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Final report

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Abbreviations used:

ACIAR	: Australian Centre for International Agricultural Research
ARIA	: Agricultural Research Institute of Afghanistan
AYT	: Advance Yield Trial
BDK	: Badakhshan
BGL	: Baghlan
BLK	: Balkh
BMN	: Bamyan
CIMMYT	: International Maize & Wheat Improvement Centre
DAIL	: Directorate of Agriculture, Irrigation & Livestock
DNA	: Deoxyribo Nucleic Acid
DNAFP	: DNA finger printing
FAO	: Food and Agriculture Organization
FFD	: Farmer Field Demonstration
FP	: Farmer Practice
GBS	: Genotyping by sequencing
GoIRA	: Government of Islamic Republic of Afghanistan
HH	: Household
HRT	: Herat
HLM	: Helmand
IBS	: Identity by state
ICARDA	: International Centre for Agricultural Research in Dry Areas
ISE	: Improved Seed Enterprise
KBL	: Kabul
KND	: Kandhar
KDZ	: Kunduz
MAIL	: Ministry of Agriculture, Irrigation & Livestock
NARS	: National Agricultural Research System
NGO	: Non-Governmental Organization
NGR	: Nangarhar
NPN/ NPhN	: National Phenology Nursery
NRSN	: National Rust Screening Nursery
NDSN	: National Disease Screening Nursery
NUT	: National Uniformity Trial
OPV	: Open Pollinated Variety
PSE	: Private Seed Enterprise
PYT	: Preliminary Yield Trial

SNP : Single Nucleotide Polymorphism

TCI : Turkey-CIMMYT-ICARDA

TL : Truthfully Labelled

TKR : Takhar

Contents

1 Acknowledgments

The Ministry of Agriculture, Irrigation & Livestock (MAIL) of Government of Islamic Republic of Afghanistan

Agricultural Research Institute of Afghanistan (ARIA)

Food and Agriculture Organization (FAO), Afghanistan

Australian Centre for International Agricultural Research (ACIAR)

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Faculty of Agriculture, Kabul University.

Improved Seed Enterprises, Ministry of Economy.

National Seed Board, Afghanistan.

International Centre for Agricultural Research in Dry Areas (ICARDA).

Afghanistan Seed Companies Association, Afghanistan.

2 Executive summary

Wheat is Afghanistan's staple food item. Country grows wheat on about 2.3 million hectares which is about 25% of its agricultural land devoted to temporary crops. Irrigated wheat on average covers 60% of the wheat acreage whereas rainfed is grown over remaining 0.91 million hectares. Similarly, irrigated crop contributes about 75% of the total production clearly indicating importance of irrigated wheat in Afghan wheat production system. Average Afghan wheat yield is around two tonnes per hectare which is relatively lower than that in neighbouring countries. Irrigated wheat yields around 2.7 tonne/ ha, whereas rainfed is only about 45% of irrigated wheat at about 1.2 t/ha. Yellow rust is the major disease of wheat in Afghanistan and therefore growing yellow rust resistant wheat is important since chemical control of rust is quite expensive and reliable fungicides may not be available at right time. Ever since Ug99 was discovered to be a threat to wheat in the region, CIMMYT has been regularly screening all its germplasm against Ug99 race and all new wheat varieties released in Afghanistan during last ten years have been Ug99 resistant. The project introduced 7895 new genotypes of wheat and 161 of maize during the project tenure, and tested them in 620 yield evaluation trials. Starting in October 2012, the project has successfully released 27 varieties of different crops *viz*., 18 of wheat, two of barley, three maize hybrids and four maize open pollinated varieties. Though the wheat seed production in the country has been inconsistent for some time, the post 2000 CIMMYT varieties account for about 80% of certified seed planned for the year 2017-18. Even the varieties released during this phase have reached certified seed production stage and account for about 15% of total certified seed production planned for 2017-18. Seven bread wheat varieties released during this phase have entered breeder seed production plan also. 1277 wheat accessions available with ARIA were phenotyped at Kabul and were also sent to Mexico for genotyping and creating a reference population for Afghanistan. The resultant reference population comprised of 761 genotypes. The National Phenology Nursery revealed four wheat climatic zones *viz.*, Northern, Central Highland, Eastern and South Western zone. Though this is just a beginning and further efforts covering unrepresented geographies would fine tune this delineation. Current and future evaluation of varieties will take the zone into account, resulting into better adapted planting material released to farmers. All aspects of wheat crop production were investigated through 104 agronomy experiments on winter wheat, 144 on spring wheat, 63 on rainfed wheat and 96 on maize. The earlier published national wheat agronomy fact sheet was revised and four editions, one each for the four wheat climatic zones were brought out. Similarly, a revised national maize agronomy fact sheet was also published. The National Rust Screening Nursery comprising of all seed chain varieties and second and final year entries in various yield evaluation trials became an annual feature and screened a total of 1396 genotypes during the project life and played a proactive role in alerting decision makers about any shift in rust races. A regular vigil on rust scenario is essential as 2017-18 NRSN revealed that about 50% of certified seed being produced is of susceptible varieties.

The project trained about 640 Afghan researchers in 17 in country trainings/ workshops etc. A total of 65 Afghan researchers were deputed for 23 trainings/ meetings abroad. The four informal technical information and dissemination hubs in four provinces of Kabul, Balkh, Nangarhar and Herat organised 2766 farmer field demonstrations in the four provinces of which 1060 during 2016-17 and 2017-18 were all line sown. Additionally, HUBs organised 25 trainings attended by 1160 farmers and 101 field days attended by 3422 farmers and extension workers etc. Additionally, a total of 18 extension messages/ fact sheets were brought out.

To augment the seed supply at village level and to empower farmers, eight mobile seed cleaners were supplied to the four hubs. 441 demo growing farmers cleaned their seed in their villages and made available the resultant 200 MT seed to about 1925 farmers. This would allow planting of about 2,000 ha, which would be enough to multiply seeds for up to 80,000 hectares. However only released varieties could be produced locally, therefore the

latest material from the project could not be tested and produced on farm. Material released in the last years will take several years to be available in scaled up quantities.

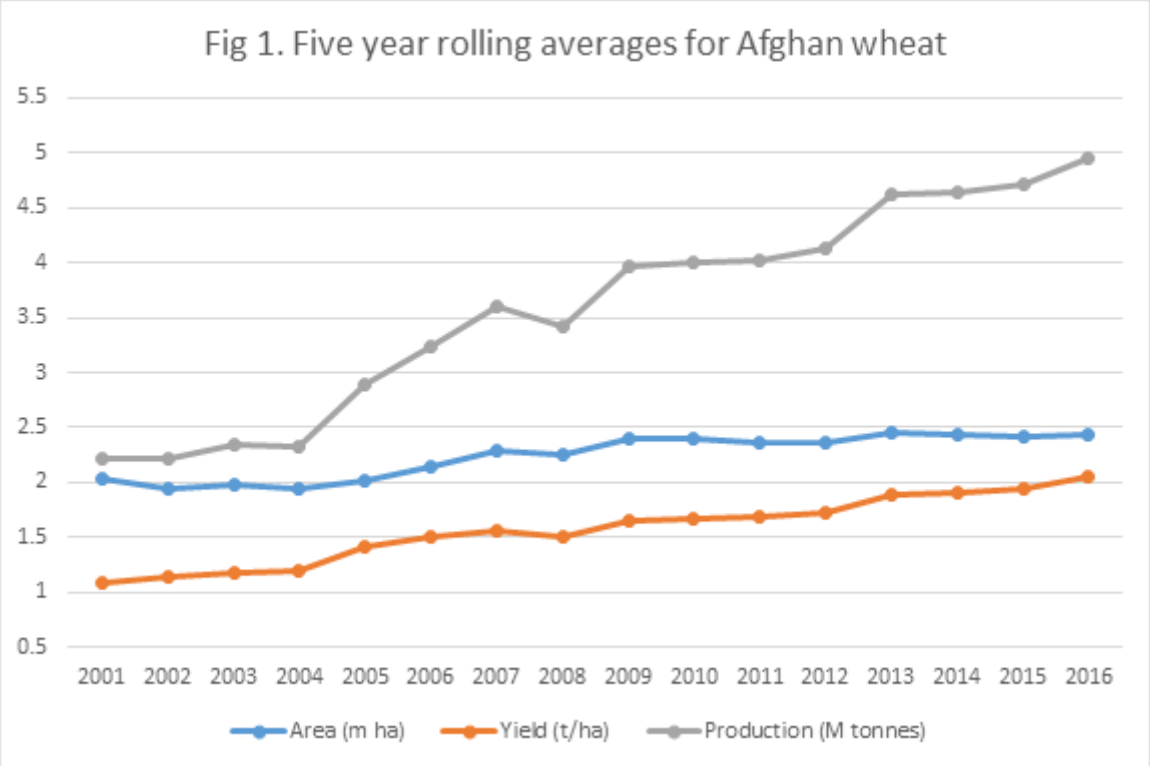
A baseline survey of 2013 involving 399 farm households in four HUBs revealed higher prevalence of local varieties as compared to improved varieties. The impact assessment survey completed in the final year involving 240 treatment households and 360 control households revealed that the percentage of farmers growing seed chain varieties ranged from a low of 53% in Herat to 64% in Balkh, 75% in Kabul and a high of 100% in Nangarhar. Overall 76% of the farmers in the whole sample cultivated seed chain varieties. Among various socio-economic parameters affecting adoption, wheat training participation and contact with extension worker were found to influence adoption positively among both the groups of farmers viz., control as well as treatment farmers. Other factors that positively affected adoption were distance from market and main road, highlighting the importance of infrastructure in adoption.

Afghan wheat germplasm was phenotyped both at Kabul and Mexico for important traits including disease resistance. A set of ten lines was identified possessing resistance to multiple diseases. The germplasm set was genotyped to create a reference population for Afghanistan. However, the germplasm contained multiple entries by same name which were found to be genetically different. The utility of this reference population can be enhanced by including Afghan varieties from confirmed seed sources so as to remove erroneous duplicates. The 600 farmer field samples were DNA finger printed and 94% of the samples could be identified against the reference population. The DNA analysis revealed that more than 85% of farmers grew varieties that were less than 20 year old. The widespread adoption of new varieties by farmers around the project hubs suggests that future efforts to increase productivity of wheat should include: continuous introduction and release of disease resistant and well adapted varieties, demonstration of new varieties and improved agronomic practices to farmers and dissemination of these technologies to farmers over the whole country.

Project also published a total of 19 research/ review articles on various topics of interest in international journals.

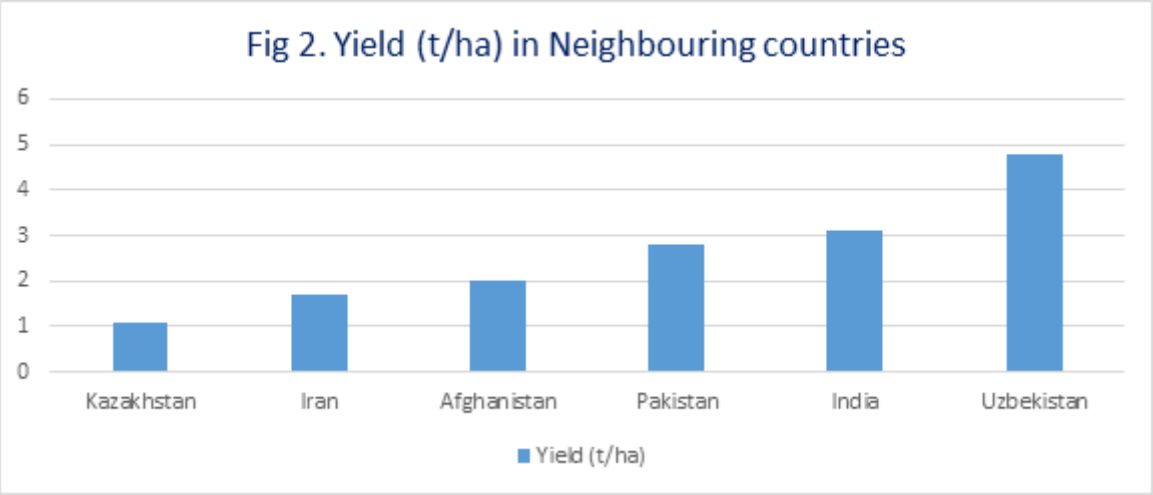
3 Background

Wheat is Afghanistan's staple food item which accounts for up to 60% of caloric intake (Government of Afghanistan, 2003) with an average annual per capita consumption of over 200Kg (Persaud, 2012). The country devotes about 25% of its total agricultural land to wheat cultivation but it is unable to produce enough for its growing population. It has been producing about 4.5 to 5.5 million tonne of wheat for past few years but has been importing varying quantities year after year to meet its domestic needs. It imported around 2.2 million tonne of wheat in 2016-17 (CSO, 2017). Out of a total of 9.7 million hectare agricultural land, wheat occupies approximately 2.3 million hectares (APR, 2016). Five year rolling averages for Afghanistan's wheat acreage shows that wheat area has been almost stagnant since the beginning of current decade, however yield per unit area has been showing an increasing trend (Fig1). Afghan wheat yield are still one of the lowest in the region (Fig 2). Improved seed (variety) is the most important of the factors that contribute to production. The country has not been able to produce enough wheat seed to meet domestic requirements. The current seed replacement rate is less than 5% for wheat. Recent studies (Lantican *et al*., 2016) have estimated an average annual yield gain of 1.18% from breeding research, meaning newer the varieties, higher would be the yield. Also, newer varieties are rust resistant and thus reduce cost of cultivation as farmers do not have to use fungicides to control rusts thereby increasing overall profitability of wheat production. Therefore, lack of seed of new improved varieties is one of the major factors limiting wheat production in Afghanistan.



