Science for resilient livelihoods in dry areas

RESEARCH PROGRAM ON Livestock

Using promising range and cacti species to improve provisioning of ecosystem services during long-term restoration of arid lands

Annual Report 2018

Project Title: Using promising range and cacti species to improve provisioning of ecosystem services during long-term restoration of arid lands

Project Leader: Mounir Louhaichi
Scientists involved: Sawsan Hassan and Hloniphani Peter Moyo
Partners: NCARE

Rationale

Rangelands are recognized for their importance and value in providing a number of ecosystem services that are often not considered when valuing this resource (Kroeger and Casey, 2007). Not only do rangelands support livestock production, these landscapes also provide society with valuable products and services that support our wellbeing and quality of life, such as firewood, mitigating climate change via carbon sequestration, purifying water via bioremediation, and storing genetic diversity within the flora and fauna of these environments (Kremen 2005; Kroeger and Casey, 2007).

Over the last few decades, complex political, social, and environmental factors and management practices have degraded these fragile environments through a combination of the effects of land clearing for agriculture purposes and overgrazing (Kremen and Ostfeld, 2005; Kremen 2005; Egoh et al. 2008). These effects have accelerated the decline in native forage production and the deterioration of native forage species gene pools, thus threatening biodiversity (Hobbs et al. 2008; De Groot et al. 2010). With these threats in mind, there is a need to identify, multiply and disseminate range and forage species that are well adapted to these environments. Such species should potentially be resistant/tolerant to drought, cold, and salinity to rehabilitate and restore these degraded landscapes (Izaurralde et al. 2011; Tsegaye et al. 2010). Also, such species must withstand water shortage, high temperature, and salt affected soils having poor fertility (Milchunas et al. 2005). Several indigenous species already exist in such harsh environments (Izaurralde et al. 2011), but are rapidly declining, giving rise to a need to identify and promote the adoption of these species by resource users in these environments.

The combined effects of climate change (recurrent droughts) and overgrazing on dryland rangeland environments are detrimental: altering plant community composition, impairing ecological processes, and facilitating colonization by invasive species (Izaurralde et al. 2011; Milchunas et al. 2005). Therefore, the future of dryland regions depends on the cultivation of appropriate alternative crops capable of withstanding water shortages, high temperatures, and poor soil fertility (Izaurralde et al. 2011). Cacti, for example, satisfy these requirements, and are becoming increasingly important for both subsistence and market-oriented activities (Khalafalla et al. 2007; Nefzaoui et al. 2014). Replacing what the rangeland has lost and maintaining species composition, diversity and production levels already present are central to ICARDA's, and its partner NCARE's, mandate. Techniques developed and adopted in degraded rangeland areas include rotational grazing, the collection and identification of valuable native plant species, the introduction of new tree and shrub species, and cost-effective water harvesting and reseeding techniques. ICARDA scientists are increasingly recognizing the positive attributes of cacti: these plants are an important source of fruit, forage and fodder, and can be productive even in years of severe drought.

Objective:

To facilitate effective adaptation to conditions in West Asia and North Africa, ICARDA's work at Mchaqqar aims at identifying and evaluating drought, cold, and salt-tolerant rangeland/forage species – with a particular emphasis on screening and evaluating for cold-tolerant cacti species and drought tolerant rangeland species. The work also aims at developing conservation agriculture techniques which enhance yields for agricultural crops, as well as improving ecosystem services such as; soil conservation and improving soil nutrient status through the use of leguminous shrubs. Specific objectives include:

- Promoting cactus pear (*Opuntia ficus-indica*) as a multi-purpose species
- Conduct agronomic trials of promising species
- Conservation of rangeland genetic resources
- Evaluate integration of conservation agriculture and alley cropping
- Capacity development of NRAS and partners
- Publish key findings through factsheets, reports and ISI papers

Promoting cactus pear (*Opuntia ficus-indica*) as a multi-purpose species

Currently, more than 120 cactus accessions imported from different countries (Italy, USA, Brazil, Tunisia, South Africa, Mexico, Morocco, etc.) have been established at Mchaqqar Research Station (MRS). These accessions have different genetic characteristics in terms of productivity, specifications and purpose of use. The cactus field genebank is now serving as source of genetic sources of cactus materials that can be easily accessed and promoted to other countries. It is used to raise awareness and conduct field days and host visitors interested in this crop.
In addition to cactus gene pool maintenance, several activities took place in 2018 with the below objectives:

- Investigate and describe morphological characterization of vegetative organs of cactus accessions to identify the main characteristics contributing to discriminate cactus accessions
- Undertake agronomic trials to determine proper season for transplantation and method of plantation (density),
- Promote cactus pear in other countries.

