DIIVA-PR:
Dissemination of Interspecific ICARDA Varieties and Elites through Participatory Research

THIS **PROJECT AGREEMENT** dated _____is made BETWEEN:

(1) The GLOBAL CROP DIVERSITY TRUST (the 'Crop Trust') with its address at Platz Der Vereinten Nationen 7, 53113 Bonn, Germany

and

(2) The International Center for the Agricultural Research in the Dry Areas (ICARDA) with its address at Dalia Building 2nd Floor, Bashir El Kassar Street, Verdun, Beirut, Lebanon 1108-2010

Project Proposal

A. PROJECT SUMMARY

1. Grant No: GS18009
2. Program: Crop Wild Relatives (CWR)
1. Project title: DIIVA-PR: Dissemination of Interspecific ICARDA Varieties and Elites through Participatory Research
2. Abstract/Project description: Since its inception, ICARDA's breeding programs of durum wheat, barley, and lentil have made extensive use of wild relatives to develop elite germplasm well adapted to the drastic and frequent droughts that affect the region in which ICARDA operates. To date, several elites and released varieties from these programs are ready for final testing and uptake by farmers in the driest areas of Morocco and Ethiopia, and heat affected regions along the Senegal River. Now that the (pre-)breeding pipeline has completed its course, it is time to seek the appreciation by clients by demonstrating the performances of these new lines to farmers. Additionally, new CWR-derived lines have been generated during phase I of funded projects, and hence can now be used to better target the existing gaps between farmers needs and climate change impacts. Hence, this project aims at using wide crosses for durum wheat, barley, and lentil to achieve the following goals: i. Evaluate and fix inbreeding germplasm developed during pre-breeding phase 1 projects (barley and durum) and evaluate and fix to inbreeding CWR-derived germplasm (lentil) ii. Conduct multi-locations testing in dryland research stations of Morocco assessing the performances of the lines issued from wide crosses against the best commercial checks (durum, barley, and lentil). iii. Assess the nutritional and industrial quality of the produced grains to determine health and economic benefits of CWR (durum, barley, and lentil). iv. Conduct on-farm participatory selection of the best candidate varieties (durum, barley, and lentil). Record farmers needs via targeted interviews and use these to develop selection indexes for better targeting the evaluation of material indicated at point 'i' (durum, barley, and lentil). v. Deploy a novel fast-track purification and pre-multiplication system to submit the best CWR candidates for variety release in Morocco (durum, barley, and lentil).

vi. Deploy a novel fast-track purification and pre-multiplication system to submit the best CWR candidates for variety release in Lebanon (durum, barley, and lentil).
vii. Assess the most promising candidates identified for Morocco in Ethiopia (durum, barley, and lentil).
viii. Assess the best wide crosses derived lines for adaptation to heat stress in Senegal (durum, and lentil).
ix. Share the best material containing CWR introgressions with more than 100 breeders worldwide via the International Nursery of ICARDA (durum, barley, and lentil), a targeted workshop (durum), and via a scientific article (durum, barley, and lentil).

Success of this project will be measured as: at least one scientific article describing the adaptation of different CWR-derived elites of 3 crops to different drylands of Morocco and their intrinsic nutritional value; at least one genotype derived from wild crosses from each crop submitted to the variety catalog of Morocco and Lebanon for consideration for release; at least 5 farmers cooperatives directly engaged in Morocco; asses heat tolerance of different crops and wide crosses in Senegal in connection with the awarded OLAM Prize for Innovation in Food Security; asses drought tolerance and disease resistance of different crops and wide crosses in the lowland of Ethiopia.

3. Crop wild relative taxa:

Aegilops speltoides, Triticum dicoccoides, Triticum araraticum, T. timopheevii, Th. bessarabicum, Ae. mutica, Th. intermedium, Ae. ventricosa, Ae. caudata, Hordeum vulgare subsp *spontaneum, Hordeum bulbosum , Lens orientalis*

4. Countries where the project is implemented: Morocco, Lebanon, Ethiopia, Senegal

5. Crops covered by the project: Durum wheat, Barley, and Lentil

6. Budget request USD: 1,010,000

Applicant (in kind) contribution USD: 222,342

7. Duration of the project: **Start:** 30 June 2018 **End:** 31 October 2020

8. Institute and country:	ICARDA
Focal persons/principal investigator:	PI: Dr. Filippo M Bassi, Senior Scientist, Durum Wheat Breeding Focal admin: Tareq Bremer, Grants Management Officer
Position:	Senior scientist durum wheat breeder
Address:	Av. Belarbi Alaoui, INRA Campus, Rabat, 10000 Morocco
11. Crop Trust coordinator	Dr. Benjamin Kilian
12. Donor:	Norwegian Development Cooperation (NORAD)

B. PROJECT DESCRIPTION

1. Background, justification, feasibility and methodology *(3 pages)*

ICARDA's gene bank collection is among the largest in the world totaling 155,352 accessions (43,000 of wheat, 32,560 of barley, and 14,512 of lentil), mostly composed of landraces and crop wild relatives (CWR). This treasure trove has been extensively utilized by ICARDA's breeders to generate huge impact in farmers' fields, with a special focus to those dry areas where the harsh conditions made it impossible for other breeding strategies to work effectively.

Durum wheat:

The durum wheat germplasm supplied by ICARDA has allowed national programs in 22 countries to release 128 varieties to date. Among these, 7 were the direct result of crosses with wild relatives and 33 were derived from landraces. In particular, among the 10 most recent varieties released in 2016 and 2017, 4 were derived from top-crosses with wild relatives and 2 from landraces. Morocco released in 2017 the variety 'Nachit' (Amedakul 1/*Triticum dicoccoides* Syrian collection//Loukos) extremely well adapted to the dry conditions of the high-plateaus thanks to its deep root system and large grains, probably derived from the 25% genomic contribution of wild emmer. On-farm and on-station testing on 0.1 ha plots of this new variety revealed a significant 40% yield advantage over the commercial variety 'Louiza' and 25% over the most grown variety 'Karim'. But Morocco is not new of releasing ICARDA's wide crosses. Already in 2007 a variety under the name 'Faraj' was derived from crosses with *Triticum araraticum* became available. This variety was specifically released to target the driest areas of Morocco in the surroundings of Settat, where Hessian fly is a major issue. Testing here on-station and on-farm revealed a yield advantage of nearly 100% under high infestation by the insect (**Fig 1a**), and 50% under dry conditions.

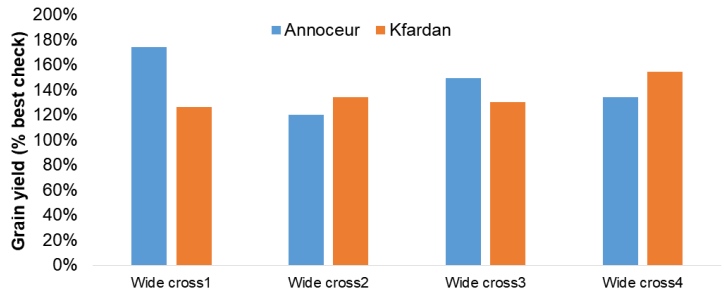
In Mauritania and Senegal, two varieties were released in 2017 'Amina' (Korifla/*Ae. speltoides*//Loukos) and 'Haby' (Mrb5/*T. dicoccoides* Aleppo Col//Cham1) also derived from simple top-crosses with *Aegilops speltoides* and wild emmer, respectively. These new varieties were selected under relentless high temperatures for a period of four years, to reveal the ability of maintaining high spike fertility under heat stress. Likely this trait is derived from their more primitive genetic makeup. The release of durum wheat varieties for the Senegal River region was recognized as a major achievement and awarded the 2017 OLAM Prize for Innovation in Food Security by a panel of Agropolis judges (http://olamgroup.com/sustainability/food-prize-re-imagine-agriculture/).

To further support the use of wild relatives in durum wheat breeding, an article was recently published under the title: *Wide crosses of durum wheat (Triticum durum Desf.) reveal good disease resistance, yield stability, and industrial quality across Mediterranean sites*[1]. Similarly, a second article was recently published to present the scientific data that resulted in the release of the two new varieties in Mauritania and Senegal under the title: *Heat tolerance of durum wheat (Triticum durum Desf.) elite germplasm tested along the Senegal River*[2]. The breeding work on

[1] Zaim et al. 2017. Wide crosses of durum wheat (Triticum durum Desf.) reveal good disease resistance, yield stability, and industrial quality across Mediterranean sites. Field Crop Research 214: 219.

[2] Sall et al. 2018. Heat tolerance of durum wheat (Triticum durum Desf.) elite germplasm tested along the Senegal River. J. Agr. Sci. 10:217.

the use of wide crosses continues and new reassuring data have been generated for the very harsh conditions of the Atlas Mountains, where severe droughts are combined with below zero temperatures (**Fig 1b**). Here, the wide crosses outperformed the best commercial check by 20-70% higher grain yield.



WC1	Ossl1/Stj5/5/Bidra1/4/BezaizSHF//SD19539/Waha/3/Stj//Jori/**Haurani**/6/Icajihan1
WC2	Korifla/**A. speltoides Syr**//**Haurani**/Jori
WC3	Icamilmus1/Waha/4/Icasyr1/3/Bcr/Sbl5//**T. Urartu**
WC 4	**Swa Algia**/Gd171/4/Icasyr1/3/Bcr/Sbl5//**T. Urartu**

Fig 1a (left). Comparison of the most grown variety 'Karim' against the CWR-based variety 'Faraj' at the drought station of Marchouch, same plot size. **1b (right).** Grain yield performances of four wide crosses (WC) expressed as ratio to the best commercial check when tested at two highland cold and drought stations (Annoceur and Kfardan).