Among other factors holding Afghanistan's wheat production are, overdependence on rainfall, poor input & output markets, and weak infrastructure. Afghanistan is a land locked country having about 65 million hectares of land and by virtue of its unique location at the junction of Central Asia, Middle East and South Asia suffers from weak transport links.

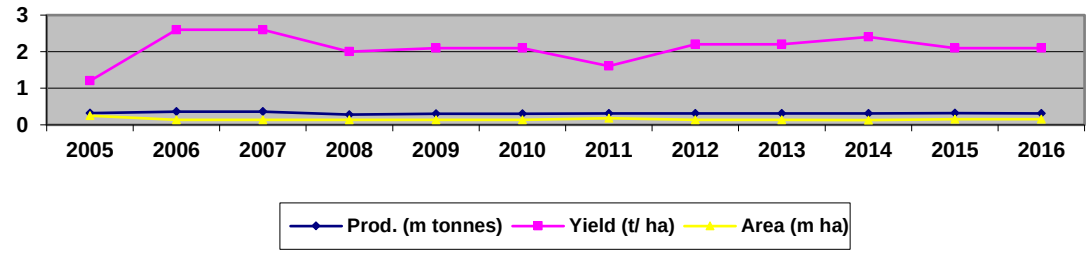
Because of these weak links, this country lacks access to international markets and depends on its neighbours for import of its staple food i.e. wheat.



The project aimed at tackling the issue of varieties, building the capacity of researchers and extension workers, and developing and disseminating the production technology among farming communities. The project accomplished all this and attempted empowering farmers to produce their own seed.

Maize is the third most important cereal crop of Afghanistan after wheat and rice. It covers about 5% of the total cereal area of the country and accounts for about 5% of total cereal production of Afghanistan (FAO, 2016). Even though historically maize has been an important crop of Afghanistan, its production in recent years has not increased (Fig 3).

Fig 3. Maize production, productivity and acreage in Afghanistan during past years



During the sixties and seventies, the country was cultivating maize on about half a million hectares but this has declined to 0.15m ha during last two decades. Similar trends exist for total production and productivity. The productivity reached close to three tons in 2002, remained between two and two and a half tons during 2006 to 2010 and sank to a low of 1.6 tons in 2011. Similarly, total production has remained less than half a million ton, being only 0.3 million ton in 2013. Table 1 depicts maize production and productivity figures in the region to indicate what should be achievable under our agro-climatic conditions with available new technology.

However, even with this low productivity maize production has been sufficient for domestic needs. Maize has more potential than what it has currently been utilized for. The self-

sufficiency targets for three and ten-year durations stand at 0.36 and 0.50 million tonnes. Maize is a highly remunerative crop for farmers as well as for industries. It is a crop whose all plant parts have specific domestic and/or industrial use. An increase in maize production will not just meet traditional domestic needs but will fuel growth of several industries.

Table 1. A comparison of maize statistics among neighbouring countries in the region (FAO, 2016)

Country/ Region	Area (m ha)	Yield (t/ha)	Prod. (m tones)
Afghanistan	0.15	2.1	0.31
Iran	0.13	6.9	0.9
Pakistan	1.3	4.6	6.1

Challenges in Maize Production. Though maize is the third most important cereal crop and its production is reported to be sufficient for domestic needs, rising population and income levels will fuel maize consumption both as food as well as feed, potentially leaving a shortfall in the country. FAO (2016) estimated import of 7.6 and 2.9 thousand tonnes of maize with import bills of four and 0.8 million USD in 2009 and 2011, respectively. The major challenges facing maize in the country include non-availability of quality seed, non-existing extension activities and non-availability of quality and quantity inputs at the right time. Poor mechanization, inadequate storage infrastructure, poor market support etc., further stifle maize growing and processing activities.

4 Objectives

Through this project, CIMMYT and its partners aimed to sustainably improve the livelihood of Afghan wheat and maize farmers, by developing high yielding, disease resistant varieties, and getting them onto fields. Through joint project implementation and capacity building, the project participants attempted to establish a robust national agricultural research system.

The implementation partners of this project pursued five specific objectives:

Objective 1: Identify new high yielding and disease resistant wheat and maize varieties adapted to local conditions, support their release, and produce basic seed.

Activity 1: Introduction of advanced wheat and maize lines from CIMMYT-Mexico and wheat lines from ICARDA and Ankara based TURKEY/CIMMYT/ICARDA (TCI). Maize OPVs and hybrids introduced from CIMMYT maize programs in Africa.

Activity 2: Multi-location testing of introduced wheat and maize germplasm at key ARIA research stations representing different agro-climatic zones.

Activity 3: Based on performance in the multi-location trials, introduced genotypes will be advanced to next stages of testing in national trials *viz*., preliminary (PYT) and advance yield trials (AYT).

Activity 4: Conduct National Wheat Rust Screening Nursery (NRSN) at key Afghan locations and Njoro, Kenya, to proactively screen the new identified superior genotypes, seed chain varieties and check varieties of different yield trials, and to immediately gauge any shift in the race profile in the country.

Activity 5: Based on at least three years" multi-location testing, superior wheat and maize genotypes will be identified and proposed by ARIA to the ministry for release as commercial varieties.

Activity 6: Demonstrate newly identified or released wheat and maize varieties on research farms and farmers' fields.

Activity 7: Produce high quality basic seed of newly released wheat and maize varieties at ARIA research stations for further multiplication as breeder seed by ARIA and FAO.

Objective 2: Reorganize the varietal testing, release and crop management in line with the wheat agro climatic zones identified in the previous phase of the project.

Activity 1: Conduct National Phenology Nursery at key Afghan locations to further fine-tune the Afghan wheat agro-climatic zones for the purpose of varietal releases.

Activity 2: Conduct crop management trials in different agro-climatic zones and production conditions to develop specific locally relevant recommendations.

Objective 3: Accelerated adoption of new improved wheat and maize varieties and crop management practices under local conditions.

Activity 1: Establish and support informal local technical information working groups (hubs) in four agro-climatic zones of the country at Jalalabad, Mazar, Herat, and Kabul. Involve local staff of agriculture department, farming community members, regional NARS researchers, and private sector.

Activity 2: Disseminate and demonstrate the new varieties and available production technologies through technical hubs with active involvement of participating partners.

Activity 3: Test line-sowing as part of the proposed technologies, using the varieties demonstrations. Include reduced tillage options if possible.

Activity 4: Local processing of seeds from improved wheat varieties in villages: 8 mobile seed cleaners will be procured and operationalised in selected villages. Seeds produced on the demonstration fields will be harvested, processed, and will be available for

distribution among local farmers as informal seed. Seed cleaners will be owned by the local MAIL office after the end of the project. To minimize the risk of elite capture or of neglect of the machine, before the end of the project communities will receive information about the seed cleaners' availability, who is responsible for it, and what is the agreed process to use it. The community briefing will be prepared with MAIL and delivered by MAIL.

Objective 4: Build capacity for wheat and maize improvement in Afghanistan.

Activity 1: Conduct in country trainings in various subject fields by involving in-country and external consultants, taking care that more women are trained than in the previous phase.

Activity 2: Provide training opportunities in the region and in international agricultural research centres involving CIMMYT and ICARDA, ensuring that there is greater participation by women than in previous phases.

Activity 3: Provide field manuals and technical information in various operational areas of wheat and maize improvement research.

Activity 4: Conduct annual crop (wheat and maize) workshops to analyse results and plan a technical program for the next season. The workshops will also attempt to make technical recommendations to the government ministries on consensus research results including those for varietal releases.

Objective 5: Verify project success and opportunities for scaling out.

Activity 1: Undertake a baseline socio-economic survey of targeted wheat maize farmers in hub regions, including the role of women and children in wheat- and maize-based systems.

Activity 2: Assess status of technology awareness, availability, and adoption among farmers of target regions at the project take-off stage.

Activity 3: Assess impact terms of technology adoption and other socio-economic parameters in the final year of the project.

Activity 4: Phenotype and genotype the wheat Afghan gene bank: The project will select, multiply and then grow about 1,000 lines from the Afghan gene bank in Kabul. The accessions will be comprehensively phenotyped at an Afghan location and certain diseases like Karnal Bunt will be screened in Mexico. The CIMMYT team will extract the DNA, determine the whole genome profile of each accession, and record and report the results so that the accessions can serve as a reference for varietal identification of wheat grown in Afghanistan.

Activity 5: Collect wheat samples from 600 randomly selected farms around the 4 hubs. Extract DNA from each collected sample, genotype using the whole genome profiling method applied to the gene bank analysis. Analyse and report the result to conclude on the identity of the farmers samples.

5 Methodology

Objective 1: **Identify new high yielding and disease resistant wheat and maize varieties adapted to local conditions, support their release and produce basic seed.**

To have new varieties for farmers the two obvious options are either to develop in country or get some from abroad, test them in country and release the ones that prove superiority in the in country testing program. Developing new varieties in country is an attractive and more sustainable option but it takes at least 15 years for a new breeding programme to deliver something on farmer fields. Therefore, the second option was the obvious choice to support Afghan wheat farmers. CIMMYT bred wheat varieties have been found both in Afghanistan and elsewhere in the world (Lantican *et al*., 2016). The project therefore opted to import nurseries, trials and other available high yielding improved genotypes from relevant institutions such as CIMMYT, ICARDA, TURKEY/CIMMYT/ICARDA, and other relevant programs. Extra efforts were made to procure heat stress and water deficit stress tolerant wheat genotypes. For maize, appropriate early maturing genotypes were sourced from CIMMYT maize breeding programs.

The varietal release system of the country requires to generate in country data on ARIA research farms. Therefore, the introduced genotypes were screened and evaluated in the country at several locations viz., Mazar, Takhar, Badakhshan, Kunduz, Baghlan, Bamyan, Kabul, Jalalabad, Herat, Kandahar, Kunar, Kapisa, Ghor, Parwan and Helmand.

The introduced and advanced material was tested against check varieties for both yield and biotic and abiotic stresses. The project operated in partnership with ARIA at research stations. The planning, trial constitution was done at CIMMYT Kabul in partnership with ARIA, Kabul while sowing of the trials, data collection, harvesting and other field operations were undertaken at various research stations by the respective ARIA staff at that station. CIMMYT staff and ARIA head quarter staff visited all the stations two to three times during the crop season to monitor the experiments at research stations. Since Afghanistan lacks proper postal and courier services, trial and data dispatch many a times involved private taxi drivers. However, CIMMYT was always in touch with ARIA research stations through phone and other ICT means. The project leader also moved to India in second half of 2015 and operated from India. He visited Afghanistan as and when needed and was communicating with CIMMYT, ARIA, MAIL and other stake holders through phone, mails etc.

Identified superior wheat and maize genotypes were advanced to next stage of testing in form of preliminary yield trials (PYT) targeted at specific production domains. ARIA has regional research stations at several locations in Afghanistan (Table 2). The research stations cover the entire length and breadth of the country for the purpose of testing new genotypes and also for developing production management technology. The genotypes identified superior in PYT were promoted to advance yield trials (AYT) and then to National Uniformity Trials (NUT).

As part of a proactive approach, a national rust screening nursery (NRSN) of wheat lines comprising of all AYT entries, all checks, and all seed chain varieties was organized every year at Herat, Jalalabad, Mazar, Kabul, Bamyan, Badakhshan, Kunduz, Takhar, Baghlan, Helmand and Kandahar. One set of this nursery was also screened at Njoro, Kenya to screen our material for Ug99 race of stem rust.

Genotypes distinctly superior to commercial check varieties in any production domain were identified and then proposed for release as commercial variety. Yield and rust resistance were the main traits of interest in wheat whereas in case of maize, yield and early maturity were the criteria to select superior varieties.

So identified varieties were also demonstrated at research farms.

Basic seed of released varieties was produced at ARIA research stations for further multiplication as breeder seed by other agencies.