Cactus accessions characterization

The cactus accessions planted in MRS were identified for description and listed to determine their plant characteristics. Single cladodes were established at a plant spacing of 3 m x 4 m in rows orientated E/W, with recommended standard orchard practices followed during the planting. Non-random, purposive sampling techniques were employed in the identification and collection of the samples. For the purpose of fruit, cladode and plant characterization, five plants from each accession were considered as replicates and the accessions as treatments. Plant characterization methods and description of accessions for vegetative, cladode and fruit characters were done following the internationally accepted and standardized descriptors. The descriptors were: plant, alternate bearing, habitus and cladode descriptors. The other descriptors included outstanding or disadvantageous characteristics of the varieties and their use. Plant shape was determined by dividing plant width (W) by plant height (H) for 2 plants per entry, where flat cladode was determined as: W>H; round: W=H; elongate: W<H.

Habitus was determined by evaluating plant shape, since plants are usually either upright or spreading, which are distinct types. If the plants fell between these classes, they were then

classified as medium. These measurements were all done in wintertime (February/March) when the plants were dormant, whereas plant width and plant height (cm) were measured just before the plants were pruned. Plant width was measured to evaluate specific plant growth allocation strategies under the growth conditions, whereas plant height (cm) was measured to get an indication of the vertical vegetative growth rate of the different accessions. Results demonstrated a wide variation among the cactus accessions, the proportion of the different colors of the accessions ranged from light (1%), green (54%) and dark green (36%). A proportion of 17% of the accessions had medium plant habit, compared to 83% with an upright habit. At least 83% of the accessions recorded emergent spines, 0.3 % recorded hard spines and the rest had sunken spines. In terms of the summary of cladodes measurements, the characteristics are presented in Figure 1.