A phase 1 pre-breeding project (GS14026) was conducted together with Prof Ian King at the University of Nottingham to introgress CWR from bread wheat introgression lines to durum wheat elites. Different accessions of 5 CWR (*Ae. caudata, T. timopheevii, Th. bessarabicum, Ae. mutica, and Th. intermedium*) were crossed to 5 ICARDA's and 2 CIMMYT's elite durum lines, backcrossed and selfed. Currently 4 BC_1F_2, 3 BC_1F_3, and 9 BC_2F_2 populations derived from these crosses are growing in small 2 m row at Marchouch station (**Table 1**). This material is yet untested in the field and still segregating. Yet, interesting spike shapes and plant vigor were recorded. In addition, several BC_2F_4 introgressions from *Ae*. *ventricosa* were produced by the ICARDA Genetic Resources Unit, also undergoing the first year of field planting in Marchouch. These entries will represent ideal sources of positive variations and shall be evaluated and selected to generate new elites.

Table 1. Durum wheat germplasm generated in project GS14026

Entry ID	Wild donor	Recurrent parent	Generation
UoN17-01	*Ae. mutica*	Kundermiki	BC1F2
UoN17-02	*Th. intermedium*	Miki3	BC1F2
UoN17-03	*Ae mutica*	Kundermiki	BC1F2
UoN17-04	*Th. intermedium*	Margarita	BC1F2
UoN17-05	*Ae. caudata*	Margarita	BC1F3
UoN17-06	*T. timopheevii*	CIMMYT Durum2	BC1F3
UoN17-07	*Th. bessarabicum*	Icarasha2	BC1F3
UoN17-08	*Ae. mutica*	CIMMYT Durum4	BC2F2
UoN17-09	*Ae. caudata*	Icarasha2	BC2F2
UoN17-10	*Ae. mutica*	Margarita	BC2F2
UoN17-11	*Th. bessarabicum*	Icarasha2	BC2F2
UoN17-12	*T. timopheevii*	CIMMYT Durum2	BC2F2
UoN17-13	*Ae. mutica*	Kundermiki	BC2F2
UoN17-14	*Ae mutica*	Omrabi5	BC2F2
UoN17-15	*Th. bessarabicum*	Omrabi5	BC2F2
UoN17-16	*Th. bessarabicum*	Margarita	BC2F2

Barley:

Barley is a critical crop of the dry areas, especially in the mountain region, where the grains are used as food, and the straw becomes essential as feed for the livestock. ICARDA holds the FAO global mandate for the genetic improvement of barley germplasm, with a special focus to its adaptation to the non-tropical dry areas. Advance breeding materials and segregating populations are constantly supplied to national programs for testing and as source of specific traits. The extensive use of ICARDA's germplasm has led to the release of 264 varieties in 45 countries directly derived from it. However, this number does not include the use of enhanced germplasm in the hybridization program by NARS partners for variety development/release. Breeders and farmers from Asia and Africa have been the biggest beneficiaries of ICARDA barley germplasm, with 176 varieties released in these two regions (**Fig 2a**).

ICARDA's list of released cultivars includes several derived from landraces, but so far there is no official record of varieties derived from crosses with CWR from secondary and tertiary genepool, even though many top performing elites were derived from crosses to *H. spontaneum*. In particular, these wild barley-derived lines have shown good levels of adaptation to dry and cold conditions in western Asian countries under low input conditions and other regions. Furthermore, the near exhaustion of the available genetic diversity has pushed breeders to recur to wild species from primary (*H. spontaneum*) and secondary (*H. bulbosum*) gene pools.

The work at the ICARDA barley breeding programs have resulted in the development of many promising germplasm from *H. spontaneum* source (Table 3A) and these have also been evaluated in recent years in Morocco, Lebanon and other places. The results (**Fig 2b**) indicate that apart from constituting sources of specific traits, these derived lines from wild barley have good yield potential and, in some instances, have out-yielded the best commercial checks by 10 to 15 % in the trials.

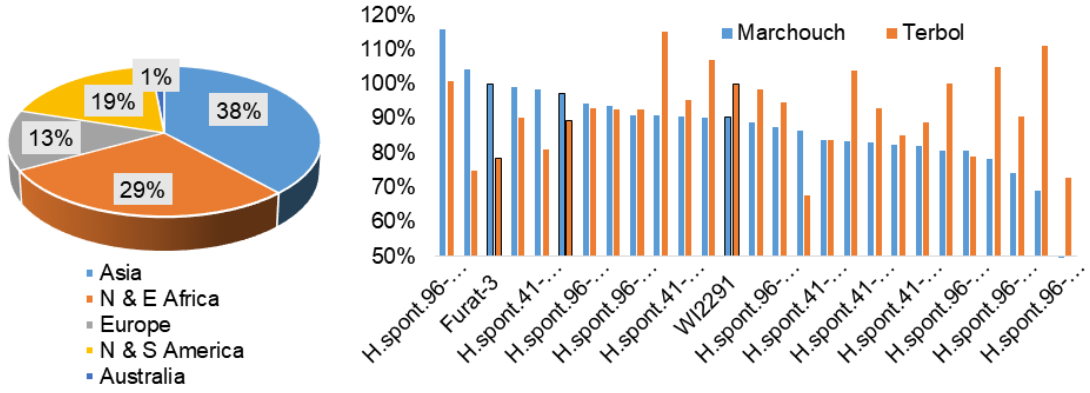


Fig 2a (left). Release of ICARDA-derived barley varieties worldwide. **2b (right).** Grain yield performances of *H. spontaneum* derivative lines at the Marchouch and Terbol stations.

Pre-breeding activities to mobilizing novel alleles from wild relatives have been initiated since the 2016-17 crop season at ICARDA under the ongoing "Trait discovery and deployment through mainstreaming the wild gene pool in barley and grass pea breeding programs to adapt to climate change" (GS16005). Identification of sources of novel diversity for diseases like leaf rust and net blotch has been taken up through efficient evaluation and precision phenotyping at hot spot locations in Morocco and Ethiopia. A total of 114 accessions of *H. spontaneum* were evaluated for resistance to major diseases in the field and greenhouse. Nine accessions showed adequate levels of resistance to the most virulent population of leaf rust and 44 accessions were resistant to net blotch. Ten accessions showed combined resistance to spot blotch and net blotch at seedling stage in growth chamber testing (**Table 2**). In addition, more than 115 *H. bulbosum*-derived lines have been grown during current season for increase in Marchouch and the net blotch data scored on it indicates some promising genotypes from these accessions.

A total of 159 new interspecific crosses to *H. spontaneum* were generated, and currently the Top Cross$_1$ F1 (TC_1F_1) generation is ready to harvest in the field (**Table 3**). Off-season selection will be conducted and in next regular season the TC_1F_3 will be field tested.

Table 2. *H. spontaneum* accessions resistant to spot blotch and net blotch of barley at seedling stage (infection responses of ≥ 3 as resistant (R), and ≤ 5 as susceptible (S)

***H. spontaneum* accessions**	**Infection responses**	
IG #	Spot blotch	Net blotch
38943	2	2
39880	3	1
39884	3	2
39891	3	3
40009	3	2
107046	2	2
107426	3	2
131642	3	0
145508	3	2
145575	3	3

Table 3. *H spontaneum* derivatives lines under development in GS16005 project, all progenies are top cross F_2

Cross code	**Pedigree**
GRS17B0113	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145502/8/ Alanda//Lignee527/Arar/3/Asal/4/AwBlack/Aths//Rhn-08/7/Man/4/Bal16 /Pro//Apm/DwII-1Y /3/ Api/CM67/5/Gas/OreS/6/Atahualpa
GRS17B0114	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 14550 /8/Henley
GRS17B0115	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145502 /8/LAMOLINA96/FALCON-BAR
GRS17B0116	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145502/8 /LAMOLINA96/Oxford
GRS17B0117	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145155 /8/Merzaga
GRS17B0118	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145155 /8/Baudin
GRS17B0119	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145508 /8/PETUNIA 2/3/AGAVE/SUMBARD400//MARCO/4/PETUNIA 1/5/TRA-B/1038//PETUNIA 1/3/ PENCO/6/BLLU
GRS17B0120	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145086 /8/Alanda//Lignee527/Arar/3/Asal/4/AwBlack/Aths//Rhn-08/7/Man/4/Bal16/Pro//Apm /DwII-1Y/3/ Api/CM67/5/Gas/OreS/6/Atahualpa
GRS17B0121	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145086 /8/LAMOLINA96/FALCON-BAR
GRS17B0122	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145086 /8/Rosalind
GRS17B0123	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145086 /8/Fathom
GRS17B0124	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145086 /8/Shepherd