Table 2. List of ARIA Research Stations

No	Site	Acronym	Institution	Latitude (N)	Longitude (E)	Altitude (m)	Mean Temperature (C°)		Annual Rainfall (mm)
							Max	Min	
1	Badakhshan	BDK	Baharak	36° 50′	70° 49″	1733	- -	-	-
2	Baghlan	BGL	Posi-e-shan	36° 42′	67° 13″	510	26.6	-2.4	413
3	Balkh	BLK	Dehdadi	36° 65’	66° 96’	387	33.1	1.1	200
4	Bamyan	BMN	Mullah Ghulam	34° 43’	37° 49″	2550	17.8	-7.1	200
5	Herat	HRT	Urdu Khan	34° 18’	62°16’	927	28.9	-0.6	367
6	Helmand	HLM	Bolan	34° 31″	70°14″	789	32	7.4	200
7	Kabul	KBL	Darulaman	34° 28’	69° 09’	1841	26.5	0	550
8	Kandahar	KND	Kokaran	31° 35'	65° 40’	630	-	-	124
9	Kunduz	KDZ	Central Farm	36° 43’	68° 51’	373	31.5	0	348
10	Nangarhar	NGR	Shishambagh	34° 49’	70° 74’	541	40.6	2	243
11	Takhar	TKR	Taloqan	36° 44″	49°30″	804	27	2.3	-

Objective 2: Reorganize the varietal testing, release and crop management in line with the wheat agro climatic zones identified in the previous phase of the project.

- Breeding aims at developing varieties that would give best performance under a given environment. This would imply that to get best performance, variety could change with any change in environment. This is the reason why agro climatically homogeneous regions should be clustered together into wheat agroclimatic zones so that different sets of varieties could be released for these different regions to enable farmers get best possible harvest (Wart et al., 2013). Flowering is one such development stage which could be used to differentiate geographic regions into different zones so that varieties displaying similar flowering patterns could be grouped in one zone (Nitcher *et al*., 2014). A National Phenology Nursery (NPN) comprising of winter wheat, facultative and spring wheat accessions was sown at all possible locations (Badakhshan, Mazar, Takhar, Baghlan, Kunduz, Kabul, Jalalabad, Herat, Kandahar, Helmand, Logar, and Ghazni, Wardak) to further fine-tune the Afghan wheat agro-climatic zones for the purpose of varietal releases.

- Initially NUT, and later AYT too were conducted in specific wheat agro climatic zones. Subsequently, this specificity was also advanced to sowing time *viz.,* fall sown, spring sown etc., depending on the importance of the sowing time in a given zone.

Objective 3: Accelerated adoption of new improved wheat and maize varieties and crop management practices under local conditions.

- A locally-stationed CIMMYT technical person facilitated the confluence of representatives of local agriculture departments, NGOs, local extension workers, and private sector representatives to form an informal local technical working group (hub). The provincial counterpart of MAIL *viz*., Directorate of Agriculture, Irrigation & Livestock (DAIL) was a crucial partner in project's outreach activities through Hub mode. DAIL extension staff was always a party to farmer field demonstrations, field days or farmer trainings that were organised in the provinces.

- Research hubs were formed in four wheat agro-climatic zones at Jalalabad, Mazar, Herat, and Kabul. Local agriculture departments, farming community members, regional NARS researchers, and private sector representatives were involved too.

- Technically led by CIMMYT, hubs developed consensus recommendations for technologies and recommendations for farmers in the region, with active involvement of participating partners.

- Hubs built local capacity to access and use advance information available from CIMMYT, ARIA and other relevant organizations to disseminate technology best suited to local conditions. We focussed on-farm demonstrations of only the released varieties as the law forbids us to grow and demonstrate unreleased varieties on farmer fields. The Hubs synthesized the locally relevant knowledge and developed extendable technical messages.

Objective 4: Build capacity for wheat and maize improvement in Afghanistan.

Specific trainings were organized for ARIA researchers and extension workers by in-country staff and invited international experts.

Six to 12 ARIA researchers were deputed for medium- to long-term training courses within the region and at international centres of CIMMYT.

Practical technical manuals and information brochures were prepared and distributed among extension workers, including guides to score diseases and fact sheets on particular topics such as Karnal Bunt, winter wheat etc.

Crop-specific workshops were organized every year during off-season for all the in-country researchers involved in conducting crop-specific experiments. The experiments conducted in the previous season were discussed and analysed, forming the basis of next season's technical program. The workshop also endeavoured to make technical recommendations

based on its research results, including recommendations on varietal release.

Objective 5: Verify project success and opportunities for scaling out.

CIMMYT‟s socio-economics program designed a baseline socioeconomic survey of end users in HUB regions to assess level of technology awareness and adoption.

Impact assessment in terms of technology adoption vis-à-vis socio economic parameters was undertaken during 2015-16. Afghan wheat germplasm was phenotyped in Kabul and also at Mexico. The germplasm was used to create a reference population and the reference population was used to genetically ascertain the identity of farmers' claims on varieties picked up from their fields.

6 Achievements against activities and outputs/milestones

Objective 1: To identify new high yielding and disease resistant wheat and maize varieties adapted to local conditions, support their release, and produce basic seed.

no.	activity	outputs/ milestones	completion date	comments
1.1	Introduction of advanced wheat and maize lines from CIMMYT-Mexico and wheat lines from ICARDA and TURKEY/CIMMYT/ICARDA. Maize OPVs and hybrids will be introduced from CIMMYT maize programs in Africa.	Irrigated wheat: 5411 new lines were introduced	2017	All these lines were tested at several locations throughout Afghanistan and promising ones were promoted to next stage of testing.
		Rainfed wheat: 2484 new lines were introduced		
		Hybrid maize: 83 new lines were introduced		
		OP Maize: 78 new lines were introduced		
1.2	Multi-location testing of introduced wheat and maize germplasm at key ARIA research stations representing different agro-climatic zones.	Irrigated wheat: 483 yield evaluation trials	2018	The data generated over years were analysed and better performing genotypes were used to constitute advance trials.
		Rainfed wheat: 102 yield trials		
		Hybrid maize: 16 yield evaluation trials		
		OP Maize: 19 yield evaluation trials		
1.3	Based on performance in the multi-location trials, introduced genotypes will be advanced to next stages of testing in national trials *viz*., preliminary (PYT) and advance yield trials (AYT).	Irrigated wheat: Total 13051 lines tested	2018	Results of these trials were used to compile information on new promising genotypes for release as commercial varieties.
		Rainfed wheat: 3316 lines tested		
		Hybrid maize: Total 220 lines tested		
		OP Maize: Total 193 lines tested		
1.4	Conduct National Wheat Rust Screening Nursery (NRSN) at key Afghan locations and Njoro, Kenya, to proactively screen the new identified superior genotypes, seed chain varieties and check varieties of different yield trials, and to immediately gauge any shift in the race profile in the country.	1396 genotypes were included in six national rust screening nurseries (NRSN) constituted in each of the six project years from 2012-13 to 2017-18. The lines included all seed chain varieties and all AYT and NUT entries.	2018	The NRSN served as a common platform to screen all the important wheat lines of Afghanistan, and provided crucial information for varietal release process.
1.5	Based on at least three years‟ multi-location testing, superior wheat and maize genotypes will be identified and proposed by ARIA to the ministry for release as commercial varieties.	A large number of release proposals were submitted to Ministry of Agriculture, Irrigation & Livestock (MAIL) of Government of Islamic Republic of Afghanistan (GoIRA) during the project life.	2018	Irrigated wheat: 15 new varieties released including 2 barleys
				Rainfed wheat: 5 new varieties released
				Hybrid maize: 3 hybrids released
				OP Maize:4 varieties released ***Appendix I***

1.6	Demonstrate newly identified or released wheat and maize varieties on research farms and farmers' fields.	452 wheat demonstration plots of new varieties were conducted at research farms between 2012-13 and 2017-18. Similarly, 23 plots of maize were also planted during the same period. Additionally, 2766 farmer field demonstrations were conducted in the four provinces of Kabul, Nangarhar, Balkh and Herat.	2018	Demonstration cum seed production plots were conducted at research farms of ARIA.
1.7	Produce high quality basic seed of newly released wheat and maize varieties at ARIA research stations for further multiplication as breeder seed by ARIA and FAO.	24 plots of maize as well as 452 plots of wheat were raised at ARIA research farms to produce basic seed of newly released varieties.	2018	The seed produced was handed over to ARIA to produce breeder seed of the new varieties.

Objective 2: To reorganize the varietal testing, release and crop management in line with the wheat agro climatic zones identified in the previous phase of the project. …

no.	activity	outputs/ milestones	completion date	comments
2.1	Conduct National Phenology Nursery at key Afghan locations to further fine-tune the Afghan wheat agro-climatic zones for the purpose of varietal releases.	NPN conducted during project life led to the creation of four wheat climatic zones viz., Eastern, Northern, South-Western and Central Highland.	2017	ARIA has integrated this information in its varietal testing system and even varieties have been released based on this information.
2.2	Conduct crop management trials in different agro-climatic zones and production conditions to develop specific locally relevant recommendations.	104 agronomic experiments on winter wheat, 144 on spring wheat, 63 on rainfed wheat and 96 on maize were successfully conducted during the project life across the length and breadth of the country.	2017	18 extension messages and new revised agronomy fact sheets of maize and wheat were developed based on these experiments.

Objective 3: Accelerated adoption of new improved wheat and maize varieties and crop management practices under local conditions.

no.	activity	outputs/ milestones	completion date	comments
3.1	Establish and support informal local technical information working group hubs in four agro-climatic zones of the country at Jalalabad, Mazar, Herat, and Kabul. Involve local staff of agriculture department, farming community members, regional NARS researchers, and private sector.	The four informal groups were formed in the four provinces of Kabul, Nangarhar, Herat and Balkh.	2012	The hubs started working with effect from 2012-13 season and accomplished 2766 farmer field demonstrations during the project under report.

3.2	Disseminate and demonstrate the new varieties and available system independent production technologies through the technical hubs with active involvement of participating partners.	Project accomplished 2766 farmer field demonstrations during the project under report. Also, produced about 18 new extension messages and/or fact sheets. Interviewed and collected more than 588 samples from farmer fields.	2018	Hub staff also organised field days and trainings for farmers and other stake holders in the region. 4779 Afghans attended these events.
3.3	Demonstrate line sowing for crop establishment. Include reduced- or no-tillage options if possible.	More than 80% farmer field demos were line sown during 2016-17 and 2017-18	2018	The seed drills kept with the project will be donated to provincial DAILs to enable them continue demonstrate advantages of line sowing to farmers.
3.4	Procure, install and commission 8 mobile seed cleaners in selected villages. Train seed cleaner operators. Process one crop of wheat seed.	The four provinces received eight seed cleaners. The harvest of 2016-17 demo farmers was cleaned at their doorstep.	2018	441 farmers cleaned 200 MT of wheat seed at their doorstep. 1925 farmers benefited from this cleaned seed.

Objective 4: Build capacity for wheat and maize improvement in Afghanistan.

no.	**activity**	**outputs/ milestones**	**completion date**	**comments**
4.1	Conduct in country trainings in various subject fields by involving in-country and external consultants, taking care that more women are trained than in the previous phase.	640 Afghan researchers benefitted from in country trainings organised by the project.	2018	All trainings topics were identified in consultation with ARIA. ***Appendix II***
4.2	Provide training opportunities in the region and in international agricultural research centres involving CIMMYT and ICARDA, ensuring that there is greater participation by women than in previous phases.	65 ARIA and other Afghan researchers were trained abroad by the project.	2018	The trainings were organised in Mexico, Turkey, India, Nepal and other neighbouring countries. ***Appendix III***
4.3	Provide field manuals and technical information in various operational areas of wheat and maize improvement research.	18 new extension messages/ fact sheets were developed and disseminated among target beneficiaries.	2018	The topics covered included agronomic recommendations, plant protection and weed management etc.
4.4	Conduct annual crop (wheat and maize) workshops to analyse results and plan a technical program for the next season. The workshops will also attempt to make technical recommendations to the government ministries on consensus research results including those for varietal releases.	Five wheat and five maize workshops were organised during the project life.	2018	Workshops have become platforms for wheat and maize researchers to discuss results of previous season and plan for the coming one.