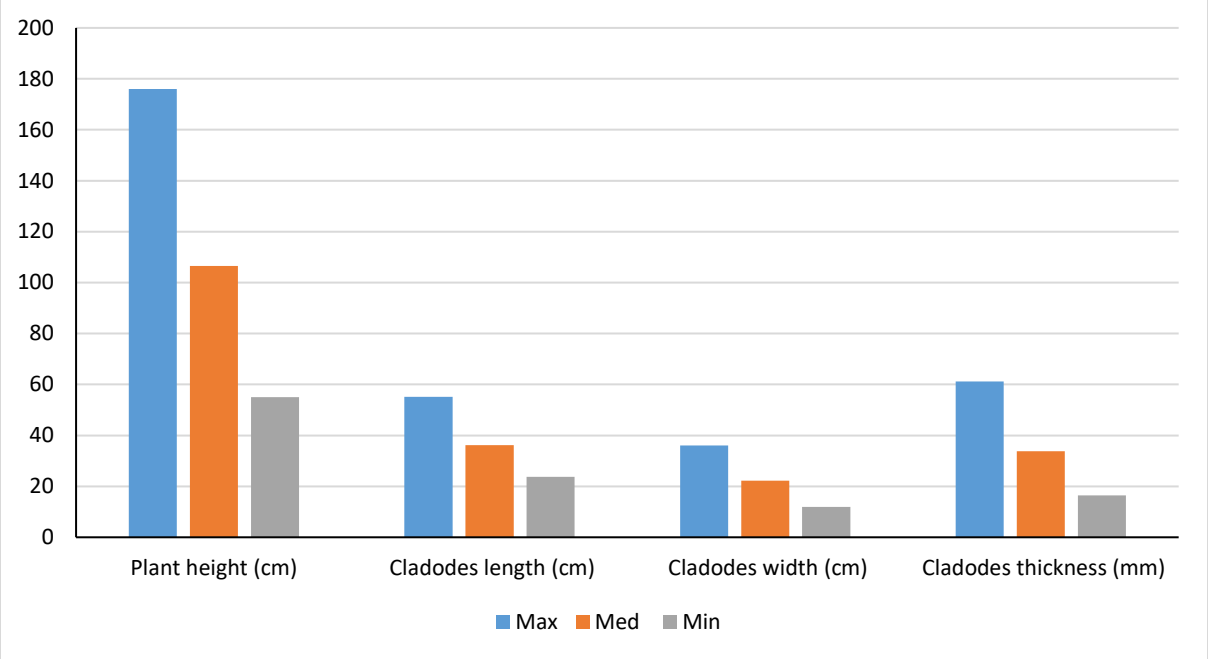

Figure 1. Summary of cladode measurements of 120 of cactus pear accessions in Mushaqqar station.

Majority of the identified accessions were with medium plant height and cladodes measurements. The superior accessions are presented in Table (1)

Table 1: List of the superior cactus accessions in terms of plant height (cm), cladode length (cm), cladode width (cm) and cladode thickness)

Plant height (≥ 130 cm)	**Cladode length (≥ 40 cm)**	**Cladode width (≥ 25 cm)**	**Cladode thickness (≥ 38mm)**
VN_ Villanueva	Zastron 4	VN_ Villanueva	plant
2_26_21	2_11_85	Morado	19_3_Algeria_69200
Zastron 4	26_Djebel Bargou_68247	N	9_ FOZA9
F1_COPENA F1	Blue Motto	20 – Chico – 73056 – S. AFRICA	66F_O. ellisiana - 400_Argentina
2_11_85	Spineless	White San Cono	10_ FOZA10

34_Caref 58_69219	F1_COPENA F1	V1_ COPENA V1	15_Sicile Le folin_73063
9_ FOZA9	10_ FOZA10	Syria	Blue Motto
2_25_15	V1_ COPENA V1	M3 Bianca di Macomer	2_17_25
42_Mornag_74077	VN_ Villanueva	80_Mexico_ USA	94_Mexico_ USA
117_24 - Tunisia	White San Cono	17- Carefin -1, 69198-ALGERIA	2_21_68
Blue Motto	Morado	F1_COPENA F1	Roly Poly
23- O. MAXIMA-73062	Yellow Santa Margherita Belice	Zastron 4	18 - Mexico/ New Mexico
10_ FOZA10	9_ FOZA9	GSH Gialla di sarroch	4_Mexico_73049
46_Mornag B_74076	White Santa Margherita Belice	Trunzara Red San Cono	26_Djebel Bargou_68247
2_21_68	Red Santa Margherita Belice	Red San Cono	F1_COPENA F1
15_Sicile Le folin_73063	Tunzara Bianca bronte	47_Mornag B	Zastron 4
4_Mexico_73049	Trunzara yellow San Cono	22_El Borouj_75018	1233_Mexico_ USA
19_3_Algeria_69200	2_26_21	**53C_ANV1-1.08_Argentina**	10_44_Bianca_69235
V1_ COPENA V1	Yellow San Cono	Red Santa Margherita Belice	Trunzara Red San Cono
	19_3_Algeria_69200	Yellow Belpasso	32_27_Matmata_69242
	White San Cono	Tunzara Bianca bronte	2_11_85
	Syria	Trunzara red Bronte	8_Leavis_New Mexico_74010
	Nepal		
	Red San Cono		
	Seedless Roccapalumba		

The above traits are very important parameters that contribute to cactus accessions variability and potential of their productivities. The taller plants with higher cladode length lead to higher biomass production, while the cladode thickness can reflect the water content.

Cactus agronomic trials:

Cactus grows well under low water availability and extreme temperature changes, and its utilization as a forage for livestock is mainly due to its availability during critical dry months of the year. Thus, this study aims to investigate how the method of, and timing (seasonal) of, planting influence the productive performance of cactus. The objectives of the study are;

a) Assess the survival of cactus pads planted using different methods and planted in different seasons
b) Investigate the growth performance of cactus pads grown using different methods and planted in different seasons.

