDA's Arabian Peninsula Regional Program, Working Paper. ICARDA.
- Al Wawi H.M., Al Yafei, M.S., Al Marri M., Louhaichi M., Ouled Belgacem A. 2019. Evaluation of morphological and chemical characteristics of spineless cactus pears under the environmental conditions of Qatar. in: Proc. IX Int. Congress on Cactus Pear and Cochineal: CAM Crops for a Hotter and Drier World Eds.: C. Sáenz et al., *Acta Hortic*. DOI 10.17660/ActaHortic.2019.1247. https://repo.mel.cgiar.org/handle/20.500.11766/10398
- Ouled Belgacem A., Nejatian A. 2019. Improving food security and sustainable natural resources management through enhancing integrated agricultural production systems in the Arabian Peninsula 2014-2019. ICARDA. International Center for Agricultural Research in the Dry Areas (ICARDA), Beirut, Lebanon. vi+81 pages. https://mel.cgiar.org/reporting/download/report_file_id/16343
- Mazahrih N., Nejatian A., Ouled Belgacem A. 2019. Status and prospects of protected agriculture in GCC countries, Book Chapter (unlocking the potential of protected agriculture in the GCC countries), draft published, final version expected early 2019. FAO, ICARDA, ICBA.
- Mazahrih N., Nejatian A., Ouled Belgacem A. 2019. Conclusion and recommendations for public and private sector decision-makers, Book Chapter (unlocking the potential of protected agriculture in the GCC countries), draft published, final version expected early 2019, FAO, ICARDA, ICBA. https://cgspace.cgiar.org/handle/10568/105758
- Ouled Belgacem, A., Louhaichi, M., Baltenweck, I. 2019. Opportunities and constraints in pastoral and agro-pastoral livestock systems: the ICARDA/ILRI experience. Presented at the Euro Tier middle east 2019 Conference, Abu Dhabi, 2-4 September 2019. https://cgspace.cgiar.org/handle/10568/105758
- Al Shamsi S., Oldbeziou A., Nejatian A. 2019. Utilizing biological control inside the greenhouse, UAEU Annual Research and Innovation Conference, 4-5 February 2020, United Arab Emirates University.
- Al Shamsi S., Ibrahim H., Al Mazrouie S., Naqbi T., Ono E., Nejatian A. 2019. Comparative study the productivity of 5 commercial tomato varieties under hydroponics production system with cooled greenhouse versus the net house, UAEU Annual Research and Innovation Conference, 4-5 February 2020, United Arab Emirates University.
- Dhehibi B., Nejatian A., Ouled Belgacem A. 2019. Adoption and Economic Assessment of Improved Technologies in ICARDA's Arabian Peninsula Regional Program, paper presented at Global Forum on Innovations for Marginal Environments, 20-21 November 2019 Dubai
- Hilali M., Nejatian A. and Ouled Belgacem A. 2019. Enhanced animal feeding using agricultural by-products and innovative technologies in the Arabian Peninsula, poster presentation, presented at Global Forum on Innovations for Marginal Environments, 20-21 November 2019 Dubai

7. Project work plan 2020

Reference is made to the project document and the technical committee meeting held in Kuwait on 9-10 December 2019, where the 2020 work plan was developed and discussed by researchers and scientists in different working group sessions. The project steering committee (composed of country national coordinators, donors (KFAED) and ICARDA) met in Kuwait on 12 December 2010 and reviewed and approved the project work plan for 2020. The main activities of this work plan are listed below under the different project outputs:

Output 1: Technology packages suitable for the Arabian Peninsula environment that increase crop and livestock production while conserving natural resources are developed, tested and verified.

Key activity 1: Rangeland rehabilitation, management, and monitoring

Activities	Country
Rangeland resources characterized and mapped for prioritization for rehabilitation and technological interventions	KSA: At Jouf Center, Kuwait: 1 location (Salmi Site) Yemen: 7 sites (hima)
Restoration and rehabilitation of degraded pilot rangeland sites	KSA: Management and rehabilitation Yemen: WHT, protection, etc.
Development and implementation of suitable participative management strategies at pilot rangeland sites	KSA (on farm) Yemen (at farm level) Kuwait (Salmi Site, 100 ha)
Comparing the agro-economic performance (including benefit-cost analysis) of the production of different irrigated forages in the region	All countries

Key activity 2: Indigenous irrigated forages and spineless cactus

Activities	Country
Collecting and identifying different forage species suitable for the region with heat tolerance and high-water productivity.	This activity is ongoing in the following countries: UAE, Qatar, Yemen, Oman, Kuwait
Testing and evaluating the productivity per unit of water and of land of different indigenous irrigated forage species and spineless cactus.	UAE, Yemen, Oman
Comparing the agro-economic performance of the various accessions for production of fodder and fruit in the region, with a particular focus on the impact of these accessions on markets and farmers' income.	Yemen
Use of treated wastewater for the production of perennial forage crops and spineless cactus.	Oman

