The International Treaty
ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Full Project Proposal Format

Third Call for Proposals under the Benefit-sharing Fund

Deadline for submitting full project proposal: 5th of December 2014
at Treaty-Fund@fao.org and PGRFA-Treaty@fao.org

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PROJECT PROPOSAL COVER SHEET

Project No. ________________ (*For Treaty use. Do not write anything here)*

Project Title: An Integrated Approach to Identify and Characterize Climate Resilient Wheat for the West Asia and North Africa Region

Project duration: 36 Months

Target crops: Wheat (*Triticum spp*.)

Targeted developing country/ies:, Egypt, Ethiopia, Jordan and Sudan

Other Contracting Party/ies involved:

Ethiopian Institute of Agricultural Research (EIAR)- Ethiopia, National Center for Agricultural Research and Extension (NCARE)- Jordan, Agriculture Research Center (ARC)- Egypt, Agricultural Research Corporation (ARC)- Sudan

Project geographic extension (km²): 296,540.

Total requested funding: 500,000 $

Total co-funding: 500,000 $

Please select the type of project you are applying for:

☐ Single-country Immediate Action Project (Window 2)
☐ Multi-country Immediate Action Programme (Window 2)
☐ Single-country Co-development and Transfer of Technology project (Window 3)
☒ Multi-country Co-development and Transfer of Technology project (Window 3)

Applicant

Name of Organization: International Center for Agricultural Research in the Dry Areas (ICARDA)

Type of organization: CGIAR Center

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GENERAL REQUIREMENTS

These guidelines have been prepared to support applicants in the development of full project proposals. They describe the requirements that all applicants should adhere to when developing their full project proposal.

Please make sure you read these guidelines carefully before proceeding to fill in the Project Proposal Form. The full proposal should be prepared taking into account the thematic focus of the Third Call for Proposals, including in particular, the rationale, scope and expected outputs for each Window and sub-Window.

Project proposals must be clear and realistic on the problem to be addressed and objectives it tries to achieve. Project objectives have to fit in the thematic focus of the call and ultimately contribute to food security and poverty alleviation. Project objectives have to be logically interlinked with the planned activities, outputs and expected outcomes. The objectives and outputs have to be feasible in terms of duration and resources requested. The information to be provided in each section has to be focused and straightforward, qualitatively and quantitatively measurable in terms of what will be done, with what purpose, who, why and how will be involved in the activities to be implemented, who and how many will directly and indirectly benefit from the implementation of the project. A good full proposal will have a sound, clear and logically linked methodology of implementation and management.

The full project proposal should contain no more than fifteen (15) pages of text (Appendixes, table of contents and cover sheets excluded). The number of pages allocated to each section is a guide. The information required can be less but not more than the pages stipulated. All Appendixes should be duly filled in according to the provided guidelines as they form an integral part of the full project proposal. Project proposals lacking at least one Appendix, will be excluded from the selection process. The Appendixes will be provided to you in separate files together with the present document.

When submitting the full project proposal, additional attachments (endorsement letters, funding commitments, certification of the status of the organization) can be provided.

Please ensure that the project proposal and all attachments are legible in Times New Roman 12 and provided in two formats (pdf and word). Make sure the signature of the project coordinator is put on the signature page.

The project proposal, if approved for funding by the Bureau of the Sixth Session of the Governing Body, will form an integral part of the contractual agreement (Letter of Agreement) that will be signed with each applicant organization of the approved projects.

SECTION A: EXECUTIVE SUMMARY

1. Executive summary

Climate change is expected to cause adverse effects to agriculture around the globe, with many countries showing increasing concerns about their possible devastating ripercussions. Earth temperatures are expected to increase by approximately 2 ˚C in the next 100 years, which will result in dramtic changes in rainfall patterns in many parts of the world and particularly in dry areas. Temperature and water availability are major determinants of plant productivity. Limited water supply (drought stress) and warmer temperatures (heat stress) will certainly reduce crop production. Wheat yields are expected to drop by approximately 5% at each 0.5 ˚C increase in temperature.

Wheat (*Triticum aestivum* L. and *Triticum durum*) is the third most cultivated crop on the planet and the first for human uptake of dietary proteins and fibers (FAOSTAT 2012). Modern wheat cultivars were developed from a genetically narrow germplasm by means of pedigree. This increased its vulnerability to climate change, stress, and diseases. Decrease in potential wheat yield due to climate change stresses is very likely the outcome of the inability of the modern variety to adapt to hotter and/or shorter growing periods and prolonged water deficit conditions and heat stress. Such conditions are already very explicit in most of the dry areas of the World, especially within West Asia and North Africa (WANA) region. Furthermore, in most of the countries of WANA, wheat production is currently not sufficient to meet the rising domestic demands by the growing populations. Millions of tons of grain are imported annually to satisfy these needs, which raises the question of what will happen when climate change will cause a reduction in the global production and therefore to the exportations.