The trial is being conducted in a complete randomized design with two season differences; fall (September-early October) and Spring (end of March-April); and four planting methods (one

cactus pad, mother pad with one pad, mickey mouse pads and three single cactus pads together). With six replicates of each treatment combination, there is a total of 48 pads for the experiment. In three 50 x 3.5 m strip plots, planting was randomized in each strip in the middle, and pads spaced at 3 m apart in each strip plot. The fall treatment was planted before the end of September 2017, while the spring treatment was planted early April 2018. Primary observations showed of 100 % survival rate of both treated and control cladodes for both planting season. The spring plantation showed heathier plants resulted of the treated cladodes comparing to the untreated cladodes. The micky mouse cladodes planted in Spring showed better plant growth comparing to the single pads and the three single pads, this might be explained by the fact that the mother cladode in mickey mouse planation plays a role as a source of nutrients for the correlated pads. No differences were observed for the fall plantation as the newly planted cactus cladodes can suffer from winter (low temperature). The trial is ongoing, and the data will be collected during the spring of 2019.

Promoting cactus to other countries: shipping cactus to Syria

A total of 66 cactus cladodes of 22 various accessions were dispatched to Syria (3 cladodes each from 23 accessions) in November 2018 (Table 2). These cladodes are planted in two nurseries, for further multiplication.

Table 2: List of cactus accession shipped to Syria

Accession	Origin	Number of cladodes
J_ Jalpa	Mexico	3
VN_ Villanueva	Mexico	3
Morado	Sicilia ITALY	3
Algerian 3/2	Sicilia ITALY	3
Blue Motto	Sicilia ITALY	3
Roly Poly	Sicilia ITALY	3
Yellow Santa Margherita Belice	Sicilia ITALY	3
White Santa Margherita Belice	Sicilia ITALY	3
Yellow San Cono	Sicilia ITALY	3
Yellow Belpasso	Sicilia ITALY	3
Trunzara yellow Bronte	Sicilia ITALY	3
Mezzojuso	Sicilia ITALY	3
R	Tunisia	3
26_Montarnaud_Tunis_69239	Tunisia	3
10_Bianca_Sicily_69235	Tunisia	3
GS	Tunisia	3
30_Mdjez El Bab_Tunisia_73952	Tunisia	3
38_Sbeitla_Tunis_74071	Tunisia	3
Jordan station	Jordan	3
42	USA	3
94	USA	3
1233	USA	3

Conservation of rangeland genetic resources

The conservation of genetic resources is important particularly in the dry areas, where the impact of climate change on biodiversity creates more challenges for their recovery. In June 2015 ICARDA established a pastoratum in MRS as an ex situ method of genetic resources conservation. The pastoratum was also established to serve as a seed source to contribute towards enhancing rehabilitation of degraded dry areas. In 2018, new species were added including *A. mollis* (Tunisia), *A. undulata* (North America), *Rhus tripartita* (Tunisia), *Aloe vera* (Arabian Peninsula), *Hylocereus undatus, Haloxylon aphyllum (Central Asia) and Thymus syriacus* (Syria) (Table 3). The pastoratum has served as a seed source for an AFESD funded restoration project in Jordan's Badia, through supplying *Salsola vermiculata* seeds. In the Badia direct seeding of Salsola has been implemented in both summers of 2017 and 2018. Seeds of other shrub species have been harvested and stored in MRS research lab for dissemination to other countries within the region, where restoration initiatives will be implemented.

Table 3. Summary table of rangeland species at Mchaqqar Station, Jordan.

Scientific name	Common name	Origin
Atriplex halimus L.	Silvery orache	Mediterranean Basin
A. canescens (Pursh) Nutt.	Fourwing saltbush	Arid North American
A. lentiformis (Torr.) S. Watson	Big Saltbush	North America
A. leucoclada	Wild Orache, Raghl	East Saharo-Sindian
A. leucoclada Boiss.	Saltbush orache	Middle East
A. nummularia Lindl.	Oldman saltbush	Australia
A. polycarpa	Cattle saltbush	North America
A. tridentate	Fourwing saltbush	North America
A. mollis		North America
A. undulata	Wavy-Leaf Saltbush	North America
Acacia stenophylla	Shoestring acacia	Australia
Acacia tortilis	Umbrella thorn acacia	The savanna and Sahel of Africa
Rhus tripartita	Sumac	Mediterranean regions and Northern Africa
Aloe vera	Aloe vera	Arabian Peninsula
Hylocereus undatus	Dragon fruit	
Haloxylon aphyllum	Black Saxaoul	Central Asia
Artemisia herba-alba	white wormwood	Mediterranean regions in Northern Africa
Bassia prostrata	Prostrate summer cypress	Europe-Asia
Clitoria ternatea	Asian pigeonwings	Tropical equatorial Asia
Colutea Istria	Bladder-senna	Southern-Europe, south-west Asia
Coronilla glauca	Scorpion vetch	Europe
Farsetia aegyptiaca	El aoud el abiyad	North Africa and Asia.
Lavandula angustifolia	true lavender	Mediterranean (Spain, France, Italy
Lavandula Stoechas	Spanish lavender	Mediterranean countries
Maireana brevifolia	Cotton-bush	Australia
Medicago arborea	Alfalfa arborea	Mediterranean Basin
Myrtus communis	Common myrtle	Southern Europe, north Africa