GRS17B0125	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 38823 /8/Lignee527/NK1272//BF891M-612/3/Lignee527/Rihane//Arar
GRS17B0126	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 38823 /8/PENCO/CHERVON-BAR/5/ABETO//GLORIA-BAR/COME/3/SEN/4/MJA/6/PENCO/CHERVON-BAR//CANTUA
GRS17B0127	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 38823 /8/Rabat 071
GRS17B0127	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 38682 /8/Rabat 071
GRS17B0128	Alanda//Lignee527/Arar/3/Asal/4/AwBlack/Aths//Rhn-08/7/Man/4/Bal16/Pro//Apm/DwII-1Y/3/ Api/CM67/5/Gas/OreS/6/Atahualpa/8/ IG 145080/9/PETUNIA2/M111//QUINA/M112
GRS17B0129	Alanda//Lignee527/Arar/3/Asal/4/AwBlack/Aths//Rhn-08/7/Man/4/Bal16/Pro//Apm/DwII-1Y/3/ Api/CM67/5/Gas/OreS/6/Atahualpa/8/ IG 145080/9/Rabat 071
GRS17B0129	Alanda//Lignee527/Arar/3/Asal/4/AwBlack/Aths//Rhn-08/7/Man/4/Bal16/Pro//Apm/DwII-1Y/3/ Api/CM67/5/Gas/OreS/6/Atahualpa/8/ IG 142356/9/Rabat 071
GRS17B0130	CC33MS/5/NY65005-18/3/13929/NUM/ASSE/4/KBR/6/ IG 146811/7/Rabat 071
GRS17B0131	CC33MS/5/NY65005-18/3/13929/NUM/ASSE/4/KBR/6/ IG 146811/7/GrangeR
GRS17B0132	Merzaga 077/Alanda-01// IG 145498/Oxford
GRS17B0133	Merzaga 077/Alanda-01// IG 145498/Rabat 071
GRS17B0134	Merzaga 077/Alanda-01// IG 146811/Compass
GRS17B0135	Merzaga 077/Alanda-01// IG 146811/Merzaga
GRS17B0136	Merzaga 077/Alanda-01// IG 83658/Rabat 071
GRS17B0137	Rhn-03//Lignee527/NK1272/3/Lignee527/Chn-01//Alanda/4/Osiris/5/ IG 142486/6/PETUNIA2/ M111 //QUINA/M112
GRS17B0138	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 145555/5/Flinders
GRS17B0139	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 145555/5/GrangeR
GRS17B0140	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 145555/5/Shepherd
GRS17B0141	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 145089/5/GrangeR
GRS17B0142	Alanda/5/Aths/4/Pro/TolI//Cer*2/TolI/3/5106/6/Baca'S'/3/AC253//CI08887/CI 05761/7/IG 145502 /8/Oxford
GRS17B0143	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 142356/5/Capstan
GRS17B0144	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 142356/5/Flinders
GRS17B0145	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 142356/5/Oxford
GRS17B0146	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 145508/5/Oxford
GRS17B0147	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 145535/5/Shepherd
GRS17B0148	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 116004/5/Oxford
GRS17B0149	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 38615/5/Shepherd
GRS17B0150	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 39884/5/Commander
GRS17B0151	Atahualpa//Alanda-01/Hamra/3/Keel/4/ IG 39933/5/Rabat 071
GRS17B0152	WI3257/4/ALISO/CI3909.2//HB602/3/MOLA/SHYRI//ARUPO*2/JET/5/ IG 142356/6/Commander
GRS17B0153	WI3257/4/ALISO/CI3909.2//HB602/3/MOLA/SHYRI//ARUPO*2/JET/5/ IG 142356/6/LAMOLINA96 /FALCON-BAR
GRS17B0154	WI3257/4/ALISO/CI3909.2//HB602/3/MOLA/SHYRI//ARUPO*2/JET/5/ IG 145555/6/LAMOLINA96 /FALCON-BAR

GRS17B0155	WI3257/4/ALISO/CI3909.2//HB602/3/MOLA/SHYRI//ARUPO*2/JET/5/ IG 145555/6/Oxford
GRS17B0156	WI3257/4/ALISO/CI3909.2//HB602/3/MOLA/SHYRI//ARUPO*2/JET/5/ IG 39884/6/PETUNIA2 /M111//QUINA/M112
GRS17B0157	WI3257/4/ALISO/CI3909.2//HB602/3/MOLA/SHYRI//ARUPO*2/JET/5/ IG 38615/6/ LAMOLINA96 /FALCON-BAR
GRS17B0158	WI3257/4/ALISO/CI3909.2//HB602/3/MOLA/SHYRI//ARUPO*2/JET/5/ IG 38615/6/Oxford

Lentil:

ICARDA supplies lentil nurseries to national programs comprising a range of genetically fixed materials and segregating populations to select according to their specific needs. On the basis of phenological adaptation, agronomically desirable traits, resistance to prevailing stresses, quality aspects, farmer's and consumer's preference, national scientists identify and select promising lines/single plants for eventual release for commercial cultivation. To date 137 lentil varieties have been registered in 34 countries for improved yield, disease resistance, and other traits. In South Asia, one of the major achievements is the breaking of an ancient bottleneck of narrow genetic base in lentil: The genetic base of South Asian lentils has been broadened through introgression of genes from its center of origin. In Bangladesh, adoption of improved varieties like BARImasur-4, BARImasur-5, BARImasur-6, BARImasur-7, and BARImasur-8 has led to an increase in lentil production from 119,639 tons in 2011 to 173,886 tons in 2015, the annual growth rate being 10.9% (Kumar et al. 2016[3]). In India, the crosses between Precoz and local lentils have resulted in the development of rust resistant large-seeded and early maturing cultivars. Some of them viz., VL Masoor 507, Narendra M1, Priya and Angoori with large seeds are popular among farmers in India. ICARDA in collaboration with NARS partners in India have initiated a pre-breeding program on lentil, which has been instrumental in introgressing useful genes in the mainstream breeding. Genes for yield traits like 100-seed weight and pods/plant have been discovered in *L. lamottei* and *L. culinaris* ssp *orientalis* (Singh et al. 2014[4]). Sources of extra earliness in ILWL118 having less than 90 days maturity and high iron and zinc content in ILWL74 and ILWL90 have encouraged breeders to biofortify short-duration lentil through pre-breeding. These germplasms have been utilized in ICARDA's breeding programs, resulting in a large number of elite lines from wide crosses in various yield trials, showing up to 40% yield advantage when tested in Moroccan research stations, in addition to early maturity, drought tolerance and high Fe and Zn content (**Fig 3**).

[3]Kumar J, Dikshit H, Ali O, Nath R, Sarker A and Kumar S. 2016. Lentil for rice-based cropping systems in South Asia. In: CRP DC and GL Review Meeting (phase 1: 2012-16) - Reflections on four years of research aimed to improve the lives of smallholder farmers, ICRISAT, India, 3-7 Oct 2016. Pp 36.

[4]Singh M, Bisht IS, Kumar S, Dutta M, Bansal KC, Karale M, Sarker A, Amri A, Kumar S and Datta SK. 2014. Global wild annual Lens collection: A potential resource for lentil genetic base broadening and yield enhancement. *PLoS ONE* 9(9): e107781. Doi 10.1371/journal.pone.0107781.

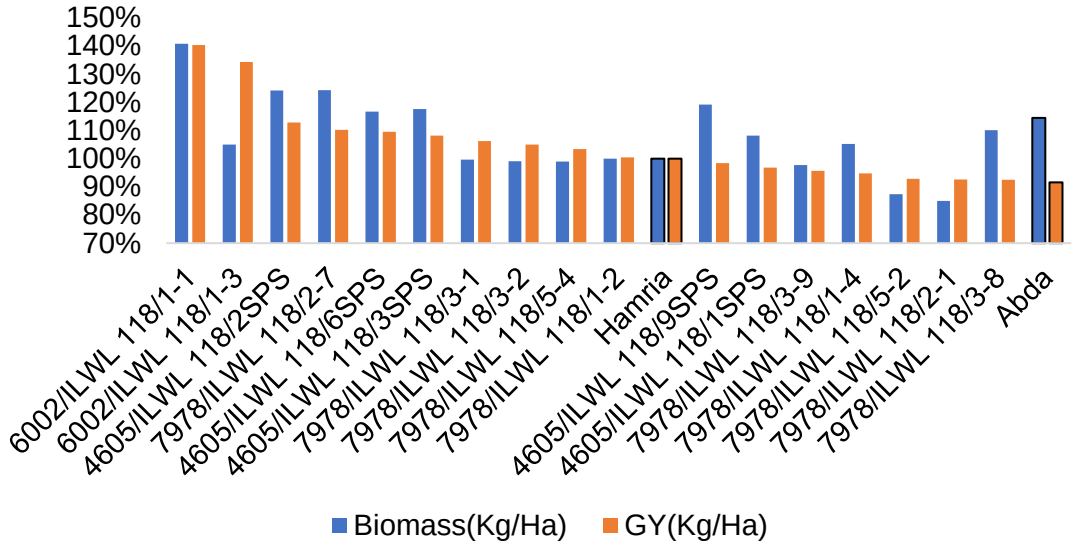


Fig 3. Performances of lentil elite lines derived from *Lens orientalis* (ILWL118) in Morocco during 2016-17 expressed as percentage of best commercial check (Hamria and Abda).

Since 2010, the lentil program has mainstreamed introgression of useful traits from the wild *Lens* species targeting primarily earliness, high iron and zinc content, Orobanche tolerance and Fusarium wilt resistance. Extensive use in hybridization of *Lens orientalis* derived lines ILWL118 (earliness and iron and zinc), ILWL 90 (high iron and zinc and Orobanche tolerance), and ILWL74 (high iron and zinc) has resulted in advanced breeding lines not only with earliness and high iron and zinc content but also high in yield and biomass in preliminary yield trials at Marchouch during 2016-17 season. Some of these lines have also shown partial tolerance to Orobanche, drought and Fusarium wilt. Several new crosses with wild ancestors are currently at the F_3, F_4 F_5, and BC_1F_3 stage, and their selection shall continue (**Table 4**).

In 2014, 39 pre-breeding lines were received from University of Saskatchewan and were screened against Orobanche in Morocco, followed by drought screening in 2015-16 (part of GS13051). Unfortunately, the material showed limited vigor, and unadapted flowering habit, with several photoperiod and temperature sensitive lines that never reached flowering. Furthermore, none of the lines tested showed tolerance to Orobanche. Hence, after two years of replicated field trials, it was not possible to identify any line worth promoting to yield trials nor to hybridization schemes.