Wheat landraces, with high level of adaptation to drought and heat stresses, are rapidly disappearing from the main wheat production areas in the targeted countries and are replaced by new genetically uniform cultivars. Therefore, there is an urgent need to collect such wheat material and to characterize it at the molecular and phenotypic levels to enable their utilization in future breeding strategies to cope with climate change. Collected wheat genetic material deposited in ICARDA and national genebanks is not fully exploited (less than 8% are utilized) and their potential as a source of new alleles for breeding for drought and heat stress tolerance is not fully utilized. Therefore, there is a need to study the durability and variability in such material, which have been selected over millennia and that might be adapted to local harsh environments. This will lead to the identification of new alleles for tolerance against drought and heat stress, which will be utilized in ICARDA and National Agricultural Research Systems (NARS) breeding programs.

In this study, an integrated approach that includes different molecular, phenotypic and informatics tools, will be adopted to identify and characterize wheat genetic resources resilient to climate change with special emphasis on drought and heat stresses. The study will seek the establishment of an effective long-lasting partnership between ICARDA, as a leading institute, and NARS in targeted countries. This will provide the breeders and other scientists at ICARDA and NARS with the proper tools to share and integrate phenotypic and genetic information to accelerate the delivery of new wheat varieties that are adapted to the climate change-related challenges with particular emphasis on information exchange, technology transfer and capacity-building.

SECTION B: PROJECT DESCRIPTION AND CONTENTS

2.1. Problem definition

Climate change and associated conditions are growing concerns affecting many regions and earth temperature is expected to increase causing changes in rainfall patterns in many parts of the world (Thornton et al., 2014). The worst climate change scenarios envisage major impact on food production and food insecurity implying direct effects on agriculture in many countries around the globe (Challinor et al., 2014). In West Asia and North Africa (WANA) region, the dryland farming systems are expected to be severely affected by climate change (Thomas 2008) and projected to reduce renewable surafce and ground water reseources with inceased temperature in most dry regions (IPCC, 2014). Temperature and water availability are major determinants of plant productivity and, under climate change, limited water supply and warmer temperatures will most probably reduce the yield of any given crop. Such new conditions, associated with climate change, will have major negative impacts on crop productivity of many cereal crops, including wheat, adding more suffering to the growing populations and poor-resource farmers in dry areas.

The WANA region is considered among the largest food-deficit regions in the world where large scale importation of grains, particularly wheat, is common. Future scenarios predict an increased dependency on food importation, thus worsening the food security situation in the region. Besides, countries with high population growth rates will face natural resource degradation resulting in facing high rates of food insecurity. Taking Ethiopia as an example, the country is among the poorest countries in the world, with a per capita income of $470. Approximately 40 percent of the population still lives below the poverty line and life expectancy of the population at birth is only 56.19 years (World Bank 2014). To improve the food security in the country, there are governmental plans to expand wheat cultivation into new areas across the country. However, growing wheat in such areas will require cultivating high yielding and drought and heat tolerant varieties. Similar plans are being made by Egyptian government to boost wheat production in the new valley and Toshka areas in southern parts of Egypt. Such areas are prone to climate change associated conditions, particularly drought and heat stress. In Sudan, which imports 80 percent of its annual wheat needs, there are plans to boost wheat production by increasing the cultivated area. Climate change scenarios estimate a crop yield reduction in Sudan by over 20% due to heat stress (Jones and Thornton, 2003). Based on the water stress index (the value of annual rainfall divided by total population), the availability of water in Jordan is classified as “absolute scarcity” (Mudabber, 2007). The impacts of dry conditions associated with climate change on rainfed agriculture in Jordan is clear and include the complete failure of crops in the field and increased cost of providing extra feed to animals on smallholder-farmers. Drought will affect the dryland mixed systems by excluding wheat and replacing it with other crops.

Many models predict that climate change will have major negative effects on wheat production areas, especially in the WANA region (Habash et al., 2009). This reduction in yield is expected due to temperature increase, uneven distribution of rainfall and the shift toward short growing seasons. Therefore, a major challenge for wheat improvement in WANA region is how to plan for future climate change worst scenarios. Under climate change conditions, wheat plant will require complex tolerances to the extreme pressures of drought and heat (Habash et al., 2009). In a recent study, a process-based model to predict wheat adaption to the detrimental effect of climate change indicted that the negative impact on yield through climate change would be decreased and mitigated due to the adoption of new short growing and faster maturating varieties with enhanced tolerance to drought and heat stresses (Semenov et al., 2014). In another recent study, a data set based on more than

1700 simulation models indicates a negative impact of climate change on wheat yield in different regions around the globe if no adaptation measurements are considered (Challinor et al., 2014). However, the same data set predicts a yield increase, 8 to 15%, if more effective climate change adaptive varieties were developed. Therefore, tolerance to heat and drought stresses should remain a priority for the genetic improvement of wheat in dry areas.