Nitraria retusa	Garkad	Northern Africa
Origanum vulgare	sweet marjoram	Eurasia and the Mediterranean region
Thymus syriacus		Southern Europe and Asia
Retama Retam	*White weeping broom*	*Northern Africa and the Middle East.*
Rose	*Rose*	*Europe, North America, and northwestern Africa*
Rosmarinus officinalis	rosemary	Africa, Europe, western Asia
Salsola schweinfurthii	Darniella schweinfurthii	Lower Jordan Valley along the Dead Sea
Salsola vermiculata L.	Mediterranean saltwort	Middle East

Evaluate integration of conservation agriculture and alley cropping

In arid environments, there are limited inputs available to smallholder farmers, leading to a need to promote low-input regenerative production systems such as alley cropping. Such cropping systems incorporate food crops grown in alleys formed by hedgerows of mainly leguminous trees or shrubs (Singh et al 1989). These traditional fodder-crop production systems are based largely on the restorative properties of woody species, which in addition to soil fertility regeneration, are also sources of staking materials, firewood and animal and sometimes human food (Lehmann et al. 1995). The aim of setting up the alley cropping trial is to evaluate the effects of different semiarid and arid shrub species on food crop yields as well as biomass production in planted shrubs.

Biomass production of shrub species was determined in the winter of 2018 and then the biomass was used to evaluate each shrub based on adaptability, effect on yield of the crop planted, palatability, accessibility, impact on soil and biomass (Figure 2). This resulted in a suitability index (ranking each species out of 5). Compared to the Atriplex shrubs, leguminous shrubs such as *C. glauca* and *C. istria* are expected to have a positive impact on soil nutrient status through their nitrogen fixing ability. The consequent positive impact on soil nutrient status is also expected to result in higher crop yields, while supplying forage for livestock to during the dry summer period. For example, while cactus is ideal for providing summer forage for livestock, it has a low suitability index (0.8) because this biomass is not readily accessible to livestock for browsing.

Cactus pads need to be harvested and processed (chopping) before feeding livestock, thus increasing labor costs. Also, cactus cannot be fed alone as it needs a protein supplement to increase the nutrient content of the diet if fed to animals (Nefzaoui et al. 2014). *M. arborea* has a low suitability index because its biomass production and the timing of grazing have more weight than any other factors such as the accessibility of forage produced or forage palatability (Figure 2). The Atriplex species have high suitability index scores due to their high biomass production during both the summer and winter. Due to higher biomass produced, organic matter contribution from the Atriplex species is expected to be higher due to leaf material produced and shoot dieback. Animals are also expected to easily browse on the shrubs during the summer period.. While leguminous species such as *C. glauca* will most certainly improve the soil nutrient status in an alley cropping system, the low biomass productivity (in the summer May/June) of such species resulted in a low suitability index for alley cropping (Figure 2).