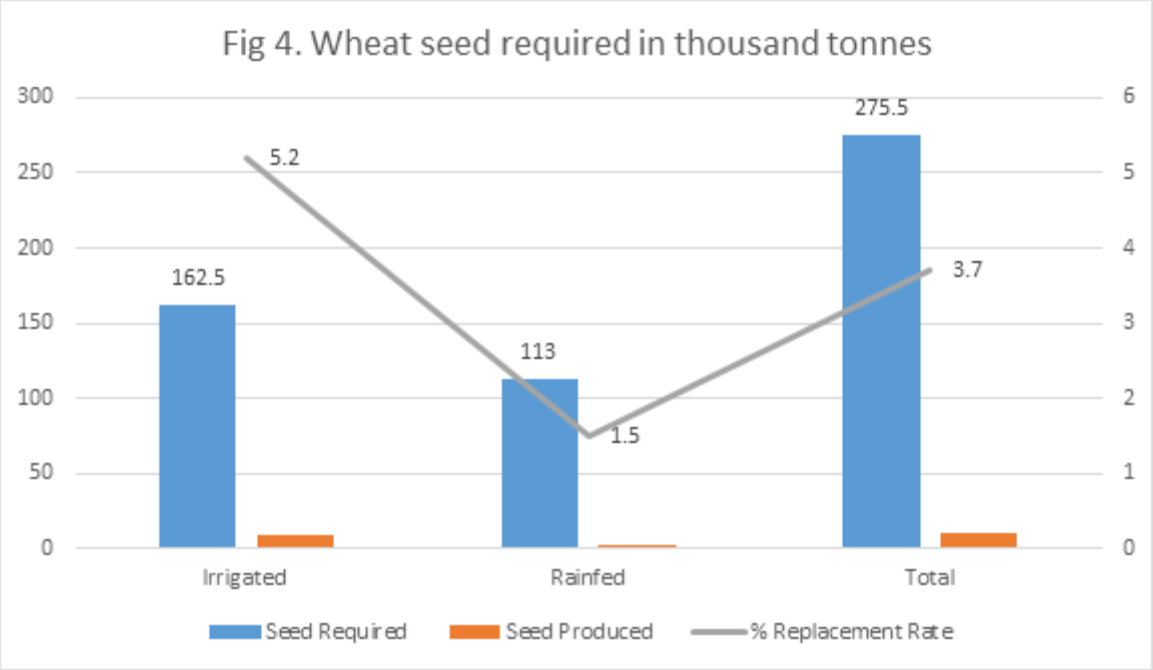
Objective 5: Verify project success and opportunities for scaling out

no.	activity	outputs/ milestones	completion date	comments
5.1	Undertake a baseline socio-economic survey of targeted wheat maize farmers in hub regions, including the role of women and children in wheat- and maize-based systems.	Main Outcome: 1. The adoption of local varieties are higher than improved varieties 2. Major seed sources are other farmers, CIMMYT, own seed and seed companies 3. Sources of irrigation varies according to region. Main sources are river, Kariz, Canal and tube well The constraints faced by the farmers are many and the major ones among them are problems related to seed availability and quality, access to information, credit availability and input availability Women mainly control livestock management but utilization of produce is controlled by man. Women have no role in agricultural technology adoption. The main profession is farming and there is no secondary occupation. The level of varietal adoption is high in Kabul and Balkh.	2014	399 households were surveyed in four provinces. The survey revealed that 76% of HH heads have agriculture as primary occupation and 60% of HH heads contribute 100% of their time to family labour. Wheat was reported as main winter crop and only Nangarhar reported growing maize. The broadcasting was reported to be the most common sowing method.
5.2	Design impact assessment questionnaire and conduct the survey	40% of farmers in each province received improved variety in 2014-15. The % of farmers growing seed chain varieties in 2015-16 were 53% in Herat, 75% in Kabul, 64% in Balkh and 100% in Nangarhar.	2018	600 farmers were surveyed in four provinces. 60 treatment farmers and 90 control farmers in each province. ***Annexure I***
5.3	Phenotype and genotype 1,000 wheat lines from the Afghan gene bank	The phenotyping revealed that days to maturity ranged from 188 to 214 and height ranged from 30 cm to 135 cm. 1019 genotypes were genotyped and reduced to 761 to represent a reference library for Afghanistan. Screening for resistance at Mexico revealed several lines resistant to various diseases. Ten lines including a land race viz., Nish Shotor were identified to be a donor for multiple disease resistance ***(Appendix VI, Annexure II).***	2018	1277 wheat genotypes comprising of all that was available with ARIA were characterized at Kabul during 2014-15 ***(Appendix IV).*** The genotyping revealed the genes present in Afghan collection ***(Appendix V).***
5.4	Establish genetic identity of the wheat varieties grown by a random sample of farmers with reference to the Afghan wheat gene bank	94% of samples could be identified using the genotyping tools. Large number of improved varieties were grown by farmers and 60% of them correctly predicted their varieties. Local landrace stocks and the Afghan wheat collection are diverse and valuable resources for the country and deserve to be maintained.	2018	A total of 588 farmer field samples were analysed to ascertain identities. A group of 761 lines was used as a reference set for ascertaining the identities. ***(Annexure III).***

7 Key results and discussion

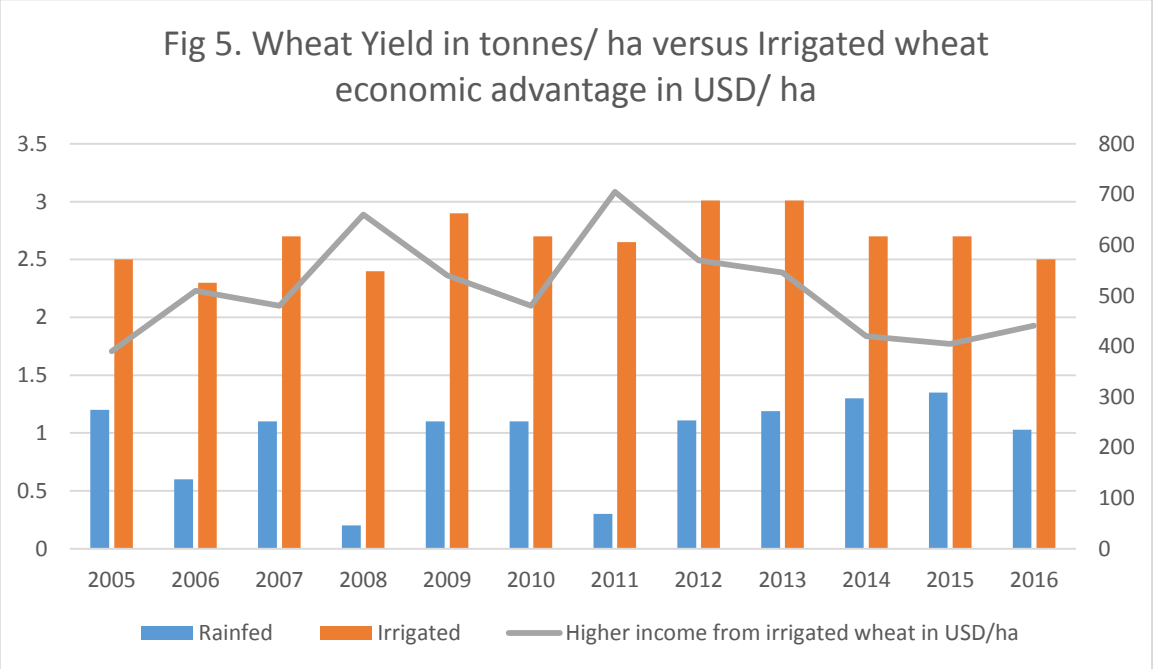
Objective 1: **Identify new high yielding and disease resistant wheat and maize varieties adapted to local conditions, support their release and produce basic seed.**

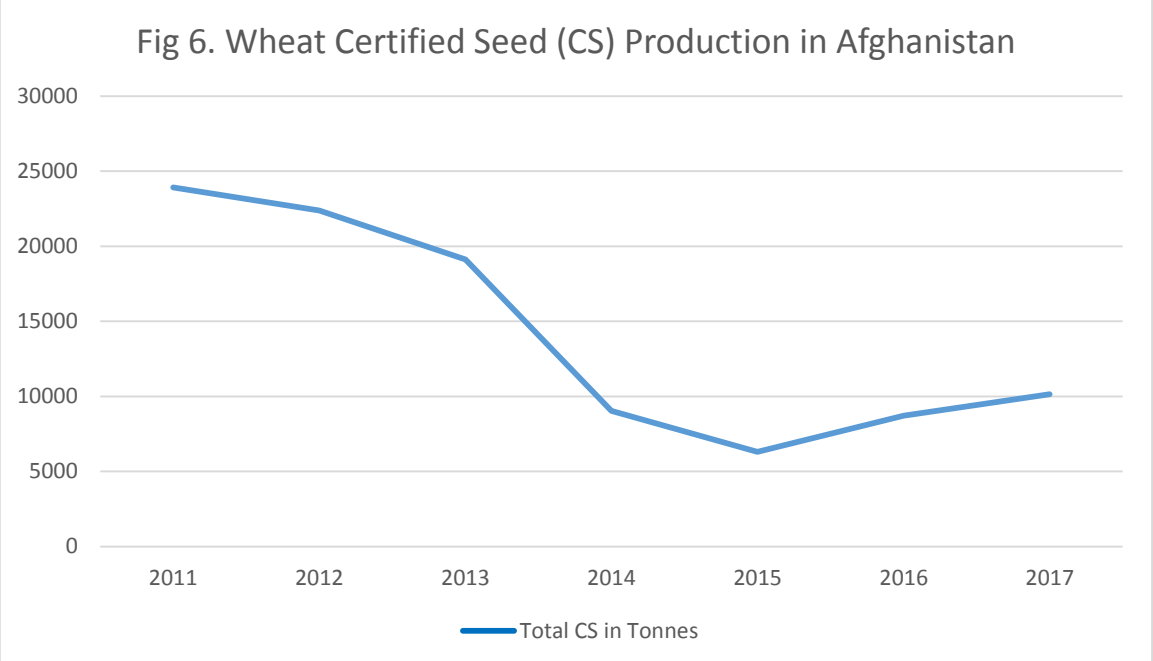
WHEAT: 14 new bread wheat varieties, four durum and two barley varieties were released during the project period. As explained in the methodology section, the major target traits for wheat were yield and rust resistance. All wheat varieties released were resistant to all prevalent races of rust and their yield superiority is mentioned in ***Appendix 1***. This proves that CIMMYT bred wheat varieties are very well adapted to Afghan conditions. The fact that country has remained free from any disease epidemic also shows the efficacy of not just CIMMYT resistance breeding approach and its suitability for Afghanistan but also of the advocacy in Afghanistan. Most of the varieties released during the project life have entered seed production as evidenced by the fact that current project varieties account for 15% of total certified seed (CS) and post 2002 varieties of ACIAR CIMMYT implemented projects account for over 80% of total CS produced (2017-18 plan) in country. However this needs to be noted that while wheat breeding has been so successful in developing and releasing new varieties in the country, MAIL and its agencies involved in seed production have not been successful in producing required quantities. Fig 4 below shows the wheat CS requirement and supply situation in the country.



The seed replacement rate for rainfed wheat is only about 1.5%, whereas for irrigated wheat it stands at 5%. The country needs to have at least 50% replacement rate so that every wheat field gets new seed every third year. The breeding work needs to be continued, however as Afghanistan develops, ARIA needs to initiate a systematic breeding work. The project has already initiated a germplasm characterization work and results are available with ARIA. Since rainfed wheat is contributing only about 25% of the total wheat production, therefore, country needs to emphasize irrigated domain for ensuring wheat security. This does not mean that rainfed wheat can be ignored but that rainfed wheat by virtue of being an inconsistent supplier should be seen as a bonus harvest. Rainfed wheat crop can at best be described as uncertain. Irrigated wheat crop has earned its growers USD 350 per hectare to up to USD 700 per hectare extra over and above any rainfed wheat crop in that year (Fig 5). The uncertainty associated with rainfed

wheat deters farmers from investing in rainfed wheat. This perhaps is the biggest reason why there is almost no demand for certified seed of rainfed wheat. Another reason for declining seed production in country is the huge easy money that was available with Government to buy seed and distribute free or on high subsidy among farmers. With that easy money drying up total certified seed production of the country also saw a declining trend (Fig 6).





MAIZE: Three maize hybrids and four maize OP varieties were released during the project duration. This proves that CIMMYT bred maize varieties are very well adapted to Afghan conditions. The main traits of interest in maize breeding are higher yield and a shorter

duration. The yield advantages of the new varieties is mentioned in the list in ***Appendix I***. The average maturity of OP varieties released during the project ranged between 115 and 119 compared to 115 to 117 of released checks. Similarly, the released hybrids had a maturity range of 106 to 107 days compared to 107 to 111 of check varieties used in hybrid trials. Our efforts to stimulate system to produce seed of hybrid maize did not succeed for various reasons including lack of isolation, weak infrastructure and poor participation from private companies. OP maize varieties on the other hand were integrated into the seed system and found acceptance among companies as well as ARIA and ISE. Since maize occupies just 5% of total cereals' acreage in the country, let us for the time being continue with OP varieties as hybrid seed production requires a much higher level of technical competency and infrastructural support.

Objective 2: **Reorganize the varietal testing, release and crop management in line with the wheat agro climatic zones identified in the previous phase of the project.**

Current practice of releasing new wheat varieties makes use of yield evaluation trials conducted throughout the country. Afghanistan has wide range of agro-ecologies characterized by cold winters and hot summers. Though eastern Afghanistan does receive monsoon rains, most of the Afghanistan is semi-arid or arid (Saidajan, 2012). Therefore project took up this responsibility to generate information to categorize country into all possible wheat climatic zones to not only fine-tune production management but also identify best adapted varieties for each zone. Phenological traits - mainly days to flowering - is a reflection of agro climatic features of any location and can be aptly

Table 3 Regions falling under different categories based on average number of days to 50% flowering (ADF).