Under climate change conditions, the adaptation of new wheat varieties is needed to cope with yield reduction associated with heat and drought stresses. To cope with these new conditions, there is a need to breed for new high yielding wheat varieties with improved resilience to climate change and particularly drought and heat stress. Efficient and effective genotypes with a short growing season and tolerance to major abiotic stresses should be utilized to produce new improved cultivars with enhanced productivity to overcome the adverse effects of climate change (Semenov and Halford, 2009). Therefore, improving and upgrading capacities of current wheat breeding programs at ICARDA and NARS in WANA region through the utilization of wheat genetic resources and modern molecular breeding tools are required to accelerate the delivery of such varieties. In addition, breeders need to use techniques from single selection to complex molecular methods to integrate desirable traits into existing varieties to improve wheat productivity in production areas vulnerable to climate change (Araus, et al., 2008). Out-scaling current selection technologies to national partners through training will help breeders select new material with desired traits for their programs.

Based on the frame conditions and challenges encountered due to climate change, the proposed study will focus on new emerging technologies and information tools to utilize genetic resources for the benefits of gene banks and wheat breeding programs in WANA region. This project will provide the breeders and other plant scientists, as direct beneficiaries, at ICARDA and NARS with the proper tools, and phenotypic and genetic information to accelerate the delivery of new wheat varieties that are adapted to the climate-related challenges in WANA regions. Furthermore, the proposed study will utilize plant genetic resources from ICARDA and national wheat breeding programs in WANA region besides the identification of putative wheat genetic resources at ICARDA, NARS and other gene banks that are resilient to climate change associated stresses (with particular emphasis on drought and heat tolerance) using the Focused Identification of Germplasm Strategy (FIGS) aligned with WANA geographical and climatic data available from the newly developed ICARDA Geoinformatics Portal (http://geoagro.icarda.org/).

This special set of wheat germplasm (elite lines, breeding material and landraces) will be assembled and managed by the ICARDA gene bank team and will be subject to genetic diversity analysis using a defined set of SNP markers (~50 markers) that will include already developed diagnostic markers for major agronomical traits (plant height, flowering time) and major pathogens resistance genes (rusts). Two selected subsets of a total of ~250 durum and ~250 bread wheat accessions will be evaluated in research stations in the targeted countries for their performance under heat and drought field conditions. To identify marker associations with heat and drought tolerance, the two subsets will be genotyped with a suitable robust and high-density SNP genotyping platform. The identified climate change resilient wheat lines and the molecular data of SNP markers associated with improved performance under heat and drought tolerance in targeted areas will be made available to the national program for future breeding applications.

In addition, all genotypic, phenotypic, collection sites and related data of the characterized wheat material will be integrated and used to develop a web-based tool to help ICARDA and national programs and scientists in WANA region to facilitate future selection in their breeding programs. The new database will be designed as an open access for data (molecular and phenotypic) sharing and deposition to the benefits of all national institutions in the region and the world (taking into consideration the legislation and regulations regarding intellectual property protection) with options to enable new data deposition and linkage with other existing platforms.

Finally, the proposed study will include a capacity development component including training of human resources from the key national partners on the use of molecular markers in wheat breeding programs (with special emphasis on new genotyping technologies for large scale analysis) and the resulted information management systems beside already existing gene bank management systems.

2.2. Project objectives: Overall and specific objectives

The overall goal of this study is to identify and characterize climate-resilient wheat germplasm that can be used to develop high yielding varieties with improved adaptation to the drought and stress conditions prevalent in the WANA region.

The identification and utilization of PGRFA to develop new wheat lines with improved tolerance to drought and heat stress conditions prevalent in WANA region is needed for better food security and sustainable productivity. This will eventually improve the productivity of wheat in the targeted region, increase the livelihood of low income communities and resource-poor framers in WANA region and contributes to food security in targeted countries.

In addition, the proposed study aims to enhance the current capacities of NARS breeders, to promote partnerships and participation and to ensure knowledge sharing with the wheat scientists in the region.

The project specific objectives are:

1- To evaluate a large collection of genebank accessions for two years, under contrasting drought and heat field conditions.

2- To identify novel wheat genetic material with improved tolerance to drought and heat stresses.

3- To identify useful alleles for breeding drought and heat stress tolerance by means of association mapping.