Table 4. Lentil germplasm from wide crosses at various generations

Entry ID	Wild donor	Recipient	Generation
123806	*Lens orientalis* (ILWL118)	ILL 4605	F4
122635	*Lens orientalis* (ILWL118)	ILL 6002	F4
121796	*Lens orientalis* (ILWL118)	ILL 9787	F4
122256	*Lens orientalis* (ILWL118)	ILL 10140	F4
122236	*Lens orientalis* (ILWL417)	ILL 1880	F4
122656	*Lens orientalis* (ILWL90)	ILL 2585	F4
122156	*Lens orientalis* (ILWL118)	Sel 99/209	BC1F4
121060	*Lens orientalis* (ILWL417)	Sel 99/209	BC1F4

121170	*Lens orientalis* (ILWL368)	DPL 62	F4
123116	*Lens orientalis* (ILWL118)	F1X2011S	BC1F3
121130	*Lens orientalis* (ILWL90)	ILL 10140	F4
126026	*Lens orientalis* (ILWL76)	ILL 2585	F4
125886	*Lens orientalis* (ILWL37)	ILL 4605	F4
125706	*Lens orientalis* (ILWL79)	ILL 4605	F4
121090	*Lens orientalis* (ILWL90)	ILL 4605	F3
121210	*Lens orientalis* (ILWL203)	ILL 6994	F3
125096	*Lens orientalis* (ILWL113)	ILL 7978	F5
124276	*Lens orientalis* (ILWL371)	ILL 7978	F4
121816	*Lens orientalis* (ILWL118)	LRIL 22-1	F3
121190	*Lens orientalis* (ILWL245)	LRIL 22-107	F3

Justification

Wide crosses have proven very valuable for ICARDA's breeding programs. It is therefore a need to convert and insure the transfer of the good results obtained with the promising durum wheat, barley, and lentil on-station into impact in farmers' fields.

The pipeline for variety release and promotion in Morocco can be extremely slow and tedious. Similarly, Ethiopia, Senegal and Lebanon have strict requirements to achieve variety registration that can cause delays of up to 10 years. One of the main issues is the need for high purity of breeders seeds that must be derived from individual F_9 plants, a process that alone can require up to 3 years. Furthermore, seed multiplication of candidate varieties is often delayed until after the final registration is obtained, which can add additional 5 years to the process. Finally, farmers are seldom involved in the decision process of which varieties to release, and rarely made aware of new available varieties.

In this project we present a new model to create a paradigm shift and accelerate both release, fast-track pre-multiplication, and involvement of farmers in the decision process, while also making them aware of the new available varieties. In particular, the project targets the use of the off-season to accelerate the production of pure seeds, followed by a pre-multiplication since the moment a candidate variety is presented to the catalog, and a proven method for the involvement of farmers via participatory variety selection (PVS).

The basic principle is to utilize some of the poorest areas of Morocco as pilot study, since preliminary data on the yield superiority of CWR-derived elites is already available, to then promote both germplasm and method to other 3 partner countries (Lebanon, Senegal, and Ethiopia). In addition, the project includes a careful understanding of adaptation as well as nutritional value of the three crops across regions, which in turns ensures better targeting and aims at improving diets in poor rural communities.

Another component of this project is the creation and dissemination of new superior cultivars for tomorrow, through the exploitation of the CWR introgression generated in the first phase. The PVS process will identify existing gaps between the promoted CWR material and the farmers' preferences. These gaps will be converted into selection indexes and used to better target cultivars for tomorrow among the existing CWR segregating populations. In the course of the

project, the CWR segregating populations will be evaluated across sites, specific traits of interest will be identified, and pedigree selection used to integrate them into superior inbred lines.

Finally, both existing and to be developed CWR-derived elites, shall be promoted not only in farmers' fields, but also among fellow breeders from Morocco, Ethiopia, Senegal, and Lebanon. The absolute best CWR lines will enter the ICARDA international nurseries system and be disseminated to more than 100 partners in over 40 countries in the world. Also, the data generated from this project will be disseminated in the form of a research article to show the potential of CWR-derived varieties to the whole plant science community, similarly to the article of Zaim et al. 2017[5] and Sall et al. 2018[6]. All data generated will also be provided to Germinate 3 database for storage and use.

Beneficiaries

Farmers and breeders are the main beneficiaries of this project, but other actors along the value chain will also benefit such as plant scientists, seed companies, local NGOs and cooperatives, consumer, etc.

The selected target areas for on-farm demonstration in Morocco are among the poorest in the country (**Fig 4**)**.** Similarly, the Beqqa Valley in Lebanon is currently hosting over 1 million Syrian refugees, which is causing severe issues in terms of food security and employment of the local population. In Ethiopia, the target regions are the lowlands of Deraa and Alemthena, where droughts are a reality and the population lives with less than 1 dollar per day. Finally, the Senegal River is home to more than 1 million smallholder farmers families, and their survival depends entirely on the ability to ensure a good harvest against the growing temperatures exceeding 35 ºC throughout the growing season. In **Fig 5** is shown the predicted level of agriculture employment if agriculture technologies to face climate change are not put in place.

Farmers productivity per unit of land is tightly linked to the ability of the food industry to convert the harvest into products for the market. Hence, the promotion of varieties with enhanced capacity to yield more and produce more nutritious grains under severe stress has an impact on the whole national durum wheat value chain.

In addition, the demonstration to the farmers of new varieties that exceed the previous production shall promote their interest in the purchase of new certified grains. As such, the currently stagnating seed business could be revamped through this project. Furthermore, the model presented here ensures a fast variety turnaround time, thus favoring a more dynamic seed market.

Finally, breeders and plant scientists will be directly targeted in this project. The free delivery of superior CWR-derived elites shall ensure a renewed potential to generate genetic gain, but also it might convince more breeders and plant scientists to utilize this type of material in their programs.

[5]Zaim et al. 2017. Wide crosses of durum wheat (Triticum durum Desf.) reveal good disease resistance, yield stability, and industrial quality across Mediterranean sites. Field Crop Research 214: 219.

[6]Sall et al. 2018. Heat tolerance of durum wheat (Triticum durum Desf.) elite germplasm tested along the Senegal River. J. Agr. Sci. 10:217.

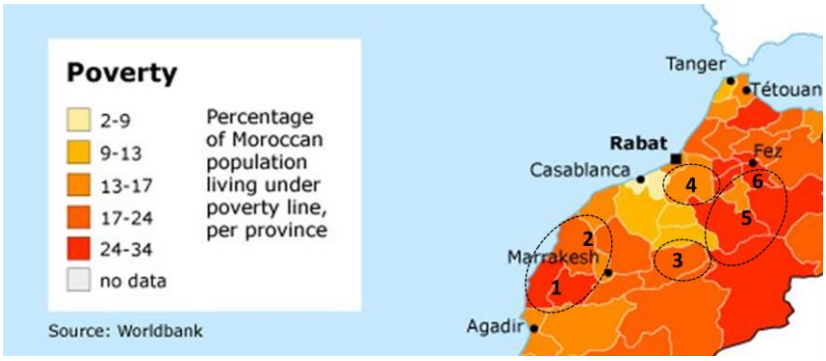


Fig 4. Poverty map of Morocco as described by the World Bank. The areas targeted by this project are indicated with dashed black circles, the number represents research stations used. Dry high plateaus with recurrent droughts, diseases, and pests: 1-Jemaa Shaim and 2-Sidi el Aydi represent area of Safi-Settat, 3-Tedla represents the area of Beni Mellal, 4-Marchouch represents Rommani-Tiflet-Kemisset area. Atlas Mountains with severe droughts and cold winters: 5-Annoceur station represents well the mountain area of 1000 to 2000 m altitude, 6-Douyet represents the 500-900 m altitude areas of Fes-Teounet-Taza.

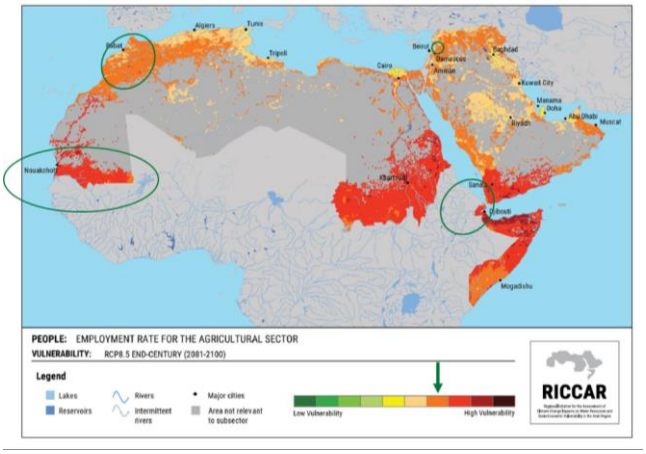


Fig 5. Vulnerability of employment in agriculture by 2100 as reported in *Arab Climate Change Assessment Report 2017*. Orange to red indicates severe vulnerability. The areas targeted by this project are presented as green circles. Data for Ethiopia and Senegal are not presented as these are not Arab countries, but their vulnerability can be estimated based on the results of the neighboring countries. The pixel resolution for Lebanon is low due to the scale of the map and small size of the country, but the actual value for the Beqaa Valley is of high vulnerability.

Feasibility

On the basis of the data already available, no issue can be foreseen in converting experimental data into appreciation by farmers. However, farmers are individuals with subjective preferences and work in complex systems. Hence, the key to success is to integrate their opinion in the variety development and variety release process and use their participative appreciation to determine the most suitable breeding lines for submission to the national catalog.