ADF Range	E	N	S	W	NE	CH
<100	NGR (95)	-	-	-	-	
100-120	-	BGL, TKR, KDZ (112)	KND (101)	HRT (111)	-	
120-140		BLK (124)				
>140					BDK (161)	BMN, KBL (153)
ADF mean for proposed zone	**95**	**118**	**106**		**157**	

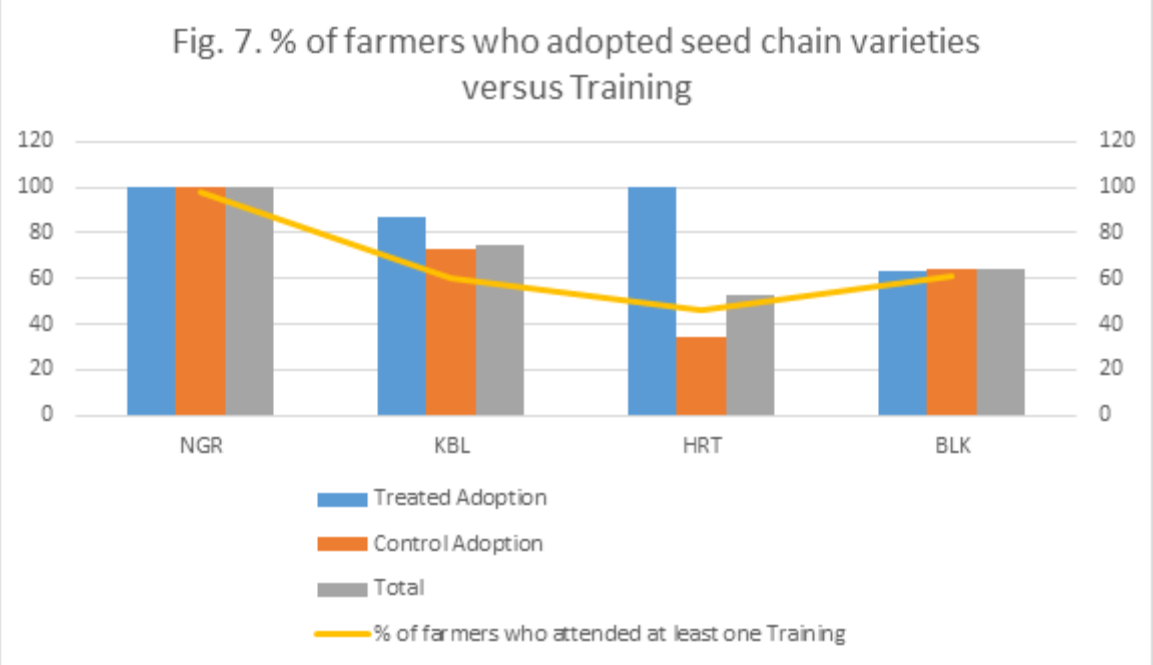
ADF: Average number of Days to 50% Flowering; E: East; N: North; S: South; W: West; NE: North East; CH: Central Highland

employed to characterize different agro climatic zones (Diaz et al., 2012; Pearce et al., 2016). Afghan wheat acreage was scientifically grouped into four climatic zones (Table 3) (Obaidi et al., 2016), agronomy packages for each zone was developed, varietal testing was also designed accordingly and even a wheat variety was released for one of the zones. The exercise would help maximise varietal performance and thereby increase wheat production in the country. The varietal testing programme has started using this zonal classification and one such variety specific for Northern zone was released by MAIL.

ARIA and CIMMYT had together compiled a Wheat Agronomy Factsheet in 2012. Since project initiated delineation of wheat agro climatic zones, it also took the responsibility of developing agronomy fact sheet for all the zones. Information from a total of 407 wheat and maize agronomy experiments led to the development of domain and zone specific production packages. The same were accepted by farmers is evident from their demands for seed drills for line sowing which alone increased yields by up to 20% in farmer fields.

Objective 3: **Accelerated adoption of new improved wheat and maize varieties and crop management practices under local conditions.**

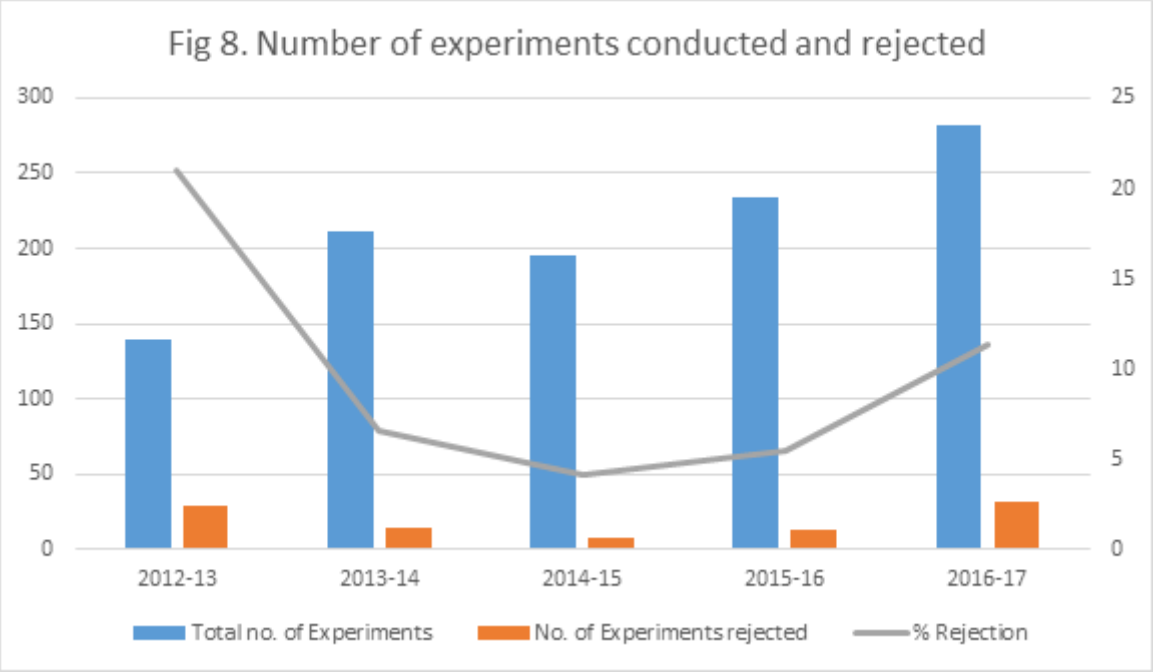
To demonstrate the effectiveness of technology, project identified four provinces covering major wheat agroclimatic zones viz., at Nangarhar in east, Mazar in north, Kabul in centre and Herat in west, and created informal technical information assessment and dissemination hubs. The main purpose was to brainstorm with all the stakeholders involved in the region and develop consensus extendable information. Hubs started with coordination meetings attended by all the stakeholders in the region including DAIL staff. These coordination meetings assessed the status of technical know-how for wheat and maize and informed the project research teams of gaps. The agronomy research teams then formulated experiments to address those gaps and thus revised wheat and maize agronomy fact sheets were developed. These four hubs organised a total of 133 crop production trainings/ field days during the project life which saw participation by over 4500 farmers/ extension workers and others. These capacity building exercises coupled with 2766 farmer field demonstrations initiated farmers into adopting line sowing and best agronomy practices for higher yields. We conducted a survey among 600 farmers (Table 4) during 2015-16 season. 240 farmers in the four provinces of Kabul, Herat, Nangarhar and Balkh who received seed in 2014-15 season were considered treatment (T) as compared to 360 non recipient as controls (C). The farmers who claimed to have grown a seed chain variety were regarded as adopters in this survey. Our 2016 survey has found higher adoption among farmers who attended some training (Fig 7). Farmers used mobile seed cleaners



to clean their own harvest into 200 MT of informal improved seed at their doorstep empowering themselves with low cost high quality technology. The major factors limiting extension activities are (1) insecurity in countryside, (2) inadequate staff, (3) lack of training, and (4) lack of infrastructural support to extension. During our field visits or meetings, it was not unusual to hear from farmers that that was the first time they met their extension worker. Even the basic minimum facility viz., transport is missing at most places.

Objective 4: **Build capacity for wheat and maize improvement in Afghanistan.**

As demanded by them, NARS researchers were initiated into hybridization work and were demonstrated handling of segregating material to lay the foundation of a national wheat breeding programme. The project's capacity building efforts included 65 Afghan researchers visiting abroad and 640 of them attending in country trainings. Off late project could not nominate researchers for training to Mexico owing to absence of Mexican embassy in Kabul and sever visa restrictions imposed by European countries. However, this may be noted that almost all researchers working on wheat have had international exposure through ACIAR supported projects during various project phases. Many a times MAIL nominated inappropriate researchers for foreign trainings.



The in country trainings covered topics requested by ARIA. The in country training topics included Experimental Design and Analysis, Seed Production, Disease Management including Karnal Bunt etc. All this raised the bar for National research system which saw marked improvement in the conduct of experiments (Fig 8). They are now capable of selecting lines for advancing to next stage of testing, constituting trials, scoring rusts in trials and nurseries, and many of them are also able to statistically analyse their trials results. Also, ARIA organised wheat workshop for 2017 on its own and is on its way to organise the one for 2018. Researchers at regional stations, however, have not been exposed to trial constitution and many of them may not be able to do their own statistical analysis.

Objective 5: **Verify project success and opportunities for scaling out.**

Against the back drop of baseline survey of 2013, wheat samples were picked up from 600 farmers of 2015-16 season. The 600 farmers belonged to 21 villages of five districts of four provinces (Table 4). The farmers were grouped into two categories viz., treated (T) i.e., those who received seed from the project for a farmer field demonstration during 2014-15 crop season. There were 60 'T' farmers in each province making a total of 240 'T' farmers. The second group was termed as control 'C' farmers who were neighbours of 'T' farmers. Both the groups of farmers were asked a set of questions during 2015-16 crop season to study their socio-economic status and level of adoption of agricultural technologies mainly varieties developed under ACIAR projects and which are still in seed chain. The survey revealed that level of adoption varied between the two groups of farmers. A total of 88% of treated farmers reported growing seed chain varieties. This number was highest in Nangarhar followed by Herat (Fig 9). Treated farmers of both of these provinces only grew seed chain varieties. Treated farmers of Balkh (37%) and Kabul (13%) also grew local varieties (Table 5). A total of 68.1 % of 'C' farmers grew seed chain varieties. Again this number was highest in Nangarhar (100%) followed by 73.3% in Kabul and 64.4% in Balkh. The survey revealed that 66% of 'C' farmers in Herat grew local varieties, followed by 36% in Balkh and 27% in Kabul. Overall 76% of farmers grew seed chain varieties. It was highest in Nangarhar (100%) followed by Kabul (74.4%), Balkh (64%) and Kabul (27%).

Study of various socio-economic factors of the surveyed farmers revealed that some of them aided adoption, while some other hindered or were neutral to adoption (Table 6). Education level of house hold head (HH) and number of male family members affected adoption positively only among 'C' farmers and had no role among 'T' farmers. Two parameters viz., wheat training participation, and total house hold expenditure had positive affect on adoption among both the groups of farmers. Wheat growing experience of HH had positive effect on adoption among 'T', but a negative on 'C', just like total land holding which had a negative effect on 'C'. The opposite phenomenon was observed for age of HH which affected adoption positively among 'C' but had a negative effect on 'T'. Association of several other parameters with adoption is shown in figures from 10 to 17.