4- To use molecular markers for simplifying the transfer of useful alleles associated with drought and heat tolerance into ICARDA and national breeding programs.

5- To improve the current capacities of the conventional wheat breeding programs in the region by using cutting-edge molecular and breeding tools.

6- To develop a web-based tool for integrating data at the accession level with genomic and phenotypic information with accessibility to all institutions in WANA region.

7- To provide training courses in targeted countries, workshops and scientific publications.

2.3 Targeted outputs, activities and related methodology of implementation

Output 1: *Climate change resilient wheat genetic resources with improved tolerance to drought and heat stress are identified and conserved.*

Target: Assembly of a wheat genetic resources special set that include climate resilient, drought and heat stress tolerance wheat accessions and germplasm from ICARDA and NARS breeding programs and gene banks.

Activities:

1. Identification and multiplication of wheat accessions from drought and heat stress prone areas using an improved FIGS approach.
2. Utilization of wheat breeding material and populations from ICARDA, international and national breeding programs.

Outcomes: ~1250 diverse wheat accessions are characterized, multiplied and conserved.

Output 2: *Two diverse subsets that include climate resilient, drought and heat stress tolerance durum and bread wheat genotypes identified using improved FIGS and modern genomics tools.*

Target: Genetic diversity and population structure analysis of the wheat special set using diagnostic SNP markers linked to growth habit, plant height and other related traits to produce two subsets (bread and durum wheat).

Activities:

1. Testing ~50 SNP markers on ~1250 wheat accessions from the special collection set using the KASP® genotyping assays.
2. Genetic diversity and population structure analysis to produce two subsets for bread and durum wheat genotypes for genome wide association mapping studies.

Outcomes: Two subsets for bread and durum wheat that contain at least 250 diverse wheat accessions per species are characterized using molecular markers available.

Output 3: *Field evaluation of the two subsets for yield potential and stability under drought and heat stress conditions.*

Target: Identification of wheat lines with improved tolerance against drought and heat stress and phenotypic data to execute a genome wide association study.

Activities:

1. Evaluation of the two AM panels (250 for each species) for their performance under drought and heat stress conditions.
2. Phenotypic data collection and analysis for major yield and yield components traits associated with drought and heat stress tolerance in the two panels.

Outcomes: Phenotypic data for the field performance of the two subsets under drought and heat stress tolerance available.

Identification of at least 20 wheat lines from each species with improved tolerance against drought and heat stress.

Output 4: *New alleles for drought and heat tolerance in the two subsets are identified using a genome wide association mapping approach.*

Target: Identification of molecular markers linked to traits conferring drought and heat stress tolerance in the two subsets.

Activities:

1. Genotyping of the two subsets using high-throughput SNP genotyping systems.
2. Genome wide association mapping analysis using genotypic and phenotypic data from the field evaluation experiments.

Outcomes: Identification of at least 10 QTLs against drought and heat stress in each subset.

Output 5: *Existing and newly developed SNP markers for selected agronomical traits, and abiotic stress tolerance are utilized in ICARDA and NARS wheat breeding.*

Target: Marker assisted selection using high-throughput genotyping platforms are deployed in ICARDA and NARS breeding programs.

Activities:

1. Conversion of at least 10 SNP markers associated with drought and heat stress tolerance into KASP® assays.

2. Screening at least 500 lines from ICARDA and NARS wheat (durum and bread) breeding programs using at least 20 SNP markers associated with drought and heat tolerance through the KASP® genotyping assays.

Outcomes: Implementation of a marker assisted selection system for selected traits in ICARDA and NARS breeding programs using SNP markers and high-throughput genotyping platforms.

Note: The activities of this particular output might be extended after the end of the third year (year four in Appendix 3) as a continuity of impact operations of the proposed study.

Output 6: *Open access integrated database with accession passport information, genomics and phenotypic data*

Target: Development of user friendly web-based tools to facilitate data and information exchange between participants.

Activities:

1. Database development and incorporation of field and molecular data, results and markers information for wheat material used in this study.
2. Database made available online at ICARDA web site for public.

Outcomes: Facilitate information exchange and data use between the collaborating institutions and for scientific, technical and environmental matters related to plant genetic resources and climate change in WANA region is available.

Output 7: *Increased capacity of NARS institutions and breeders in WANA region to use molecular markers to breed climate change resilient wheat.*

Target: At least 20 NARS breeders and scientists (disaggregated by gender) from participating countries trained on genetic resources management, breeding and molecular tools using SNP markers and bioinformatics.

Activities:

1. Training courses targeting NARS scientists and breeders to acquire skills in specific areas of molecular breeding.
2. A workshop on the use of web-based tools for breeding activities.

Outcomes: Increased capacity of NARS institutions and breeders on using molecular markers for breeding climate change resilient wheat varieties.