Further, the 2.5 years period set for this project allows for conducting two full field seasons (2018-19 and 2019-20) and the planting of a third. In addition, ICARDA's scientists have already dedicated 1 season (2017-18) to multiply seeds of candidate varieties for on-farm demonstrations. Altogether, this is a realistic amount of time to achieve the set goals. However, variety release in Morocco and other countries is a hard process involving two years of multi-location testing, very strict tests for homogeneity (less than 0.6% allowed), and objective decision by a committee of peers. Hence, it would be unrealistic to declare that varieties will be released in the timeframe of the project, even though we will attempt it, instead we have opted for declaring only submission to the catalog. Finally, the budget does not allow to work at full scale in more than one country. Hence, we have opted for focusing our efforts in two main regions of Morocco (Atlas Mountains and high-plateaus), which are the poorest rural regions, with severe recurring droughts, and where farmers have limited access to new agriculture technologies, such as improved varieties. The results obtained here can then be used to target testing in Ethiopian very dry lowlands, the Senegal River heat-prone environments, and the Beqaa valley of Lebanon. These regions were specifically selected as representing rural areas with raging poverty, severe climatic issues, and desperate need of new agriculture technologies.
ICARDA has several decades of experience working in these countries and can ensure good leadership for the project. More importantly, national partners from each target country are part of this work and their direct involvement shall guarantee the feasible achievement of all set goals.

Objectives and methodology

i. **Evaluate and fix most promising interspecific crosses from phase 1 pre-breeding projects (durum and barley) and evaluate and fix to inbreeding segregating germplasm derived from CWR (lentil):**
   Two Crop Trust funded projects (GS14026-durum wheat and GS16005-barley) have generated useful interspecific crosses for durum wheat and barley. This novel germplasm is currently at the BC_1F_2 or BC_2F_2 stage or the TC_1F_2, meaning that have reached 75% and 88% inbreeding, respectively. Also, most of the crosses were advanced as bulks, hence the heterogeneity within populations can be as high as 100%.
   In order to convert these BC, or TC into actual inbreds that could be considered for variety registration, three seasons of selection and selfing would be required. The following explanations apply to durum and barley; for simplicity the acronym BC is used to identify both types (BC durum and TC barley). In 2018, 15 spikes/ from each interspecific entry shall be planted, bulk threshed, and planted as twin rows in the off-season (BC_1 or BC_2 $F_{2:3}$). In 2018-19 season, the selected rows of BC_1 or BC_2 $F_{2:4}$ shall be planted as $3m^2$ plots in Marchouch, but also as small rows in Sidi el Aydi, Jemaa Shaim, Tadla, and Annoceur. From each location, the best individual plants will be selected and harvested. In summer 2019, the BC_1 or BC_2 F_5 seeds will be planted as plant-to-row and the selected ones bulk harvest. In 2019-20, the BC_1 or BC_2 $F_{5:6}$ seeds will be used to conduct preliminary yield trials at Marchouch. After the time-frame of the project, in 2020-21 the best lines will be used for multi-location yield testing.
   In the case of lentil, the Crop Trust funded project (GS13051-lentil) did not generate any material sufficiently adapted to Morocco for direct exploitation. On the other hand, several F_3, F_4 F_5, and BC_1F_3 progenies have been generated through hybridization with *Lens orientalis*

germplasm (ILWL37, ILWL76, ILWL79, ILWL90, ILWL113, ILWL118, ILWL203, ILWL245, ILWL368, ILWL371, ILWL417) to incorporate various desired traits in cultivated germplasm (**Table 4**). These progenies require two seasons to achieve the homogeneity required for evaluation in yield trials. In 2018, 607 single plant progenies from 20 interspecific crosses shall be planted, bulk threshed, and planted as 3-row plot in the off-season to test their homogeneity. In 2018-19 season, the selected plant progenies shall be planted as $3m^2$ plots in Marchouch, but also as small rows in Jemaa Shaim, and Terbol. From each location, the best individual lines will be selected and harvested. In summer 2019, seeds of the selection lines will be multiplied as bulk harvest. In 2019-20, preliminary yield trials of 20 best lines will be conducted at Marchouch and Terbol. After the time-frame of the project, in 2020-21 the best lines will be used for multi-location yield testing.

ii. **Conduct multi-locations trials in dryland research stations of Morocco (durum, barley, and lentil):**

None of the material generated from Crop Trust funded projects is ready for yield testing and on-farm trials (Objective *i*). However, several CWR-derived fixed lines generated by the ICARDA's breeding programs and gene bank have shown great potential during preliminary trials. During season 2017-18 these wide crosses are undergoing further validation, and multiplication. The final list of material to be used for field trials in 2018-19 can only be provided after completion of the harvest 2018. Still, **Tables 5, 6,** and **7** provide a list of the candidates undergoing validation for each crop, and from which a subset will be selected for 2018-19 trials.

Table 5. Elite inbred lines of durum wheat to be used for multi-locations yield testing, it includes 2 cultivars, 3 elite checks, 2 newly released varieties with CWR in the pedigree, and 17 CWR-derived elites

Entry	Pedigree	CWR
Karim	Jori/Anhinga//Flamingo	*none*
Bonidur	IRIDE/LINEA-PSB-0114	*none*
Kundermiki	MorlF38//Bcrch1/Kund1149/3/Bicrederaa1/Miki	*none*
Chicca	CandocrossH25/3/Mrf2/NormalHamari//Bcr/Lks4/4/Bergh ouata1	*none*
Zagharin2	Icasyr1/3/Gcn//Stj/Mrb3	*none*
Jabal	Korifla/AegSpeltoidesSyr//Mrb5	*Ae. speltoides*
IDON3954	Korifla/AegSpeltoidesSyr/Amedakul	*Ae. speltoides*
Faraj	413J.S/3/Arthur71/Lahn//Blk2/Lahn/4/Quarmal	*T. araraticum*
Icaverve	Azeghar1/4/IcamorT. araraticum0462/3/Maamouri3//Vitron/Bidra1/5/Mgnl3/Ain zen1	*T. araraticum*
IDON3929	Azeghar2/5/IcamorT. araraticum0462/4/Stj3//Bcr/Lks4/3/Icamor"s"/6/Stj3//Bcr/L ks4/3/Ter3	*T. araraticum*
IDON3970	CandocrossH25/Bicrederaa1/3/ICAMORT. araraticum0463//Lah/Ch12504/4/Bcrch1//Ossl1/Stj5/5/Ysf 1/Otb6	*T. araraticum*
IDON3918	IcamorT. araraticum041/4/IcamorT. araraticum0469/3/Bcr/Gro1//Mgnl1/5/MIKI2	*T. araraticum*
IDON3913	IcamorT. araraticum0462/4/Gdr2//SwAlg/Gdr1-43/3/IcamorT. araraticum0463/5/Ter1//Mrf1/Stj2	*T. araraticum*
Zeina	IcamorT. araraticum0471//IcamorT. araraticum0459/Ammar8/4/Stj3//Dra2/Bcr/3/Ter3	*T. araraticum*
Icaqinzen	IcamorT. araraticum0472//Quarmal/Gbch2/3/Mgnl3/Ainzen1	*T. araraticum*
Icamoram7	ICAMORT. Araraticum0472/Ammar7	*T. araraticum*
ADYT15M-82	IcamorT. araraticum459/4/Gdr2//SwAlg/Gdr1-43/3/IcamorT. araraticum463/5/Ammar1	*T. araraticum*
IDON3996	Maamouri1/5/IcamorT. araraticum0462/4/Stj3//Bcr/Lks4/3/Icamors/6/Mgnl3/Ainz en1	*T. araraticum*
IDON3927	Quabrach1/4/IcamorT. araraticum0462/3/Maamouri3//Vitron/Bidra1/5/Murlagost 2	*T. araraticum*
Maghrour	Amedakul1/TdicoSyrCol//Cham1	*T. dicoccoides*
Nachit	Amedakul1/TdicoSyrCol//Loukos	*T. dicoccoides*
DAWRyt123	Mrb5/TdicoAlpCol//Cham1	*T. dicoccoides*
Sahi	Icasyr1/3/Bcr/Sbl5//Turartu/4/13376/Bcrch1//Ossl1/Stj5	*T. urartu*
IFWON-48	SwAlg/Gd171/4/Icasyr1/3/Bcr/Sbl5//Turartu	*T. urartu*

Table 6. *H spontaneum* elite inbred lines of barley to be used for multi-locations yield testing

SN	Cross name
1	SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1/5/Roho/4/Zanbaka/3/ER/Apm//Lignee131
2	ChiCm/An57//Albert/3/Alger/Ceres.362-1-1/4/Arta/5/Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**
3	WI2291/Tadmor/4/ChiCm/An57//Albert/3/Alger/Ceres362-1-1/5/SLB34-40/4/SLB15-05/3/**H.spont.21-3**/Arar84//WI2291/Bgs
4	Soufara-02/3/RM1508/Por//WI2269/4/Hml-02/ArabiAbiad//ER/Apm/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
5	Clipper//WI2291*2/WI2269/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
6	Clipper//WI2291*2/WI2269/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
7	Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**/4/Arta/3/Arar/H.spont.19-15//Hml
8	Moroc9-75//WI2291/WI2269/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
9	Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**/4/Arta/3/Arar/**H.spont.19-15**//Hml
10	ChiCm/An57//Albert/3/Alger/Ceres362-1-1/4/Arta/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
11	ChiCm/An57//Albert/3/Alger/Ceres.362-1-1/4/Arta/5/Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**
12	ChiCm/An57//Albert/3/Alger/Ceres362-1-1/4/Arta/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
13	WI2291/Tadmor/4/ChiCm/An57//Albert/3/Alger/Ceres362-1-1/5/SLB34-40/4/SLB15-05/3/**H.spont.21-3**/Arar84//WI2291/Bgs
14	Zanbaka/5/Pyo/Cam//Avt/RM1508/3/Pon/4/Mona/Ben//Cam/6/Moroc9-75/ArabiAswad/7/ArabiAbiad /Arar//**H.spont.41-5**/Tadmor
15	Roho/4/Zanbaka/3/ER/Apm//Lignee131/5/Moroc9-75//WI2291/CI01387/3/H.spont.41-1
16	ChiCm/An57//Albert/3/Alger/Ceres.362-1-1/4/Arta/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
17	Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**/5/Clipper/Volla/3/Arr/Esp//Alger/Ceres362-1-1/4/Hml
18	ChiCm/An57//Albert/3/Alger/Ceres.362-1-1/4/Arta/5/Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**
19	ChiCm/An57//Albert/3/Alger/Ceres.362-1-1/4/Arta/5/Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**
20	Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**/5/Clipper/Volla/3/Arr/Esp//Alger/Ceres362-1-1/4/Hml
21	Clipper//WI2291*2/WI2269/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
22	Moroc9-75//WI2291/CI01387/3/**H.spont.41-1**/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1
23	Soufara-02/3/RM1508/Por//WI2269/4/Hml-02/ArabiAbiad//ER/Apm/5/Moroc9-75//WI2291/CI01387 /3/**H.spont.41-1**
24	Clipper//WI2291*2/WI2269/5/SLB15-05/4/**H.spont.96-3**/3/Roho//Alger/Ceres362-1-1