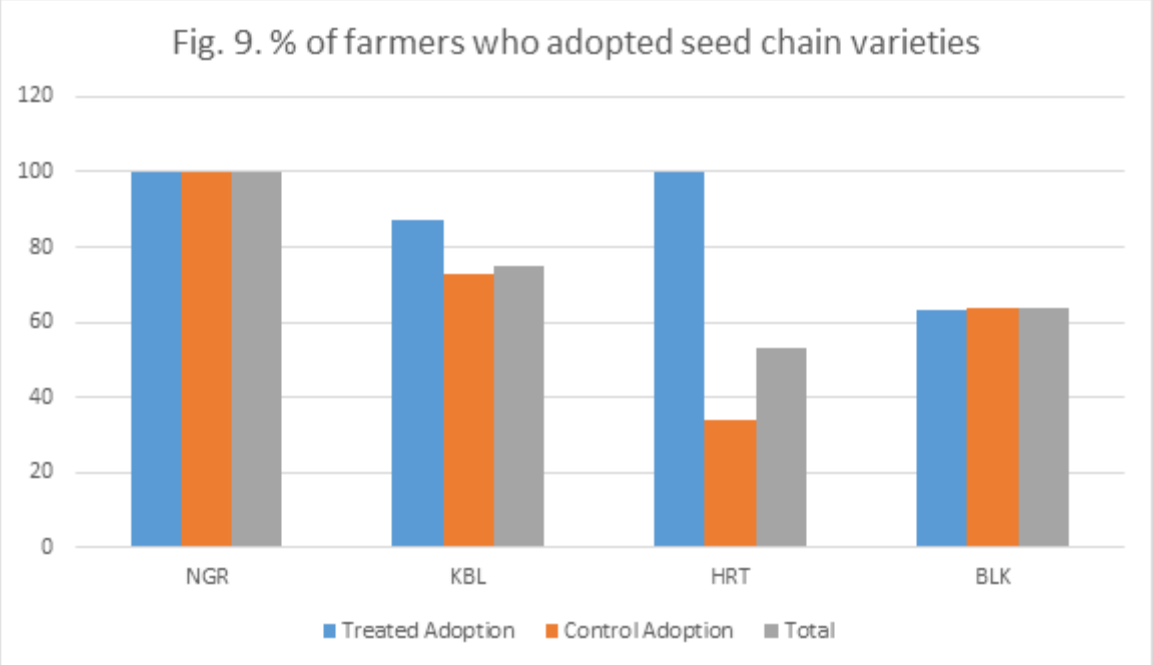


Table 4. Distribution of farmers among villages, districts and provinces.

Provinces	Districts	Villages	Households
Kabul	Bagrami	Alokhil	12
		Bagrami	13
		Gulbota	26
		Kamari	25
		Noborja	25
		Qalai Ahmad Khan	25
		Shina	24
Balkh	Dehdadi	Yaka Bagh	38
	Nahre Shahi	Langar Khana	36
		Qala Hejri	38
		Yaka Tot	38
Herat	Gozara	Khoja Shahab	30
		Mahal Dasht	30
		Qalai Mirgol	30
		Qasr Yahya	30
		Shokor Khani	30
Nangarhar	Surkhroad	Amarkhil	30
		Naghrak	32
		Nazarabad	29
		Sabz Abad	28
		Bagrami	31
Total			600

Table 5. Adoption of varieties by treated (T) and control (C) farmers

Farmers group by intervention and impact		Name of the sampled provinces			
		Kabul	Herat	Balkh	Nangarhar
Total no. of farmers sampled		150	150	150	150
Total no. of farmers in treatment group (who received seed 2014-15)		60	60	60	60
which	-No. of farmers producing wheat variety are in the seed chain (improved variety)	52	60	38	60
	-No. of farmers producing wheat variety which are not currently in the seed chain (local variety)	8	0	22	0
Total no. of farmers in the control group		90	90	90	90
which	-No. of farmers producing wheat variety are in the seed chain (improved variety)	66	31	58	90
	-No. of farmers producing wheat variety which are not currently in the seed chain (local variety)	24	59	32	0
% Currently cultivating improved wheat		74.7	52.7	64.0	100

Results showed that contact with extension worker (Figure 10), average distance from local market (Fig 11), from main road (Fig12) were positively associated with adoption. This is therefore clear that a strengthened infrastructure in terms of roads and market would lead to better adoption. A more frequent interaction with extension workers would also facilitate adoption.

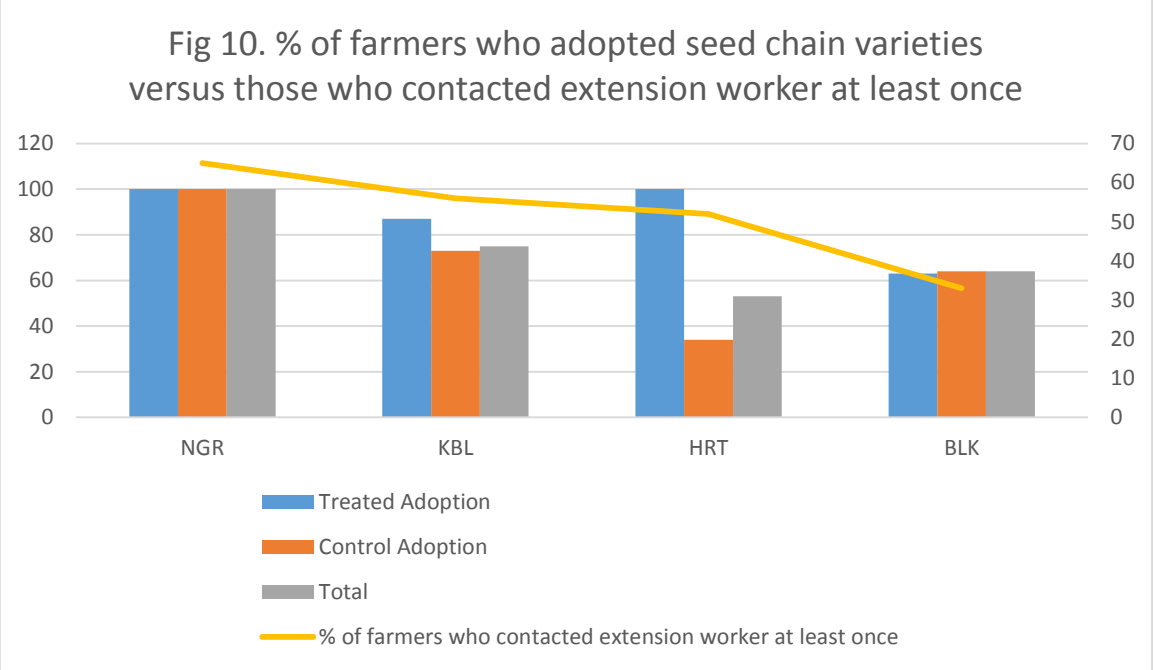


Fig 10. % of farmers who adopted seed chain varieties versus those who contacted extension worker at least once
120
100
80
60
40
20
0
70
60
50
40
30
20
10
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
% of farmers who contacted extension worker at least once

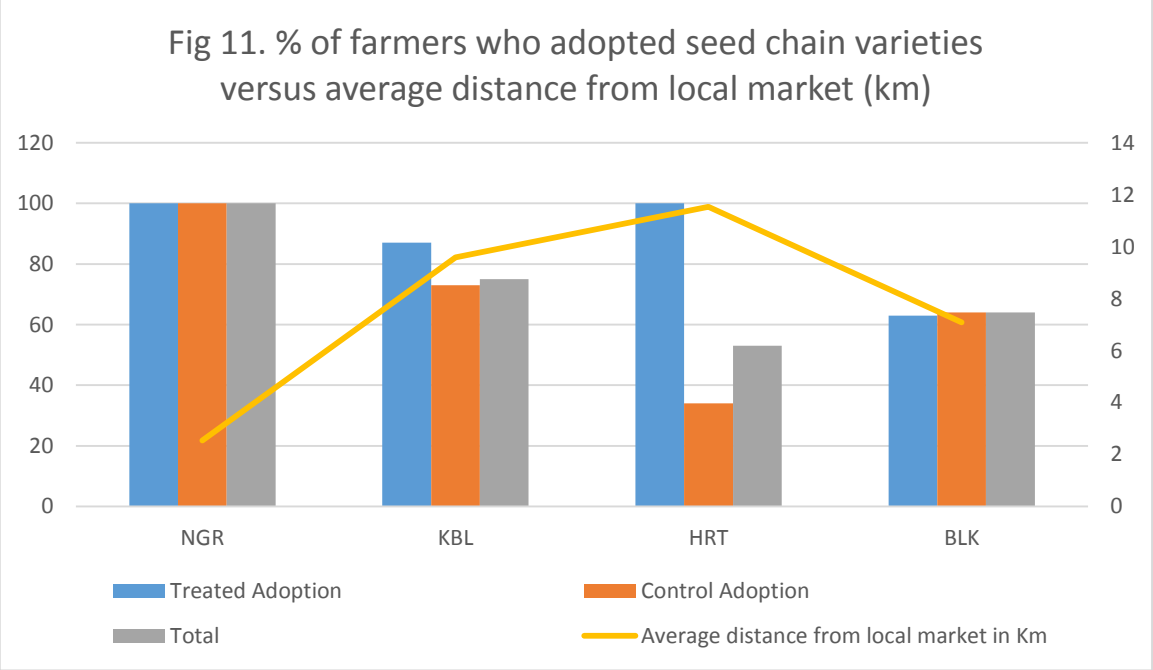


Fig 11. % of farmers who adopted seed chain varieties versus average distance from local market (km)
120
100
80
60
40
20
0
14
12
10
8
6
4
2
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
Average distance from local market in Km

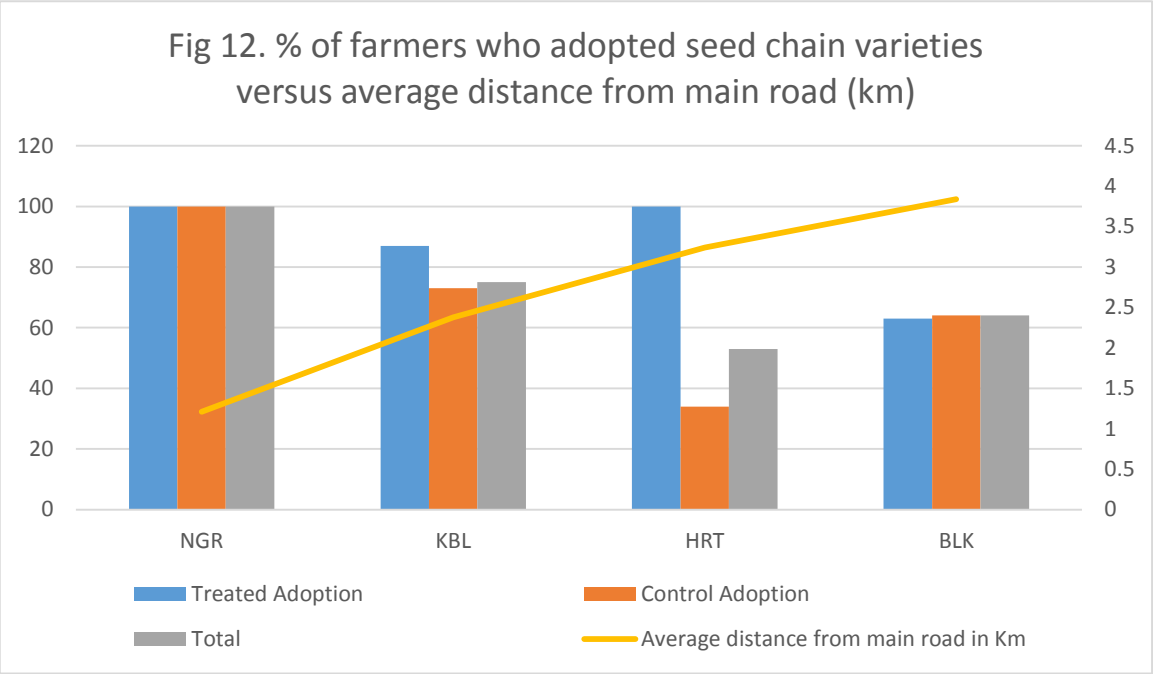


Fig 12. % of farmers who adopted seed chain varieties versus average distance from main road (km)
120
100
80
60
40
20
0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
Average distance from main road in Km

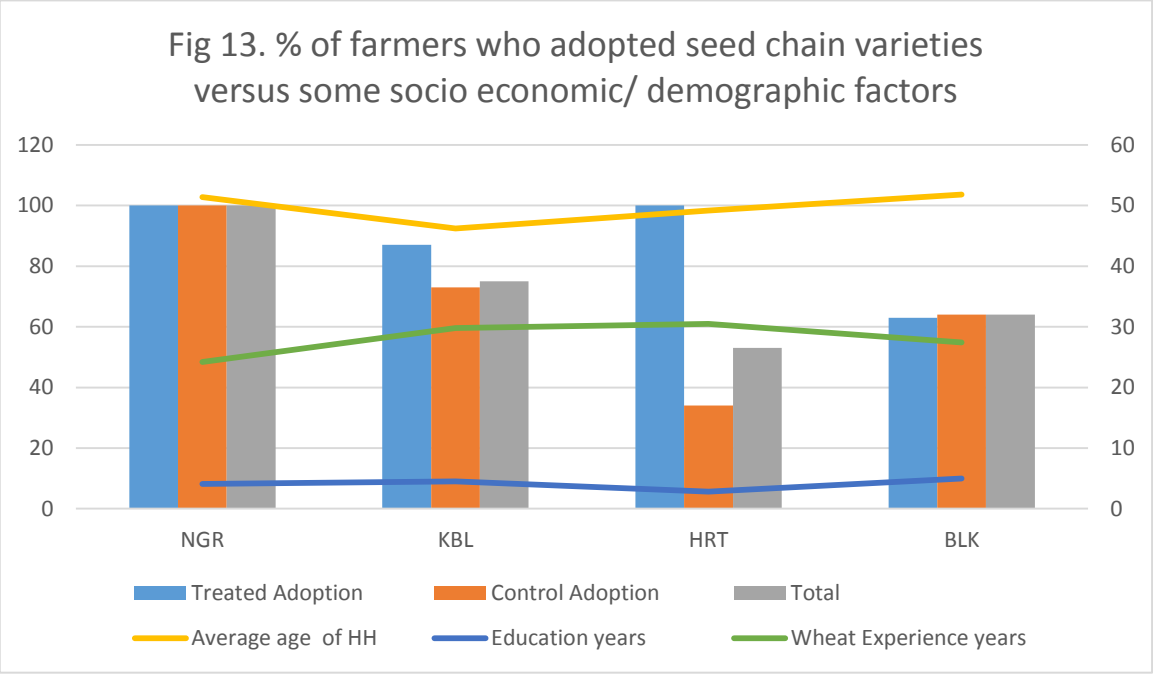


Fig 13. % of farmers who adopted seed chain varieties versus some socio economic/ demographic factors
120
100
80
60
40
20
0
60
50
40
30
20
10
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
Average age of HH
Education years
Wheat Experience years