Key activity 3: Protected agriculture and associated production systems

Activities	Country
Enhance net house design and evaluate the possibility of utilizing renewable energy sources for greenhouse irrigation and ventilation.	Oman, UAE, Kuwait, Qatar: comparing production under conventional cooled

Design, development, Enhance and testing of a new hydroponics production system including solution cooling.	greenhouse and net-house with root zone cooling. KSA: production of cucumber under net house. Yemen: compare production of vegetable crops under net house and greenhouse Bahrain, Oman, UAE, KSA: utilizing solar energy for irrigation system in greenhouse
Testing different production systems, including organic materials, and equipment to reduce investment and production costs.	Bahrain, Oman, Qatar: experiments on plant factory leafy crops Kuwait: organic mulch and fertilizer inside greenhouses (soil-based production system).
Socio-economic assessment and feasibility study of the methods developed.	Develop economic indicators and data collection instrument

Key activity 4: Integrated crop-livestock production systems (alternative feed resources)

Activities	
Conducting/completing a survey on available agricultural by-products (mainly from date palms and greenhouses) to be used as alternative feed resources.	Complete survey initiated in 2019. Yemen is almost complete
Socio-economic assessment and feasibility study of the methods developed for sustainable use of feed blocks/pellets in the target area.	Based on survey data (once completed) Business Plan on feed blocks (Yemen)

Output 2- Improved technology packages to increase crop and livestock production and productivity, increase water use efficiency while conserving natural resources, transferred to the end users.

Key activity: Transfer and disseminate the improved technology packages to increase crop and livestock production and productivity, increase water use efficiency and conserve natural resources.

	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	Emirates	Yemen	total
Rehabilitation and management of selected degraded rangelands (ha)	0	100	0	0	200[1]	0	280[2]	480
Introduce cactus and indigenous forages with valuable attributes (sites)	0	0	10[3]	4[4]	10	0	35[5]	64
Establishment of demon sites for feed block production	0	0	0	0	1	0	50	51
Introduction of soilless and IPPM packages to pilot growers	5	3	6	6	6	6	14	46

[1] Range rehabilitation & management
[2] Seven sites 40 ha each
[3] Eight buffel grass and 2 spineless cactus
[4] One Spineless cactus, 2 Buffel grass, and 1 Clitoria
[5] Spineless cactus 25 new pilot sites in 5 agro-ecological zone, and 10 sites for Clitoria

Output 3- Capacity of NARS and growers to adopt the project targeted technologies enhanced; Activities

Regional Trainings:

1. Water productivity (water requirement along with date palm project). It will be organized in Muscat, Oman.
2. Geoinformatics (data collection, dissemination, providing feedback to farmers), ICARDA Cairo
3. Regional Training: GH Management (IPPM, Water Management, Economic, Post-harvest), Kuwait

In country (on the job) training

1. Protected Agriculture: One or two visit per country based on budget availability
2. Kuwait: medicinal and aromatic plant analysis
3. Yemen
   a. Feed analysis (2)
   b. Field days on feed blocks (6)
4. Oman
   a. Conservation of forage seed, germination, viability, etc.
   b. Plant taxonomy (characterization, identification, etc.)
5. Bahrain: Recording, documenting, and maintaining the plant genetic resources in Kingdom of Bahrain
6. Kuwait: Rangeland assessing and management

8. Annexes

8.1. List of Participants-Use of Renewable Energy in the Management and Cooling of Hydroponics Nutrient Solution 17-20 March 2019.

1. Khalifa Ibrahim Al Amin, Bahrain
2. Mohamed Husain Al Jamri, Bahrain
3. Halima Al Balooshi, UAE
4. Tahra Al Naqbi, UAE
5. Arshed Kamal El Daly, UAE
6. Nour Saeed Al Nuaimi, UAE
7. Saeed Al Yammahi, UAE
8. Reem Ahmed Al Hazeem, Kuwait
9. Zamzam Moahmmad Al Hammadi, Kuwait
10. Waleed Al Abri, Oman
11. Khaled Ahmed Al Mugheiri, Oman
12. Ali Naser Al Jabri, Oman
13. Rashid Khalfan Al Shukili, Oman
14. Rahaf Salim Al Hajiri, Oman
15. Mohamad Ali Al Ghafri, Oman
16. Said Abdulla Al Abadi, Oman
17. Saud Abdulla Al Rasbi, Oman
18. Fahad Obaid Al Kaabi, Oman
19. Basim Bashir Bait Abaidoun, Oman
20. Mohammed salm albakre Al-yafei, Qatar
21. Hassan Ibrahim Al Asmakh, Qatar
22. Sanad AL Qahtani, Saudia
23. Hani Bomaheedi, Saudia
24. Khader Balem Atroosh, Yemen
25. Zahrah Ahmed Eissa, Yemen
26. Mohammed Al Zaidi, Yemen
27. Hazem Al Ashwal, Yemen
28. Khaled Al Mahafadi, Yemen