2.4. Targeted PGRFA

The targeted PGRFA in this proposed study is wheat (*Triticum* spp.). Special emphasis will be mainly given on bread (*Triticum aestivum*) and durum wheat (*Triticum durum*) that have potential to harbor new alleles for drought and heat tolerance as inferred by the FIGS approach and molecular work. The used material in the special collection set (~1250 accessions) and the two subsets (bread: ~250 and durum: ~250 accessions) are expected to contain gene bank accessions, prebreeding material, historical and elite breeding lines maintained at ICARDA genetic resources unit and breeding programs. Besides, newly released varieties by ICARDA and NARS of the targeted countries will be used in the implementation of the proposed study. The utilization of wheat germplasm in future breeding activities might result in the production of wheat varieties with improved tolerance against heat and drought that can be used by NARS for wheat improvement and to achieve better food security for poor-resources population groups in WANA region. Any material obtained from this project will be conserved in ICARDA gene bank. Furthermore, phenotypic and genetics information related to the tested material will be made available through the online database at ICARDA web site.

2.5. Direct and indirect beneficiaries

Wheat germplasm identified in this study will directly benefit ICARDA and national partners' wheat breeders in WANA region. Training targeting young scientists and breeders from the selected countries and the development of data sharing tools will allow direct technology transfer and wider access to information that will help breeders improve wheat production in WANA region. The training of breeders, scientists and extension personnel will ensure equality and gender representation. We are expecting that at least 20 NARS breeders and scientists will directly benefit from the training courses and workshops.

In addition, the scientific community will have access to the results from this project that will facilitate the utilization of the characterized wheat germplasm for other studies. We anticipate that hundreds of breeders and wheat scientists will access the web site on annual basis

The utilization of climate resilient wheat germplasm to develop improved drought and heat tolerant cultivars is expected to contribute to enhanced wheat production, food security in targeted countries and to the improvement of the livelihood of tens of thousands poor-resources farmers in WANA region. The results will be presented to the NARS directors in the targeted countries to promote the adoption of any newly released varieties with heat and drought tolerance in their future plans.

Finally, the poor-resources farmers growing wheat under dryland environments will be the ultimate beneficiaries of the results of this project.

2.6. Impact and impact pathways

The project will contribute to to the achievement of **Millennium Development Goals 1 and 7:**

- *To eradicate extreme poverty and hunger*
- *Ensure environmental sustainability*

2.6.1. Food security and poverty alleviation

As mentioned earlier, one of the main objectives in the proposed study is to develop new wheat lines with improved tolerance to drought and heat stress conditions prevalent in WANA region. The new wheat varieties could be utilized by the NARS and resource-poor farmers in the WANA countries to increase the production of wheat to achieve better food security, reduce large scale importation of grains, and alleviate poverty resulting in better livelihood of poor-communities.

In addition, the utilization of molecular markers in breeding programs will assist in accelerating breeding cycles and precise selection of wheat material for different traits. This will assist in delivering wheat lines tailored with selected alleles and genes for drought and heat stress tolerance, and other important traits such as disease resistance, quality and agronomical performance.

Furthermore, the outputs of the proposed study will align with the strategic food security goals of the local governments for wheat by providing breeders and other plant scientists with the tools they need to deliver to farmers new varieties that are adapted to the climate-related challenges with particular emphasis on drought and heat tolerance. This is further aligned with the CRP3.1 Strategic Initiative 4, Outcome 31.04.01 "Effectiveness of partners to utilize international wheat germplasm as parents in breeding programs or to select lines for release in enhanced and output 31.04.01.01 "An annual increase of 0.9% in generic yield potential gains maintainted in new wheat cultivars and elite lines for Asia, Africa and Latin America".

2.6.2. Adaptation to climate change and environmental sustainability

This study will address how the knowledge of crop genetics can assist wheat breeding by the identification of new alleles in wheat germplasm possessing potential drought and heat adaptive traits collected from dry and hot areas in WANA and identified using the FIGS approach. The genome wide association mapping approach will help in identifying important genes in the assembled material that are associated with stress tolerance and adaptation to dry and hot environments.

Such material and genetic information will increase the capacities to adapt wheat to environmental variability with particular emphasis on heat and drought. In the long term this will help in producing varieties with improved resilience to climate change conditions to achieve longer term changes in low income communities in WANA resulting in improved food security.

2.6.3. Scientific impact

The proposed study will generate a web based tool to facilitate data exchange between wheat scientists in the region. This web based tool will include molecular, phenotypic and passport data for wheat material analysed in the proposed study, breeding lines and gene bank accessions. This will enable information exchange and technology transfer between participants and scientists in the region through data dissemination, discussions and joint analysis to reach proper decisions for wheat utilization in ICARDA and NARS breeding programs.