Table 7. Elite inbred lines of lentil to be used for multi-location yield testing, it includes CWR-derived elites and one standard check (ILL4605)

Entry name	Pedigree	*CWR*
2018-CWR-1301	ILL6002/ILWL118/1-1	*Lens orientalis*
2018-CWR-1302	ILL4605/ILWL118/1SPS	*Lens orientalis*
2018-CWR-1303	ILL4605/ILWL118/2SPS	*Lens orientalis*
2018-CWR-1304	ILL4605/ILWL118/3SPS	*Lens orientalis*
2018-CWR-1305	ILL4605/ILWL118/6SPS	*Lens orientalis*
2018-CWR-1306	ILL4605/ILWL118/9SPS	*Lens orientalis*
2018-CWR-1307	ILL7986/ILWL074/10SPS	*Lens orientalis*
2018-CWR-1308	ILL6002/ILWL118/1-3	*Lens orientalis*
2018-CWR-1309	ILL7978/ILWL118/3-8	*Lens orientalis*
2018-CWR-1310	ILL7978/ILWL118/3-1	*Lens orientalis*
2018-CWR-1311	ILL7978/ILWL118/1-4	*Lens orientalis*
2018-CWR-1312	ILL2585/ILWL90/2	*Lens orientalis*
2018-CWR-1313	ILL7978/ILWL118/3-5	*Lens orientalis*
2018-CWR-1314	ILL7978/ILWL118/3-9	*Lens orientalis*
2018-CWR-1315	ILL7978/ILWL118/1-2	*Lens orientalis*
2018-CWR-1316	ILL7978/ILWL118/5-4	*Lens orientalis*
2018-CWR-1317	ILL2585/ILWL90/9-5	*Lens orientalis*
2018-CWR-1318	ILL7978/ILWL118/2-1	*Lens orientalis*
2018-CWR-1319	Sel-99/209/ILWL118/5-1	*Lens orientalis*
2018-CWR-1320	ILL7978/ILWL118/5-2	*Lens orientalis*
2018-CWR-1321	ILL7978/ILWL118/3-2	*Lens orientalis*
2018-CWR-1322	ILL2585/ILWL90/11	*Lens orientalis*
2018-CWR-1323	ILL2585/ILWL90/4-3	*Lens orientalis*
2018-CWR-1324	ILL7978/ILWL118/2-7	*Lens orientalis*
2018-CWR-1325	Standard check (ILL4605)	*Lens culinaris*

Multi-location trials shall be conducted in 2 reps alpha lattice design, in plots of 7 m^2, with side by side comparison to the most widely cultivated commercial varieties. Four main stations will be used for these trials: Marchouch, Sidi el Aydi, Jemaa Shaim, Tadal, and Annoceur. Station selection is based on their representation of the Atlas mountains and dry high-plateaus type of environments. Statistical significant yield superiority will be determined and GxE effect controlled via stability models. The entries showing yield superiority to the commercial checks will be promoted to farming communities of the region. In addition, the best elites will enter the system of the International Nurseries of ICARDA and will be shared with over 100 partners in more than 40 countries.

iii. **Assess the nutritional value/quality analysis (durum, barley, and lentil):**
Yield of protein, macro, micro nutrients, fibers, and suitability for food transformation shall be measured from at least 2 environments each year. The nutritional and quality value of the

lines will be combined to the field performances to determine the superior candidates for on-farm demonstration and variety registration.

iv. Conduct on-farm participatory selection (PVS) (durum, barley, and lentil):

On-farm trials require the production of large quantities of seeds to accommodate large surfaces for demonstration. Before the beginning of this project, ICARDA has already engaged consistent resources to multiply the most suitable lines for demonstration. In addition, a special technical team is required to conduct this type of trials and provide adequate follow up to the testing farmers. For these reasons and in consideration of the limited budget and time, only Morocco will be targeted for on-farm trials as part of this project. Here, ICARDA has partnered with the national research institute (INRA). Together and with the input of the Ministry of Agriculture, ideal farming communities will be identified to conduct demonstration trials. Several criteria are utilized to determine the most suitable farmers: i. part of a larger cooperative, ii. sufficient land to accommodate the trials, iii. ability to read and write, iv. proximity to one of the four research stations or at least similarity of agro-environmental conditions to one of the research farms, and v. the recognizable respect of his/her neighbors. On-farm trials will be planted as 'exploratory' in 2019, with few farmers, each receiving 6-10 candidate varieties for each one of the crop. These will be planted in 200 m^2 plots. During the growing cycle, the lead farmer hosting the trials will be requested to record his/her impression following a standard questionnaire used by ICARDA in previous PVS work (Walker 2007[7]; Ceccarelli & Grando, 2007[8]). A technical team will ensure the trial is correctly maintained and ideal agronomical practices are applied. After flowering, each lead farmer will be provided the funds to invite his/her neighbors to visit the trials. Before the visit, each farmer will be requested to respond to basic questions on his/her preference for certain traits, current yield in the farms, appreciation for various crops, and access to market. Gender, farm size, and age disaggregate data will be collected. During the visit, the farmers will be requested to match their traits of preference with the candidate varieties under demonstration using a score of 1 to 5. After the visit, the results will be analyzed to identify the visual preference of farmers. At maturity, grain yield and its components will be measured. A second farmers day will be held, a base line on interest for specific traits re-created. After this, the yield data and the preference data will be unveiled. At the same time, the harvested grains will be made available for farmers to look at and decide if these match their preference. Farmers cooperatives will then be requested to meet and identify together the most suitable varieties for their region. These preferences will be converted into letters addressed to the Ministry of Agriculture and included in the variety submission documents.

All results obtained will be computed into a selection index used to weight the preference for each candidate variety (Alary et al., 2018[9]). This is a new methodology recently developed by ICARDA's scientists to incorporate PVS into the breeding pipeline, with a stronger power to target multiple farmers communities and ensuring a stronger respect for the breeders long term vision and knowledge.

[7]Walker et al. 2007. Participatory Varietal Selection, Participatory Plant Breeding, and Varietal Change. World Bank

[8]Ceccarelli and Grando, 2007. Decentralized-participatory plant breeding: an example of demand driven research. Euphytica 155:349.

[9]Alary et al. [under revision]. Are objectives of global wheat breeding programs aligned with smallholder farmers' preferences? Crop Science.

v. **Propose for registration in the national catalogue of Morocco via a novel fast-track purification and pre-multiplication (durum, barley, and lentil):**
The yield data from research stations shall be used to determine true genetic (G) and stability (GxE) of the tested lines. Nutritional and transformation quality shall also be used to determine the intrinsic value of the lines under testing. The on-farm PVS shall provide additional yield information, as well as a clearly defined selection index for each region based on-farmers' preferences. The combination of these three criteria will identify the best candidate varieties to submit for registration. However, the registration system requires the respect of several requirements, among which a very high level of homogeneity for the submitted lines. In the case of Morocco, this value is particularly strict, with only 0.6% of heterogeneity allowed. To achieve this, 25 kg of seeds derived from single F_9 plant need to be provided. Since seed purification is a time consuming and complex process, this is normally initiated only at the final stages, when only 1-2 candidate varieties are left. Instead, in order to accelerate this process, the production of pure seeds for the catalog submission will start from the initial field trial in 2019 when more than 10 candidates will still be competing, and it shall also be combined with the use of the off-season to ensure faster delivery. In summer 2019, 12 spikes from each of the lines selected for trials will be planted in the summer season of Annoceur as spike-to-row, and 6 selected as homogeneous. In 2019-20, seeds harvested from each selected spike-to-row will be used to make row-to-plot of 5 m^2, and 3 homogenous plots harvested individually. In summer 2020, 100 m^2 plots will be planted from each row-to-plot, and 2 harvested independently. In 2020, two 1,000 m^2 plots will be planted for each selected candidate varieties. After the timeframe of the project, from one plot, 25 kg of pure seeds will be harvested and used for submission to the variety catalog in Morocco. Farmers letters and description of results will also be included as part of the submission to facilitate both release and subsequent dissemination. Also, the remaining seeds will be planted in 0.1 ha multiplications, for fast-track dissemination once varieties are released. Pure seeds from these multiplications will also be provided to Senegal, Lebanon, and Ethiopia to simplify their variety registrations and fast-track dissemination.

vi. **Accelerate variety release for Beqaa Valley in Lebanon (durum, barley, and lentil):**
Lebanon, similarly to Morocco has a slow variety release process that requires detailed testing across sites before accepting the registration. However, variety release can be achieved faster since the multi-location testing is sufficient for release, without the need of 2 extra years of catalog trials.
The same CWR germplasm tested on-station in Morocco will also be included in variety testing in Lebanon. During the 2018-19 season, the stations of Terbol, Tel Amara, and Kfardan, which represent the three main environments of the Beqaa Valley. Before harvest, 12 spikes will be harvested from each candidate line, and those of the selected ones will be planted in the 2019 summer off-season. In the season 2019-20, the selected entries will be tested again at the same 3 stations. At the same time, the seeds harvested from each selected spike-to-row in summer will be used to make row-to-plot of 5 m^2, and 3 homogenous plots harvested individually. In summer 2020, 100 m^2 plots will be planted from each row-to-plot, and 2 harvested independently. The candidates that confirmed superior performances to the commercial checks over the two seasons and across sites will be directly submitted to the Ministry for registration in the national variety catalog. After the timeframe of the project,

the pure seeds produced in summer 2020 will be used by LARI for starting the multiplication of the varieties, while the grains harvested from the yield trials will be used to initiate on-farm demonstrations.