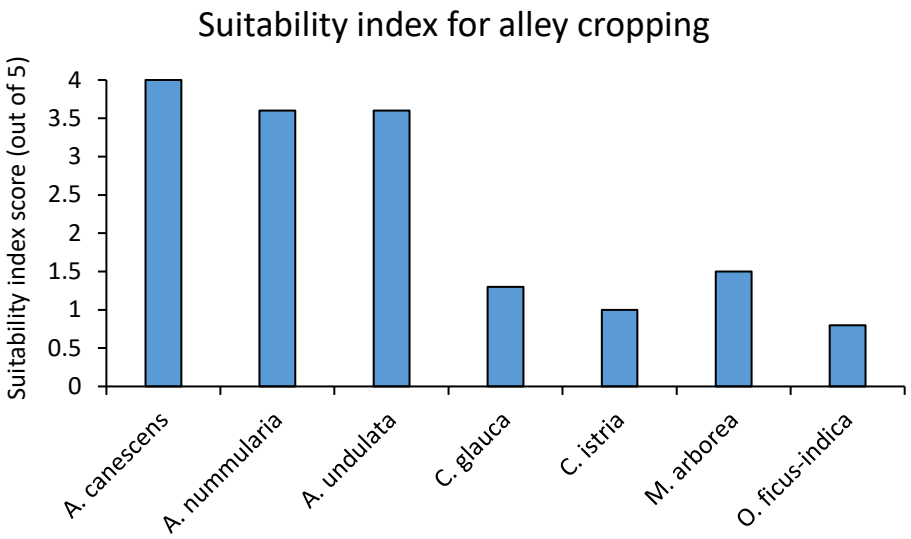

Figure 2. The relative score (out of 5) of each shrub species used in the alley cropping with wheat, vetch and barley in Mchaqqar Research Station.

Capacity building:

- An Afghan training group (5 women) visited Mushaqqar for plant propagation, nursery management, pasture production and enterprise development training, where they participated in demonstration on different the plant propagation methods (Figure 3). The training took place during 8-12 April 2018, conducted by ICARDA scientists; the Commonwealth Scientific and Industrial Research Organization in Australia; Murdoch University (Australia) and the Royal Tropical Institute (Kit from Netherlands).

Figure 3. A visit to the cactus germ plasm, greenhouse and nursery by Afghan training group.

- A Research Fellowship was offered to Dr. Sortino Giuseppe from the University of Palermo, (Italy) during 11-27 February 2018 (Figure 4). During his stay he characterized the *Opuntia ficus-indica* (cactus) accessions planted in MRS (see report).

Figure 4. Visit to the cactus germplasm in Mushaqqar research station by Dr. Sortino Giuseppe from the University of Palermo (Italy).

- Dr. Nizar Haddad (NARC) Director General - National Center for Agricultural Research (Jordan) along with Dr. Jacques Wery, ICARDA Deputy Director General - Research, visited Mchaqqar station on the 23 July 2018 where they were briefed about the activities conducted in Mushaqqar (Figure 5).

Figure 5. The visit to Mushaqqar by ICARDA DDG-Research (Dr Jacques Wery) and Dr. Nizar Haddad (NARC) Director General - National Center for Agricultural Research (Jordan).

- Dr Subbanna Ayyappan (ICARDA Board of Trustees (BoT) member) visited MRS on 26 October 2018 (Figure 6). He was accompanied by Sawsan and two scientists from the water group.
- Dr. Dr. Robert Allen Washington (visiting scholar from the University of Reno, NV, USA) visited the station on 24 November 2018, to map the cactus plantation using LiDAR (Figure 6).

Figure 6. The visit to the cactus germplasm by DR Ayyappan (BOT member) and Dr Robert Allen Washington to map cactus plantation using LiDAR.

- A field day with 44 participants took place on the 31 October 2018, which saw farmers visiting the cactus germplasm (Figure 7).

Figure 7. A field day visit by local farmers to the cactus germplasm.

Partnerships with NARS:

Right after the TV broadcasting on cactus, huge demand from farmers for cactus pads were registered across the Kingdom. NARC has appointed a person dedicated to this task. To manage this high demand (beyond what ICARDA can offer), an urgent meeting took place on August 9, 2018 at ICARDA office in Amman in the presence of Dr. Nizar Haddad, Dr. Kamel Shideed, Dr. Mounir Louhaichi and Dr. Sawsan Hassan. The meeting was aimed to agree on a road map between ICARDA and NARC on cactus research and dissemination within the kingdom (report of the minutes is available).