The utilized molecular approach (genome wide association mapping) using cut-edge technologies will enable the discovery of a huge number of molecular markers associated with drought and heat stress tolerance. This approach could be adapted for other traits using the same panels or also applied for different wheat material collected or preserved in gene banks.

The scientific findings will improve the capacities of breeders and young scientists in the targeted countries in WANA region concerning molecular markers utilization in selection by using high-throughput genotyping technologies.

Besides, the relevant scientific findings will be made available and disseminated through workshops, published articles and international conferences.

2.6.4. Capacity development and empowerment

The trained human resource capacity of national partners in the targeted countries will include at least 20 wheat breeders and young scientists. Trainees will be exposed to modern cutting-edge technologies related to molecular markers and their use in breeding programs and how to use them in future selection for wheat improvement. The use of molecular markers and high-throughput genotyping system will enable the breeders to screen a large number of wheat lines for the existence of markers of interest. This will enhance their scientific knowledge in such tools. Furthermore, such approaches will improve the capacities of breeding programs in the region and shift from the current conventional into a more molecular-classical breeding system.

2.7. Relevance to national or regional priorities in its plans and programmes for PGRFA

In an effort to increase wheat production and alleviate food insufficiency in Egypt, Ethiopia and Sudan, the three governments have adopted plans to expand wheat production into new areas. However, the environments in these new areas are characterized by a dry and hot climate, which is considered a limitation for wheat cultivations. In Jordan, the impacts of climate change on rainfed agriculture are clear and it will affect the dryland mixed systems by excluding wheat cultivation. Therefore, the proposed study is establishing a strategy to accelerate the wheat breeding program that incorporates modern tools including Marker Assisted Breeding to produce heat and drought tolerant varieties. This will help the targeted countries NARS to cope with drought and heat stress, which are expected to affect wheat productivity and might compromise their plans.

Accordingly, the strategic goal of this project is to facilitate the government’s food security goals for wheat by providing breeders and other plant scientists with the tools they need to deliver new varieties of wheat that are adapted to the climate-related challenges. This will help in intensifying smallholder wheat production in heat and drought prone areas in the four targeted countries and to cope with expected challenges related to expanding production in areas where drought and heat stress are endemic.

SECTION C: OPERATIONS

3.1. Methodology of project implementation

3.1.1- Identification of new climate resilient wheat genetic resources in breeding programs and gene banks

Accessions of genetic resources of wheat (durum and bread) with potential for resilience to climate change with special emphasis on drought and heat stress tolerance will be identified from the wheat collections conserved at ICARDA gene bank using the Focused Identification of Germplasm Strategy as described previously (FIGS; Khazaei et al., 2013). This FIGS subset is expected to include accessions having drought and heat adaptive traits besides the accessions collected from humid environments for comparison as negative controls. To assure the homogeneity and purity of the FIGS set, the wheat seeds used in this study will be only derivatives from a single spike selection and multiplication procedure adapted by ICARDA genetic resources unit. In addition, wheat advanced breeding lines and historical released cultivars and breeding populations from ICARDA, international and national breeding programs in WANA region will be included in this study.

We estimated to have over 1250 wheat accessions in this study and this collection will be named the ICARDA-WHEAT-DrHe special set. The selected accessions will be multiplied during the first year at ICARDA station in Terbol/Lebanon and used for genotyping and for evaluation under heat and drought conditions thereafter. This germplasm will be available for distribution under the regulations of the International Treaty on Plant Genetic Resources for Food and Agriculture. Moreover, arrangements will be made for their includion in the active collection and for safe duplication.

3.1.2- Genetic diversity analysis of the wheat germplasm

The whole wheat ICARDA-WHEAT-DrHe special collection will be genotyped using a defined set of SNP markers (~50 markers) that are evenly distributed on wheat chromosomes. The technology of choice for the genotyping will be the KASP® assays using selected SNP markers from the wheat panel and wheat MAS data, for details please see: (http://www.cerealsdb.uk.net/cerealgenomics/CerealsDB/kasp_mapped_snps.php). Furthermore, the SNP markers will include already developed diagnostic markers for flowering time and other major agronomical traits currently used by ICARDA breeders. Besides understanding the genetic relationship of the set, such diagnostic markers will allow the grouping of accessions in the special collection based on their growth habit, plant height and other related traits. The genetic diversity of the special set will be analysed using POWERMARKER Ver. 3.25 (Liu and Muse, 2005). The analysis of the population structure of the special set will be performed using the software package STRUCTURE v2.2 (Pritchard et al., 2000).