vii. **Assess in the low-lands of Ethiopia (durum, barley, and lentil):**
The variety release system of Ethiopia requires three to four years of multi-locations yield trials. However, targeting of lowland agriculture has become a priority only recently, so fast track 2 years release can be obtained if truly superior entries are identified for these areas.
In the season 2019-20, four sets of yield trials containing the best CWR elites identified for the drylands of Morocco will be provided to the national research institute (EIAR) for multi-location testing at the research stations of Debre Zeit (good and light soils), Deraa, Holetta and Alemtena. Testing against the most adapted commercial varieties will be used to determine the suitability of the CWR elites to the lowland conditions of Ethiopia. After the timeframe of the project, the best entries will be tested for a second season, and the most suitable promoted for variety registration.

viii. **Assess for adaptation to heat stress in Senegal (durum, and lentil):**
The variety release system of Senegal requires three to four years of multi-locations yield trials. However, durum wheat is a very novel crop for the Senegal River, so fast track 2 years release can be obtained if truly superior entries are identified.
In season 2019-20, one set of yield trials containing the best CWR elites identified for the drylands of Morocco will be provided to the national research institute (ISRA) for testing at the research stations of Fanaye. Testing against the recently released varieties will be used to determine the suitability of the CWR elites to the heat-prone conditions of the River. After the timeframe of the project, the best entries will be tested for a second season including also additional stations in Mauritania, and the most suitable will be promoted for variety registration.

ix. **Share the best material containing CWR introgressions with breeders and plant scientists (durum, barley, and lentil):**
The ICARDA's international nursery (IN) system is a global network of several hundred breeders worldwide, mostly based in developing countries. Through this network, ICARDA's partners request the best advanced material, obtain their seeds and test these in their own field station. Seeds are sent under SMTA, meaning that any breeders can use these international nurseries rather as an ideal source of hybridization, or in most cases are tested against the best commercial varieties, and the superior lines are directly released as varieties. In 2017, the durum program distributed germplasm to 96 partners in 41 countries, barley to 105 cooperators in 51 countries, and lentil to 45 cooperators in 25 countries.
These nurseries are the final product of all ICARDA's breeding programs, meaning that all material with superior performances is included in these sets. In the cases of this project, two types of material can be sent out as IN: i. The fixed and evaluated germplasm from Phase 1 projects, which will reach the first year of yield trials by the end of this project, but could be sent out as IN 2-3 years later. ii. The already fixed material, once tested across locations can show good yield superiority and hence be sent out as IN. In addition, durum wheat breeders from the four target countries (Morocco, Senegal, Ethiopia, and Lebanon) shall be invited in the second year to take part in a traveling workshop to see firsthand the

good performances of CWR-derived elite lines and conduct their selection. Finally, the data obtained as part of this project will be shared with the whole community for all three crops in the form of a peer-reviewed scientific article.

2. Work plan

The timeframe of the project allows for only two full crop seasons: 2018/19, 2019/20. Yet, in season 2017/18, the proposed inbred elite material for each crop has been already pre-multiplied in 100m^2 plots and already pre-tested across a limited number of sites that are indicated in the project plan below. The full set of activities and objectives is described previously. Yet, there are two types of germplasm that are included in this project, each corresponding to different activities: **i.** segregating germplasm derived from Phase 1 pre-breeding project funded by the Crop Trust, which will undergo breeding selection and field evaluation across sites; **ii.** Inbred elites derived from CWR produced by ICARDA not as part of a Crop Trust funded projects, which will be field tested across locations in 4 countries, used for on-farm trials, and purified for variety consideration in Morocco and Lebanon. In the case of durum wheat, the CWR-derived elites named 'Jabal' and 'Icaverve' (**Table 5**) are ready for submission for variety release in 2019, and hence could be released within the timeframe of the project. Outlook for 2021 is provided to explain the practical output of the project. The following work plan is intended for all three crops.

<u>2018</u>

1) Hire personnel and finalize agreements with national partners
2) Evaluate and fix interspecific crosses from phase 1 pre-breeding projects.
   Nb: BC is used to identify both BC (durum) and TC (barley) crosses. In the case of lentil, other generations will be under selection, full details for breeding selection of those are reported above in the text description. Here only the segregating material derived from Phase 1 projects of the Crop Trust are presented.
   a. BC_1 or BC_2 F_2 : Select 15 spikes from each and thresh in bulk
   b. BC_1 or BC_2 $F_{2:3}$: Plant as twin rows in summer season, bulk harvest
   c. BC_1 or BC_2 $F_{2:4}$: Plant in plot and short row across environments
3) Multi-location testing across Moroccan sites:
   a. Among the list provided in **Table 5, 6,** and **7**: identify most promising wide crosses of durum wheat, barley, and lentil for further field testing.
   b. Prepare a special set of germplasm for multi-location trials including some commercial checks, which are cultivated by the targeted farmers
   c. Conduct the trials under different environmental conditions at different research stations: Marchouch, Sidi el Aydi, Jemaa Shaim, Douyet, Annoceur and Tadla
4) Nutritional value/quality analysis
   a. Validate existing protocols for all crops
5) Participatory farmers' selection
   a. For the lines selected for multi-location testing, sow 0.1 ha plots for pre-multiplication
   b. With the help of the Ministry of Agriculture regional representatives, identify 5 farmers that respond to the selection criteria, and sign contracts for conducting participatory variety selection (PVS) in the following season
6) Accelerate variety release in Lebanon:

a. The same set of promising wide crosses of durum wheat, barley, and lentil used for Morocco will be provided to Lebanon.
b. Lebanese commercial checks will be included
c. Conduct the trials under different environmental conditions at different research stations: Terbol, Kfardan, and Tel Amara

2019

1) Evaluate and fix interspecific crosses
   a. BC_1 or BC_2 $F_{2:4}$: In each environment select in each best individual plants.
   b. BC_1 or BC_2 F_5 : Plant as plant-to-row in summer season, harvest each selected row
   c. BC_1 or BC_2 $F_{5:6}$: Plant as preliminary yield trials at one site in plots of $3m^2$
2) Multi-location testing trials across Moroccan sites:
   a. Collect yield and its components from multi-location testing
   b. Conduct statistical analysis and identify, for each station, the four most promising genotypes
   c. Repeat the experiment of year 1 at the field stations of: Marchouch, Sidi el Aydi, Jemaa Shaim, Annoceur, Douyet, and Tadla
3) Nutritional value:
   a. Asses the harvested grains from multi-location trials for nutritional value
4) Participatory farmers selection in Morocco
   a. Harvest 0.1 ha multiplications and assess yield performances
   b. From the 0.1 ha multiplications, and using the best 4-6 lines identified from multi-location trials and 2 commercial checks, prepare 5 on-farm trials each with plot size of 0.01 ha.
   c. Organize two farmers day for each of the five lead farmers hosting the trials. Use objective interview sheets to collect farmers appreciation and opinions.
5) Variety release Morocco
   a. Before harvest, collect 12 spikes for durum and barley, and 12 single plant seeds for lentil for each plot and plant it in summer season in Annoceur for line purification.
   b. In summer, plant as spike-to-row and harvest individually the 6 most homogeneous
   c. In on-season, plant 6 homogeneous spike-to-row in plots of $10m^2$
   d. Monitor the plots for homogeneity
6) Accelerate variety release in Lebanon
   a. Before harvest, collect 12 spikes for durum and barley, and 12 single plant seeds for lentil for each plot and plant it in summer season in Terbol for line purification.
   b. Collect yield and its components from multi-location testing
   c. Conduct statistical analysis and identify, for each station, the four most promising genotypes
   d. In on-season, plant 6 homogeneous spike-to-row in plots of $10m^2$
   e. Monitor the plots for homogeneity
   f. Repeat the experiment of year 1 at the field stations of: Terbol, Kfardan, and Tel Amara.
7) Assess performance in the lowlands of Ethiopia

a. Most promising drought tolerant lines of durum, barley, and lentils will be provided for testing at the lowland station of Deraa, Alemtena, and heavy and light soils in Debre Zeit in Ethiopia

8) For durum wheat and lentil, assess performance in the heat-prone station of Senegal
   a. Most promising lines to be provided for testing at the heat-prone station of Fanaye in Senegal

2020

1) Evaluate and fix interspecific crosses
   a. BC_1 or BC_2 $F_{5:6}$: Conduct preliminary yield trials in plots of $3m^2$ in Marchouch.
   b. BC_1 or BC_2 F_5 : Plant as plant-to-row in summer season, harvest each selected row
2) Multi-location testing across Moroccan sites:
   a. Collect yield components from multi-location testing
   b. Conduct statistical analysis and identify the most promising genotype for each crop and each station
3) Nutritional value
   a. Assess the harvested grains from multi-location trials for nutritional value
   b. Conduct statistical analysis for nutritional value, and express each crop at each site as a function of daily nutritional value generated per ha
   c. Publish a scientific article to describe the achieved results
4) Participatory farmers' selection
   a. Conduct participatory farmers' selection with the five communities per site
   b. Harvest on-farm trials and asses yield
   c. Combining farmer's preferences, multi-location trials on-station, and nutritional value, identify the best genotypes to demonstrate further
5) Variety release in Morocco
   a. Select 3 most homogenous spike/SPS-to-row-to-plot/single plant progenies
   b. Harvest the selected plots, and plant as 100 m2 large plots in the off-season.
   c. Harvest the 2 most homogeneous plots individually.
   d. In the on-season, plant 100 m^2 plots, form one of these it will be collected 300 spikes and 25 Kg for variety catalog submission
6) Accelerate variety release in Lebanon
   a. Collect yield and its components from multi-location testing
   b. Conduct statistical analysis and identify, for each station, the four most promising genotypes
   c. Use two seasons data to identify the best candidates and submit to the Ministry for registration in the catalog.
   d. Select 3 most homogenous spike/SPS-to-row-to-plot/single plant progenies
   e. Harvest the selected plots, and plant as 100 m2 large plots in the off-season.
   f. Harvest the 2 most homogeneous plots individually.
   g. In the on-season, plant 100 m^2 plots. Form one of these it will be collected pure seeds for variety pre-multiplication.
7) For all crops, assess in the high and lowlands of Ethiopia
   a. Collect yield components from two lowland stations

b. Conduct statistical analysis and identify the most promising genotype for each crop and each station
c. Repeat the experiment at the two stations using only the most promising genotypes

8) For durum wheat and lentil, assess in the heat-prone station of Senegal
a. Collect yield components from the heat affected station
b. Conduct statistical analysis and identify the most promising genotype for each crop
c. Repeat the experiment, adding one more station in Mauritania for the best genotypes.