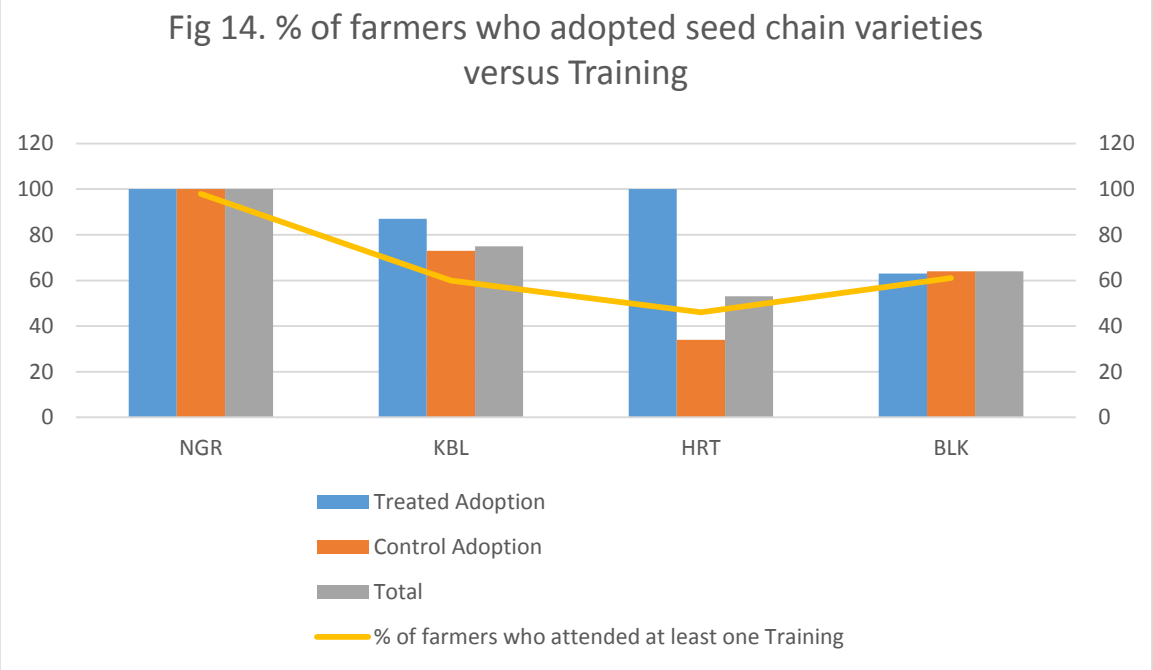


Fig 14. % of farmers who adopted seed chain varieties versus Training
120
100
80
60
40
20
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
% of farmers who attended at least one Training

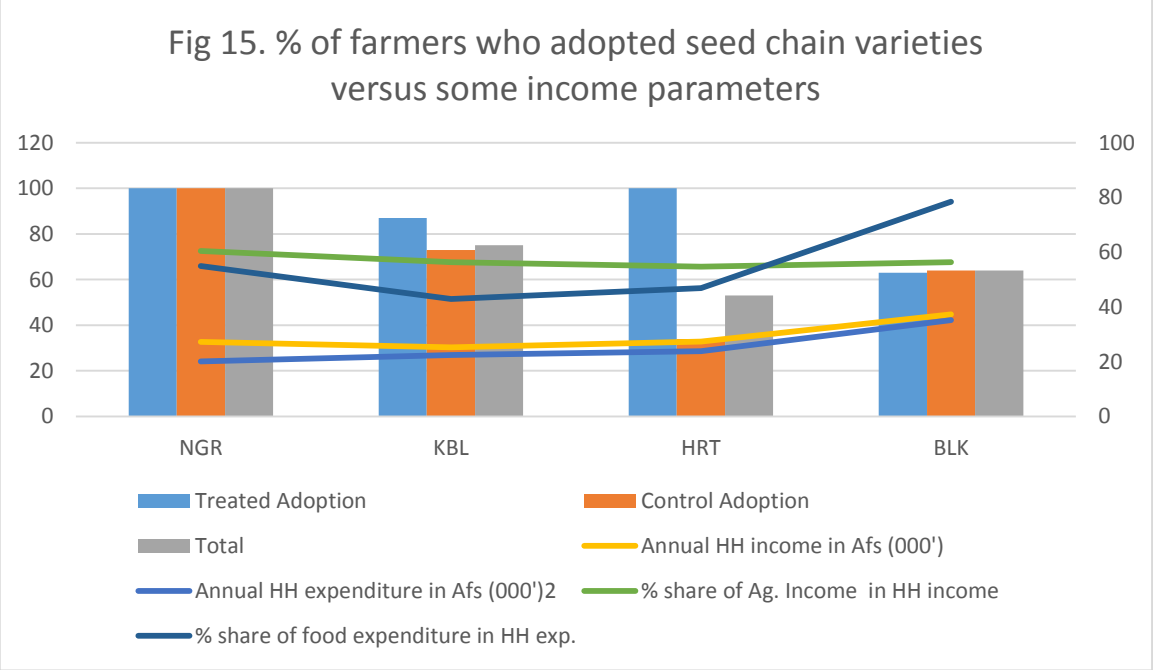


Fig 15. % of farmers who adopted seed chain varieties versus some income parameters
120
100
80
60
40
20
0
100
80
60
40
20
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
Annual HH income in Afs (000')
Annual HH expenditure in Afs (000')2
% share of Ag. Income in HH income
% share of food expenditure in HH exp.

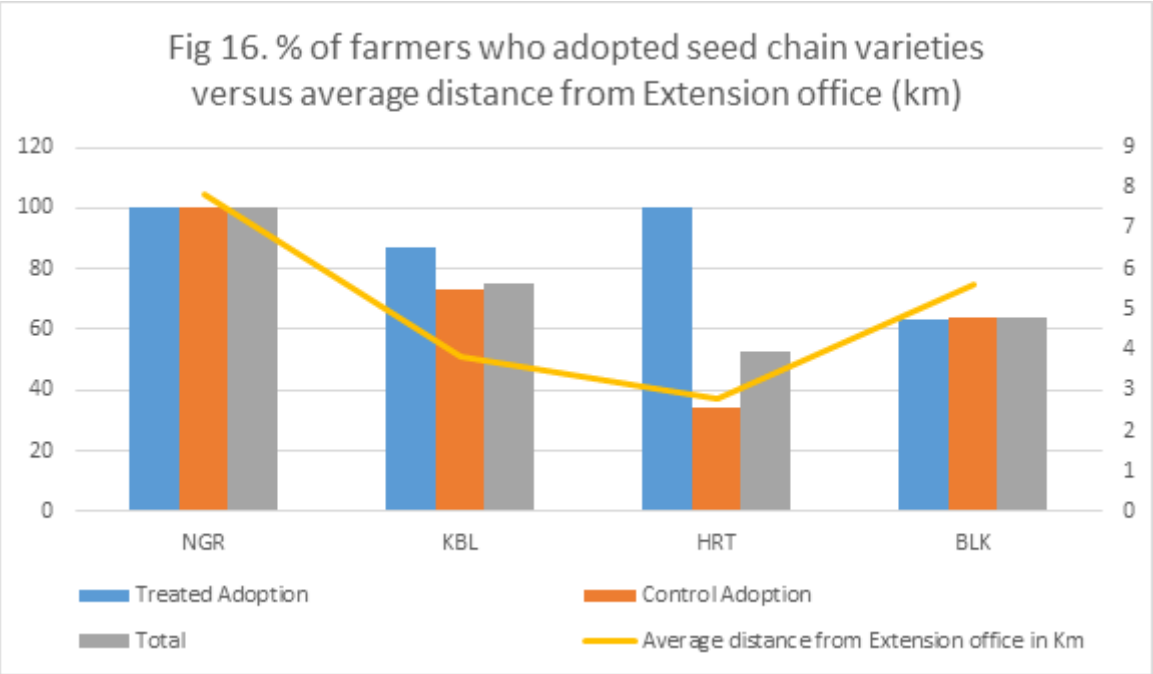


Fig 16. % of farmers who adopted seed chain varieties versus average distance from Extension office (km)
120
100
80
60
40
20
0
9
8
7
6
5
4
3
2
1
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
Average distance from Extension office in Km

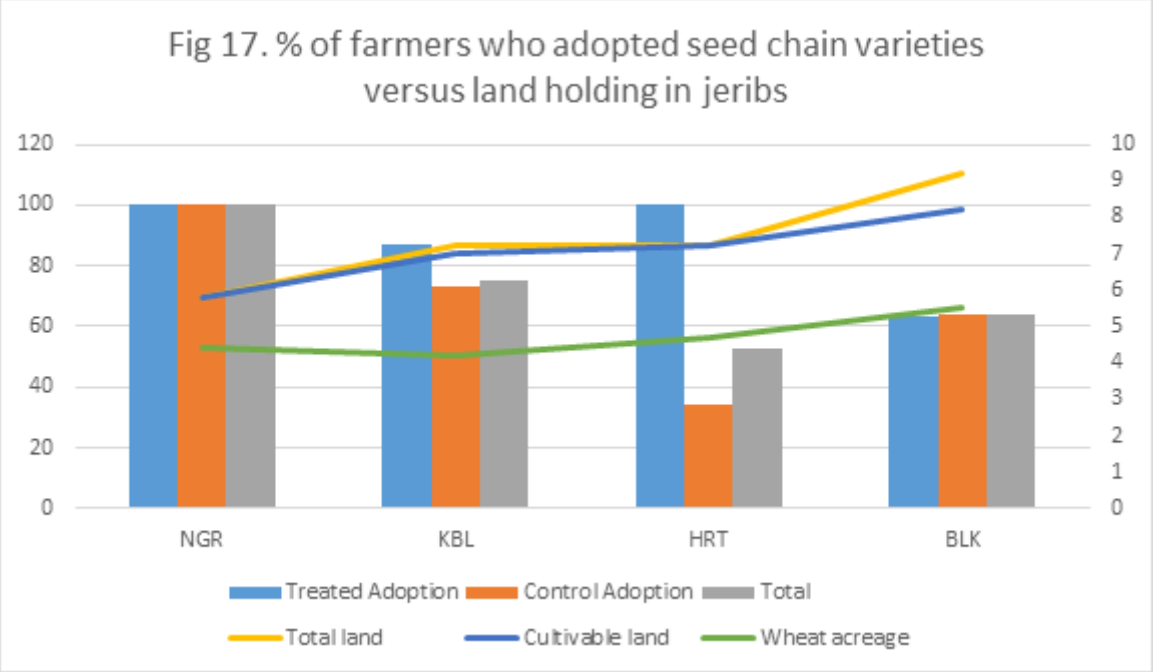


Fig 17. % of farmers who adopted seed chain varieties versus land holding in jeribs
120
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
NGR
KBL
HRT
BLK
Treated Adoption
Control Adoption
Total
Total land
Cultivable land
Wheat acreage

Table 6. Regression coefficient of some of the factors affecting adoption

No.	Factor	Control	Treatment
1	Education of HH Head	0.04*	-
2	Wheat growing exp. years	-0.004**	0.039***
3	Age of HH, years	0.002***	- 0.018 *
4	No. of male family members	0.002 *	-
5	Wheat training participation	1.129 ***	1.487 ***
6	Total house hold expenditure	0.739 ***	0.595 ***
7	Total Land	-0.554 ***	-
8	Secondary Occupation	-	-

It was revealed that while parameters like age, education, experience (Fig 13) size of land holding (Fig 17) and some others on income & expenditure (Fig 15) had no clear cut relation with adoption, whereas, factors like training (Fig 14), contact with extension staff (Fig 10), distance from main road (Fig 12), distance from market (Fig 11), distance from extension offices (Fig 16) affected adoption. Compared to the earlier impact assessment study (Jilani et al., 2013) which found 61% farmers growing improved variety, this survey found 76% farmers using improved varieties. The earlier study reported Zard Dana to be the most popular variety but also cautioned that farmers referred to any amber coloured variety as Zard Dana.