Based on the collected information from the FIGS and molecular marker data analysis, two association mapping (AM) panels (durum (~250 lines) and bread wheat (~250 lines)) will be assembled to ensure a maximum diversity with the representation of new wheat accessions carrying drought and heat-related adaptive trait within each panel. For each targeted species, the collection will be named ICARDA-BW-DrHe subset for bread and ICARDA-DW-DrHe subset for durum wheat.

3.1.3- Molecular markers for traits associated with drought and heat stress tolerance

The two assembled AM panels will be evaluated for two years regarding their growth attributed, agronomical performance, yield potential and drought and heat tolerance at different selected stations across the targeted countries in the WANA region. The selected research stations in the targeted countries will be analysed for climatic data and drought severity indices using the CGIAR Consortium for Spatial Information system and the ICARDA Geoinformatics Portal with special emphasis on research stations where drought and heat stresses are frequent.

Proper field management will be deployed to ensure uniformity and to avoid any effects of other stresses such as diseases or any other related unexpected situations. The ICARDA-DW-DrHe subset will be evaluated only in selected NARS stations in Egypt and Jordan. The ICARDA-BW-DrHe subset will be evaluated in Egypt, Ethiopia and Sudan. Furthermore, the two subsets will be tested in two ICARDA stations in Lebanon (Terbol and Khefredan). In each trial, a non-replicated augmented design will be used with selected ICARDA checks as replicated reference for each tested panel. Crop measurements under the designated field sites will include heading date, physiological maturity date, plant height, peduncle length and biological and grain yield.

To discover genetic markers associated with yield performance under heat and drought conditions, the two AM panels will be genotyped with a selected high-density SNP genotyping platform. The platform of choice will be either the wheat illumine iSelect 15K (Traitgenetics/Germany) or DArT-Seq (Diversity Arrays Technology/ Australia), and the selection will depend mainly on estimated cost, data quality and analysis robustness. SNP markers will be the markers of choice to facilitate their future use in accelerating the breeding cycle as outlined below.

Linkage disequilibrium and association mapping analysis for the drought and heat stress tolerance related-traits in response to different environments will be carried out as described previously (Edae et al., 2014). The most promising lines and the identified SNP molecular markers will be utilized to accumulate favourable traits associated with high yield and stability under drought and heat stresses in ICARDA and national wheat programs. For this purpose, the identified and most informative SNP sequences will be converted into KASP® markers suitable for high-throughput genotyping assays.

In addition, the most informative markers associated with drought and heat tolerance in the two AM panels will be incorporated with existing KASP® markers set targeting several important agronomical traits in ICARDA and NARs wheat breeding programs. The new set of markers will be introduced into the NARS breeding programs in the WANA region to complement and strengthen the conventional breeding methods. Furthermore, the newly identified markers beside the old existing KASP® markers will be used to screen parental lines from the crossing block as well as advanced wheat lines currently developed in ICARDA and NARS breeding programs to identify promising lines carrying useful genes for major traits including biotic and abiotic stresses. This will facilitate the selection of promising lines for yield trials to assess their performance in targeted areas and the production of new breeding population carrying exotic alleles for drought and heat tolerance.

3.1.4- Capacity development and the development of information sharing system and database

The ultimate goal of this project is to identify genetic resources resilient to climate change and to discover exotic alleles for drought and heat tolerance in wheat. Such phenotypic and genomic information will be used subsequently by wheat breeders and plant scientists at ICARDA and the national program to develop and release high yielding, climate-resilient wheat varieties suitable for the WANA region. To ensure continuous support and information exchange between ICARDA and NARS wheat breeders, a web-based tool will be developed to help all participants to utilize available information of phenotypically and genetically analysed wheat germplasm from the region. The new database will be easy to access and integrate data collected from this study besides any future data from future breeding or molecular work related to ICARDA wheat in the WANA region. The ICARDA IT team will develop the database in collaboration with bioinformatics and IT scientists from the region. Most importantly, the database will include molecular markers data for the most important agronomical traits and pathogen resistance genes to help NARS programs in the selection process of suitable candidates to incorporate favourable traits associated with high yield and stability, and tolerance to biotic and abiotic stresses. The database will be integrated with other existing platforms such as the GCP Integrated Breeding Platform (www.integratedbreeding.net).

Finally, the proposed study will include training of young wheat researchers from national institutes in targeted countries on genetic resources management and wheat breeding, biotechnology and genetics. Furthermore, the project will incorporate the training of young wheat researchers and scientists on the use of high throughput low-cost SNP genotyping tools for the marker assisted selection in wheat lines for desired traits. A workshop will be organized on the newly developed database and other related existing database for the utilization and accessing of the integrated accession, molecular and phenotypic data and their use for future wheat breeding activities in the region.