[2021 Outlook]

1. Evaluate and fix interspecific crosses

BC_1 or BC_2 $F_{5:7}$: Conduct multi location advanced yield trials. By now the lines have become >99% inbred, and with 3.2% or 1.5% heterogeneity, respectively.

2. Variety release

In 2021 varieties are submitted, in 2022 the first year of field data becomes available to the release committee. Only varieties that are less than 0.8 % heterogeneous will be promoted to year 2 testing. Varieties that pass the first year testing are normally released the following year.

3. Assess in the high and lowlands of Ethiopia

In 2021 the best genotypes will have accumulated 2 seasons of on-field trials and will become now candidates for variety release in Ethiopia.
This second year testing will be partially supported from TAAT project awarded to Solomon Assefa by the African Bank for Development.

4. Assess in the heat-prone station of Senegal

In 2021 the best genotypes will have accumulated 2 seasons of on-field trials and will become now candidates for variety release in Senegal and Mauritania.
This second year of field trials will be partially supported by project U-Forsk2018, awarded to Filippo M Bassi and Rodomiro Ortiz by the Swedish Research Council.

3. Plan for conservation and availability of germplasm

ICARDA exchanges freely germplasm under SMTA terms and conditions. All partners have the right to access this germplasm and use it for breeding, research and education. After release, the national programs will be granted the right to exploit the released varieties within the collaborative agreements. ICARDA's breeding programs exchange germplasm annually with hundreds of partners worldwide. All identified material from this project will be freely provided to those partners and can be immediately deployed via breeding or direct release. ICARDA's material follows closely the distribution of its germplasm and annually request an assessment of impact to its partners in terms of variety releases, use in breeding programs, use in research discoveries, and adoption by farmers. In addition, all tested material will be recorded with IG number (if not yet available) in year 3 and provided to ICARDA's gene bank for long-term storage and distribution.

4. Plan for communicating and publicizing results

ICARDA's communication team will actively collect the most fascinating results from this project and provide them back to ICARDA and Global Crop Diversity Trust communication teams. Annually, the two organizations will exchange a communication document that summarizes the most striking stories and pictures. In agreement, the two organizations will then attempt to publicize these results in the press and other media. The scientists involved in this project will make themselves available to interviews, writing of blogs and articles.
In addition, the work conducted in Senegal will be linked to the press campaign generated for the OLAM Prize for Innovation in Food Security, which has reached thus far over 60 web interfaces in Africa, Europe, and USA. Finally, the work in Ethiopia will be linked with ICARDA's core activities and communication campaign, and provided due visibility, depending on results.
Finally, in year 2 and year 3, durum wheat scientists will be invited to participate in short workshops to gain full exposure to the developed and under-development CWR germplasm, to better grasp and promote its utilization in their countries of origin.

C. PROJECT PARTNERS

1. Project Management Plan (1 page)

The submitted project builds on existing collaborations between ICARDA, INRA-Institut National de la Recherche Agronomique of Morocco, ISRA-Institut Senegalese de la Recherche Agricole, LARI-Lebanese Agriculture Research Institute, and EIAR – Ethiopian Institute of Agricultural Research. Research agreements have been put in place between these institutions and reliable scientific output has been generated over the years.
The management plan for this project follows the general guidelines in **Fig 7**. A scientific committee of three ICARDA's PI and co-PIs with expertise in each crop will provide oversight, guidance, and take technical decision. This committee oversight a project secretariat composed of the technical staff, the research staff, and the project administration. The project team will be responsible of signing detailed research agreements with all partners, including clear outputs and deadlines for annual scientific and financial reports. The project team would then be responsible to conduct the research in partnership, collect annual reports, and redact and finalize documents to be first approved by the Scientific committee, and then shared with the Crop Trust. Finally, the obtained results will be annually entered in the Monitoring Evaluation and Learning (MEL) platform and Crop Trust will be given access to monitor the progress in real time.

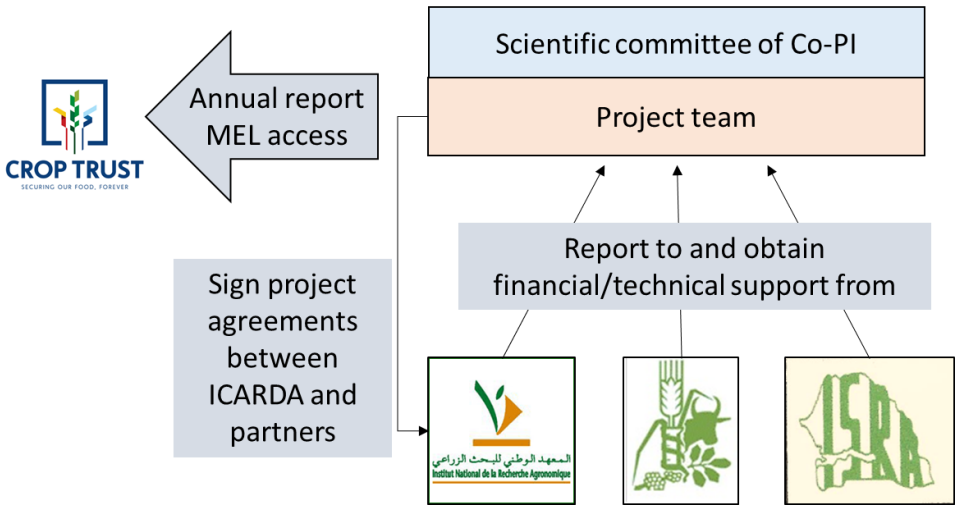


Fig 7. Schematics of reporting and support strategies for project implementation.

2. Implementing institutions and individuals

Implementing institution	Individual (name and position)	Gender	Role and responsibilities in project	Contact details (address, phone, email)
ICARDA	*Filippo M Bassi, durum wheat breeder*	*Male*	*Lead PI, responsible also for reporting to the Crop Trust*	ICARDA Av. Mohamed Belarbi Alaoui, Al Ifrane, Rabat 1000 Morocco f.bassi@cgiar.org
ICARDA	*Verma Ramesh, spring barley breeder*	*Male*	*Co-PI*	ICARDA Av. Mohamed Belarbi Alaoui, Al Ifrane, Rabat 1000 Morocco r.verma@cgiar.org
ICARDA	*Shiv Kumar, lentil breeder*	*Male*	*Co-PI*	ICARDA Av. Mohamed Belarbi Alaoui, Al Ifrane, Rabat 1000 Morocco *Sk.agrawal@cgiar.org*
ICARDA	*TBD, research assistant*	*TBD*	*Research staff, responsible for MEL reporting*	
ICARDA	*TBD, field technician*	*TBD*	*Technical staff*	
ICARDA	*TBD, field technician*	*TBD*	*Technical staff*	
ICARDA	*TBD, field technician*	*TBD*	*Technical staff*	
ICARDA	*TBD, field technician*	*TBD*	*Technical staff*	

3. Collaborators

The final list of names of cooperators will be defined after agreement with Crop Trust has been reached. The following names are suggestions based on previous joined projects. One PI will be selected in each country, who shall coordinate the activities for all three crops.

Collaborating institution	Individual (name and position)	Gender	Role and responsibilities in project	Contact details (address, phone, email)
INRA-MOR	Dr Jilal, Abderrazek, barley breeder	Male	NARS research partner	INRA Av. Mohamed Belarbi Alaoui, Al Ifrane, Rabat 1000 Morocco abderrazek_2001@YAHOO.fr
ISRA/ICARDA	Dr Amadou Sall, breeder	Male	NARS research partner	ISRA Centre de Recherche Agricole BP 240- Saint Louis Médina Champs de courses Bel Air, Senegal tidianesall11@yahoo.com
EIAR	Mr Lagesse Wasihun, durum breeder	Male	NARS research partner	Debre Zeit Agriculture Research Centre, Debre Zeit, Ethiopia wasihunl@yahoo.com
LARI	Dr. Rola Amil, cereal pathologist	Female	NARS research partner	Lebanese Agriculture Research Institute, Zahlé - Baalbek Hwy, Tal Amara campus. ramil@lari.gov.lb

ANNEX E

GRANT AGREEMENT BETWEEN
THE NORWEGIAN MINISTRY OF FOREIGN AFFAIRS AND
GLOBAL CROP DIVERSITY TRUST
REGARDING
QZA-14/0005, Adapting Agriculture to Climate Change: Collecting, Protecting and preparing Crop Wild Relatives (Phase III)