Research Activities and Deliverables – 2018

Research Activities	Expected Deliverables	Status
A 1. Evaluate cactus pear performance to low temperatures and planting methods (density and season) under West Asia conditions	* Maintain and expand cactus germplasm collections * One Proceeding papers from the International Cactus Congress published with ACTA "Cactus pear roots turnover and total carbon sequestration rate depends on soil volume availability"	100% 1 proceeding papers accepted for publication
A 2. Assess potential range species for rangeland restoration/rehabilitation	* Monitor shrub trial using native species * Seed collection and conservation	100% (done) more species were added (keeping in mind that this is a long-term activity)

	* Maintain and expand field gene bank (long term plan) including mother plants for seed production	
A 3. Long-term alley cropping with several hedgerow species under semi-arid conditions	* Establishment (seeding) of new annual crops * Report on integration of alley cropping and conservation agriculture (justifications, experimental layout, promising species for alley cropping)	100% completed Long-term trial
A 4. Capacity development of partners / dissemination of promising accessions to partners	* Report on visits made to the research station (agro-pastoral) * Report on dissemination of cactus to partners (upon request) * 1 poster about cactus	100% Link to broadcast national television https://youtu.be/85gbAtZAZso At least 10 local newspapers reported on ICARDA-NARC cactus collaboration 1 factsheet on cactus feeding https://dx.doi.org/20.500.11766/9048 100%

Publications

Proceedings abstracts

Sawsan Hassan, Giorgia Liguori, Giuseppe Sortino, Paolo Inglese, Luciano Gristina, Mounir Louhaichi. 2018. Soil organic carbon accumulation in Cactus pear as affected by soil volume. The Ecosystem Services Partnership (ESP) Regional conference. 22-25 April 2018. Dead Sea, Jordan http://hdl.handle.net/20.500.11766/9039

Reports

Mounir Louhaichi and Sawsan Hassan. 2018. Screening for cold tolerant cactus species (*Opuntia ficus indica*) under West Asia conditions. Technical Report http://hdl.handle.net/20.500.11766/8278

Giuseppe Sortino, Sawsan Hassan, and Mounir Louhaichi. 2018. Cactus pear as multiple purpose crop to improve provisioning of ecosystem services. Internship report http://hdl.handle.net/20.500.11766/9192

Factsheets

Mounir Louhaichi and Sawsan Hassan. 2018. *Opuntia ficus-indica* (L.) Mill: a sustainable fodder plant for the dry areas. ICARDA Factsheet. https://dx.doi.org/20.500.11766/9048

Video

One video was broadcast on the Jordanian national television https://youtu.be/85gbAtZAZso

Local newspapers

Several local Jordanian newspapers*:* at least ten local newspapers reported the event that took place including- Jordan News Agency, alkawn news, enjaz news agency, fact Jordan, malf news, ammon news, deeretna news, nayrouz news agency, alraqeb news, jebal albalqa news, etc.

Summary: English (10-15 lines)

More than 100 cacti accessions were introduced in Mushaqqar Station (Jordan). These accessions offer an opportunity to help farmers to diversify their products and income as the accessions have different genetic characteristics in terms of productivity, specifications and purpose of use. In addition to establishing and maintaining the cactus field genebank, the characterization, evaluation and screening of cactus pear for cold tolerance has been taking place in 2018. Results from this activity will contribute towards disseminating the most suitable accessions to specific environments, which would, for example, require accessions highly adaptable to very cold conditions. The high demand of cactus in Jordan suggests a need for more information dissemination and education programs to reach out to farmers within the community. This will educate and equip farmers so as to stimulate the adoption of cactus.

While incorporating shrubs in alley cropping systems is important for the provision of ecosystems services such as carbon sequestration and soil enrichment, the broader applicability of incorporating shrubs should factor in other factors such as the forage production during the summer. Soil enriching shrubs, for the benefit of increasing crop yields, may not necessarily yield high forage production to support livestock during the dry summer periods. Consequently, when selecting shrub species for alley cropping systems, a compromise should be accommodated for higher crop yields versus higher forage biomass for livestock sustenance. The cactus accessions disseminated to Syria are expected to be a foundation for establishing cactus to other farmers, with the aim to reduce the feed gap during the barren summer seasons. The preservation of the pastoratum will continue producing seeds for important shrub species for dissemination to local farmers and to restoration efforts around the region. The pastoratum will also serve as a capacity building demonstration site for visiting school pupils, college and university students within and beyond Jordan.

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