3.2. Partnerships and collaboration arrangements

ICARDA works through a network of partnerships with national, regional and international institutions in the developing world. ICARDA's mandate is to undertake wheat research for CWANA region, which covers 50% of the wheat area in the developing world.
ICARDA will be the primary executing agency of the submitted proposal and several scientists will be actively involved in all aspects of the proposed study to achieve the expected outputs.
ICARDA's activities will be excueted by the Genetic Resources Unit, Geoinformatics Unit, bread wheat breeding program, durum wheat breeding program, and Biotechnology Unit.
ICARDA Genetic Resoruces Unit will play a major role in idneifying new climate change reislenet wheat through FIGS and in its active collection messions in WANA region.
The ICARDA Geoinformatics Unit will be involved in the improved FIGS analysis and analyzing climatic data for research stations and collections site. Also, the ICARDA IT specilists contribute to the database and information exchange tools development.
The molecular characterization, marker assisted selection, genetic diversity analysis and genome wide association mapping studies will be excueted by the ICARDA biotechnology team, and the genotyping of material will be carried out through a service provider with special emphasis on providers from contracting parties.
Additionally, ICARDA wheat breeders will supervise field trials at ICARDA stations in Lebanon and the coordination of related experimental work with NARS partners.
ICARDA capcity and development unit will supervise the training courses and workshops and coordinate with NARS for this task.
Collaborating agencies from the NARS in the four targeted countries will include:

- Ethiopian Institute of Agricultural Research (EIAR)- Ethiopia,
- National Center for Agricultural Research and Extension (NCARE)- Jordan,
- Agriculture Research Center (ARC)- Egypt,
- Agricultural Research Corporation (ARC)- Sudan.

The NARS partners will play a major role in logistic support for data collection and most importantly in testing the plant material in field trails in their research stations acorss the selected areas in their countries.

The resulted consortium agreed to work together (endorsement letters) for achieving the main outputs and in the co-development and utilization of to utilize the wheat material described in this proposed study for future breeding activities in the targeted countries.

3.3. Project management team

ICARDA project management team:

Dr. Ayed Al-Abdallat (Senior Biotechnologist) will be the project coordinator and will be involved in all activities related to molecular work and database development.

Dr. Ahmed Amri (Head of Genetic Resources Section) and Dr. Abdallah Bari (Genetic Resources Scientist) will be involved in identifying drought and heat tolerant wheat through FIGS and in targeting new areas in active collection missions in WANA region.

Dr. Chandrashekhar Biradar (Head of Geoinformatics Unit) will be involved in climatic data analysis of collection sites locations and in the FIGS analysis. He will be also involved in the database development for information exchange and analysis.

Dr. Wuletaw Tadesse (Senior Bread Wheat Breeder) and Dr. Filippo Bassi (Senior Durum Wheat Breeder) will be involved in field experimental work and coordination with NARS partners.

From NARS institutions, the project coordinators will play a major role in providing plant material and logistic support for data collection and field trails in their research stations. The project coordinators are:

Mr Zerihun Tadesse (Wheat Breeder) EIAR, Ethiopia (zerbest.2008@gmail.com)

Dr, Izzat Tahir, (Wheat Breeder) ARC, Sudan (Tahir Izzat (izzatahir@hotmail.com) (izzatahir@hotmail.com) (izzatahir@hotmail.com)

Dr Sherif Thabet, (Wheat Breeder) ARC, Egypt (alisherif875@yahoo.com)

Dr. Nasab Rawsahdha, (Head of Genetic Resources Unit) NCARE, Jordan (nasab@ncare.gov.jo)

3.4. Sustainability

ICARDA, as a CGIAR center, will continue its efforts to improve wheat productivity in WANA region, particularly in dry areas. ICARDA through its long relationships with NARS will be capable to ensure the effective implementation of the outputs of this study in future plans and wheat breeding activities in the region. The characterized wheat material and phenotypic, molecular and field data will be used in ICARDA and NARS breeding programs on a sustainable basis to ensure the production of wheat varieties, which are heat and drought tolerant. This will contribute remarkably to sustainable production of wheat under these constrains. Furthermore, the generated database will continue to enable the scientific community to exchange and utilize information on molecular, phenotypic and genotypic issues to assure their sustainable use in breeding wheat varieties that are heat and drought tolerant and suitable for the cultivation under such conditions.

SECTION D: APPENDIXES

By signing this submission form for full proposal, the applicant confirms that all the above statements, including the attached Appendixes, are true to the best of his/her knowledge. Any deliberately untruthful response will lead to the automatic exclusion from the further screening and appraisal process, and may lead to the denial of awarded grants from the Benefit-sharing Fund.

Signature of contact person: **Date and location**