8.2. List of Participants- Information and Communication Technology to Enhance Agricultural Extension Systems, Hammamet, Tunisia: 14-18 October 2019

1. Khalifa Ibrahim Al Amin, Bahrain
2. Ali Hasan Ali Ahmed, Bahrain
3. Tahra Al Naqbi, UAE
4. Huda Khraim, UAE

5. Mohammed Al Mheiri, UAE
6. Amal Abdul Kareem Abdullah, Kuwait
7. Dana Fadel Al-Ali, Kuwait
8. Yousef Almosawi, Kuwait
9. Badriya Saif Al Hosni, Oman
10. Saif Saeed Al Habsi, Oman
11. Hamad Saket Al-Shamari, Qatar
12. Mohammed Salem Al-yafei, Qatar
13. Meshal Al Obaid, Saudia
14. Saleh Al Julaify, Saudia
15. Suaad Nasser, Yemen
16. Mohammed Amran, Yemen

8.3. List of Participants- Date Palm in the GCC Countries project, 3rd Phase Inception Workshop, 7-8 December 2019

1. Abdul Aziz Abdul Kareem, Bahrain
2. Ali Shambeh Al Balooshi, UAE
3. Amal Abdulkareem Abdullah, Kuwait
4. Shima Ali Alkhabbaz, Kuwait
5. Hamoud Al Hasani, Oman
6. Saleh Al Abri, Oman
7. Yousef Khalid Al Khulaifi, Qatar
8. Hamad S. Al Shamari, Qatar
9. Mohammed salem Al-yafei, Qatar
10. Hassan Ibrahim Al Asmakh, Qatar
11. Saleh Mohsen Al-Yafei, Qatar
12. Bander Mohamed Al Saghan, Saudia
13. Abdul Aziz Al Sharidi, Saudia
14. Mohammed Al Husaini, Saudia
15. Bander Al Odaiani, GCC
16. Othman Al Jamea, GCC
17. Hussein Al Ibrahim, GCC
18. Aly Abousabaa, ICARDA
19. Jacques Wery, ICARDA
20. Chandra Biradar, ICARDA
21. Mustapha Bouhssini, ICARDA
22. Abdul Basit Oudah, ICARDA
23. Atef Swelam, ICARDA
24. Boubaker Dhehibi, ICARDA
25. Muhi El Dine Hilali, ICARDA
26. Azaiez Ouled Belgacem, ICARDA
27. Arash Nejatian, ICARDA
28. Wael El Gaaly, ICARDA

8.4. List of Participants- ICARDA APRP annual regional meetings on December 9-12, Kuwait.

1. Mohamed Al Dhanhani, UAE
2. Amal Abdulkareem Abdullah, Kuwait
3. Abdulrahman Al-Fraih, Kuwait
4. Fatemah Al Kandari, Kuwait
5. Dana Fadel Al A-Ali, Kuwait
6. Fatemah Alameer, Kuwait
7. Hamoud Al Hasani, Oman
8. Hamdan Al Wahibi, Oman
9. Muthir Al Rawahi, Oman
10. Safa Al Farsi, Oman
11. Hamad S. Al Shamari, Qatar
12. Mohammed salem Al-yafei, Qatar
13. Hassan Ibrahim Al Asmakh, Qatar
14. Saleh Mohsen Al-Yafei, Qatar
15. Bander Mohamed Al Saghan, Saudia
16. Saud A. Al-eyyed, Saudia
17. Khaled Al Tamimi, Saudia
18. Sanad Al Qahtani, Saudia
19. Mansoor Mohamed Al Aqil, Yemen
20. Khader Balem Atroosh, Yemen
21. Jumhoryah Al-Khader Mesari, Yemen
22. Basel Abdullah Salem Al Kor, Yemen
23. Bander Al Odaiani, GCC
24. Othman Al Jamea, GCC
25. Abdullah Al-Musaibeeh, Kuwait-Fund
26. Abdulredha Bahman, Kuwait - Fund
27. Aly Abousabaa, ICARDA
28. Jacques Wery, ICARDA
29. Chandra Biradar, ICARDA
30. Mustapha Bouhssini, ICARDA
31. Mounir Louhaichi, ICARDA
32. Boubaker Dhehibi, ICARDA
33. Muhi El Dine Hilali, ICARDA
34. Ahmed T. Moustafa, ICARDA
35. Azaiez Ouled Belgacem, ICARDA
36. Arash Nejatian, ICARDA
37. Wael El Gaaly, ICARDA