Wheat germplasm genotyping:

All the wheat germplasm available with ARIA and a collection of landraces brought from Japan were phenotyped in Afghanistan (***Appendix IV***) and Mexico (***Appendix VI***), and were also genotyped in Mexico to develop a reference population. We started with 1019 genotypes belonging to four groups viz., the Afghan wheat collection, Afghan local land races, Afghan released varieties and other varieties and breeding lines. Pedigree of each line was verified by searching different data bases and other CIMMYT records. Genetic diversity measures were employed to profile the accessions. A total of 56422 GBS SNP markers were reported, however after applying various filters we used 5203 high quality SNP markers for genetic analysis. The mean of pairwise IBS similarities between each of the 28 technical replicated entries was calculated to serve as initial identity threshold. The pairwise similarity between the replicates ranged from .991 to 1with an overall mean of .998. The initial identity threshold was therefore set at .998. Based on IBS matrix and pedigree records, the reference library was reduced to 761 entries. Entries with same name and genetic profile were combined in one, as also the entries with incomplete naming and pedigrees were removed from reference set.

After cleaning, 13.7 % of the varieties had still the same name and pedigree, but distinct genetic profiles. Also, 7.2 % of the entries had the same genetic profile but different names and pedigrees. Thus, overall 20.9% of the varieties in the reference library were inconsistent. Seed sample errors and/or seed mixtures are the most probable reason for these complications. It must be understood that the reference library entries were sampled and information compiled under extremely difficult war-torn Afghanistan. The reference

library was, however, classified into four groups; Varieties from the Afghan Wheat Collection (152), Afghan Local Landraces (36), Afghan varieties (125), other varieties and breeding lines (448). Multidimensional scaling based on MRD (Modified Rogers' Distance) (Wright, 1978) distance is shown in Figure 18. All varieties and breeding lines (except three) build one close group, while most of the varieties in the Afghan Wheat Collection and the Afghan Local Landraces grouped apart. The Afghan Wheat Collection is based on a private collection initiated by Dr. Kihara and contains representative landraces from all the wheat growing areas in Afghanistan.

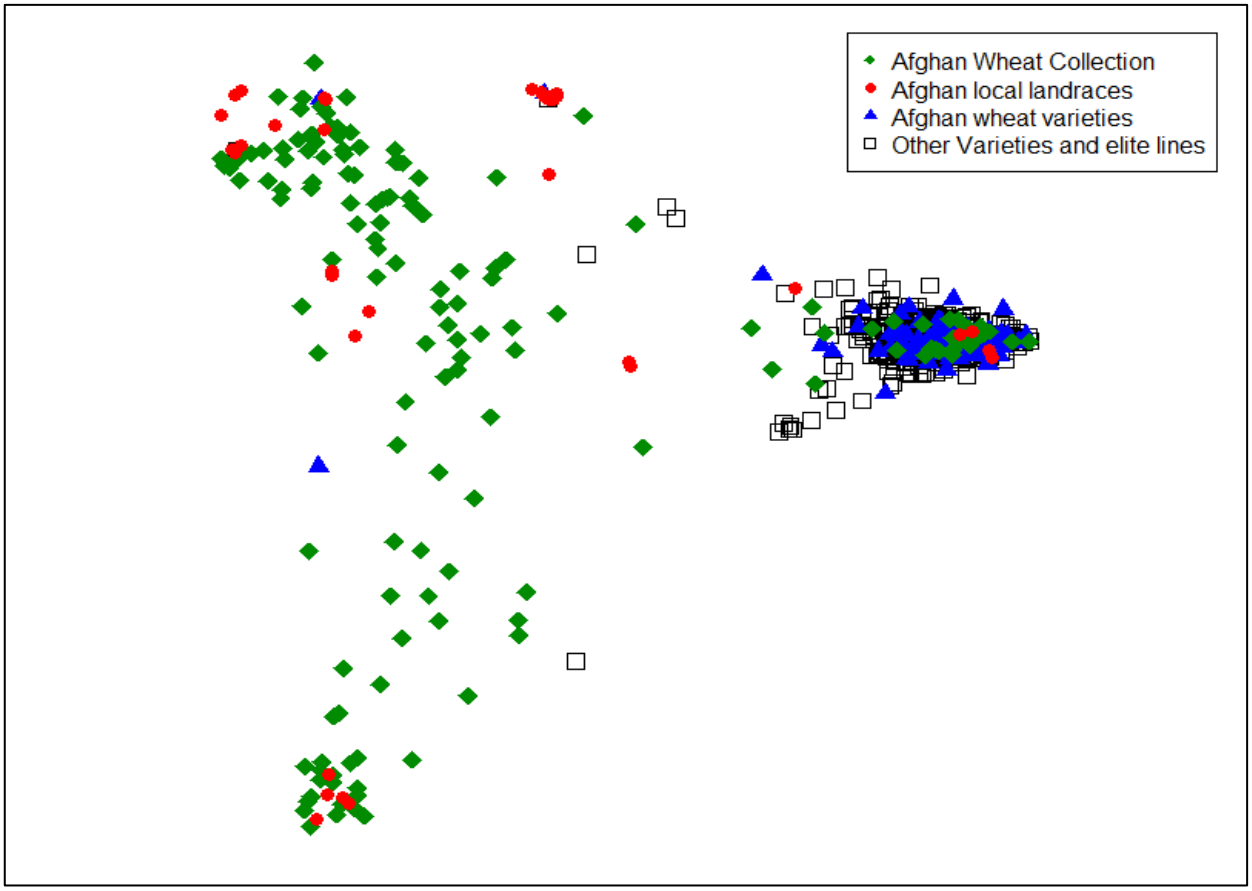


Fig. 18. Multidimentional scaling of the established Afghan reference library based on Modified Rodgers' distance.

Plotting varieties and breeding lines only revealed no clear grouping (Fig 19). Released Afghan varities fall within almost all the dimentional space that is covered by other varieties and breeding lines indicating that the varieties were derived from different germplasm sources. Diversity indices of the four germplasm groups are shown in Table 7. The Indices support the multidimentional scaling results whith the Afghan Wheat Collection and Afghan Local Landraces presenting the largest genetic diversity. Afghan varieties represent the lowest genetic diversity which is expected as the varieties represent only a subset of the fourth group of internationally released varieties and advanced breeding lines.

This reference population can be used to ascertain identity of any wheat sample from Afghanistan. Though the reference population cannot be regarded as perfect. It can certainly be improved by collecting genotypes from confirmed seed sources. Also, it would remain dynamic but any wheat sampled as of today from Afghanistan would probably relate to it and can be identified genetically. The Afghan germplasm sent to Mexico was screened for resistance under artificial epiphytotic conditions. The study revealed several

lines resistant to various diseases. Ten lines including a land race viz., Nish Shotor were identified to be a donor for multiple disease resistance (***Appendix VI, Annexure II***).

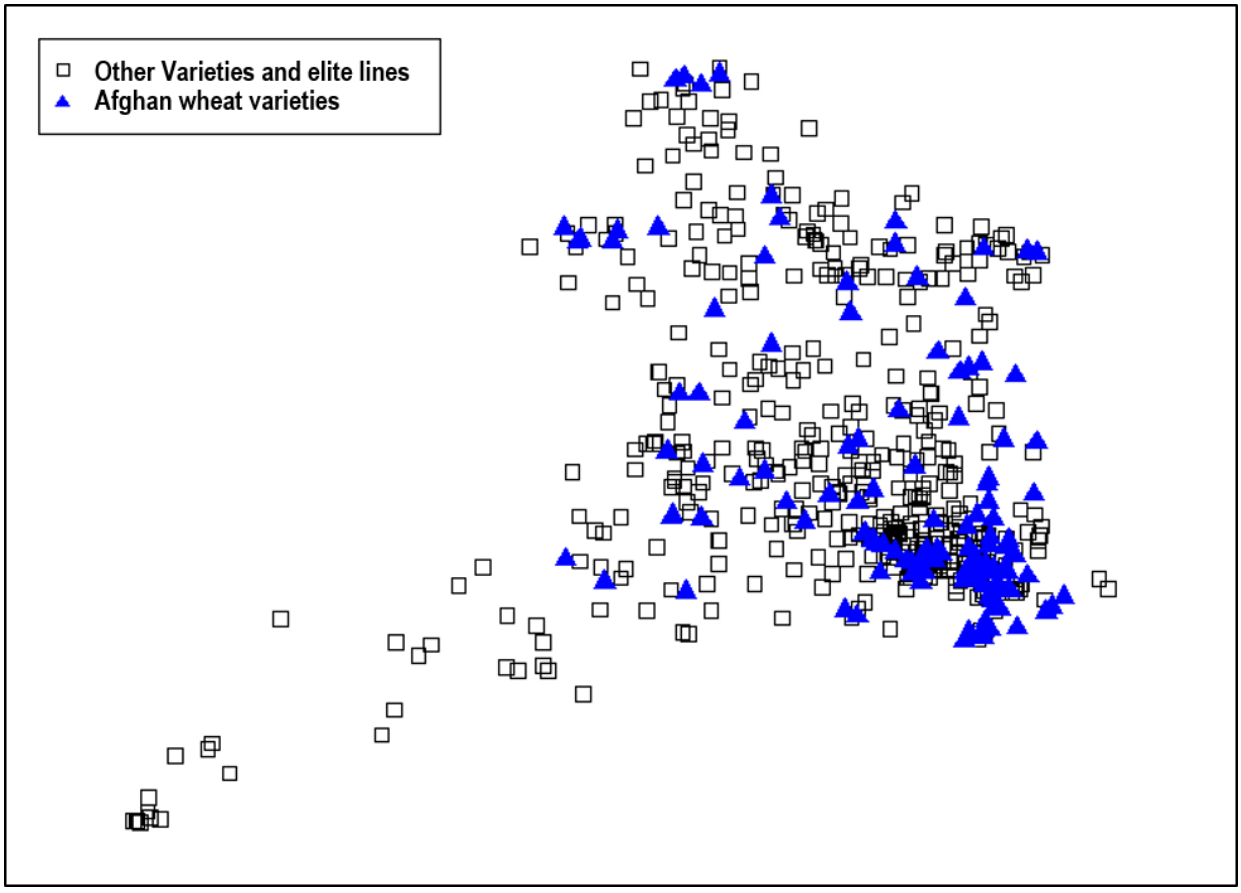


Fig. 19. Multidimentional scaling of varieties released in Afghanistan and other varieties and breeding lines released elsewhere and/or distributed internationally.

Table 7. Diversity indices of germplasm groups represented in the established Afghan reference library.

Group	Number of lines	Mean MRD	Expected Heterozygosity	Shannon Diversity Index
Afghan Wheat Collection	152	0.410 ± 0.001	0.211 ± 0.002	0.490 ± 0.005
Afghan Local Landraces	36	0.382 ± 0.004	0.275 ± 0.003	0.620 ± 0.005
Afghan Wheat Varieties	125	0.280 ± 0.001	0.105 ± 0.002	0.284 ± 0.003
Other Cultivars and Lines	448	0.325 ± 0.000	0.116 ± 0.002	0.304 ± 0.003
Total	**761**	**0.349**	**0.139**	**0.359**

Identity of cultivars in farmers fields based on DNA fingerprinting

A total of 588 field samples picked up from farmer fields in four provinces were genotyped. The reference population explained above was made use of to ascertain samples' identities. Applying the identity threshold (0.998) on the pairwise similarities across the 588 farmers' varieties and the varieties in the reference library, each farmer variety was re-identified. From the 560 unique farmers varieties (excluding the technical replicates), the identity of 527 varieties was determined (94.1%). From these, 449 varieties (80.2%) showed pairwise similarities higher than the initial declared identity threshold of 0.998 to one or more reference varieties. For 45 samples (8.5%) the initial threshold was relaxed to the minimum average pairwise similarity between technical replicates of 0.991 (***Annex III***). The identity of 33 field samples could not be determined. No pairwise similarity above the minimum threshold to any of the reference varieties or farmers' varieties was found for 18 of the 33 farmers' varieties. The remaining 15 varieties showed pairwise similarities to other farmers' varieties with different names above the critical value of 0.991 but not to any reference variety. Because of complications in naming and inconsistent genomic profiles in the reference library, varietal identification was complicated too. As the initial critical value used for the identification of the farmers' varieties was stringent, in many cases the varieties were found identical to several reference varieties.

The criteria applied to identify the varieties were the following:

1) The farmers' variety was simply identified when the variety was identical to one single reference variety.
   - This was the case for the farmers' varieties identified as AFGHAN Wheat Collection #53, Balkh Dehdadi 013, Bakhtar 013, BOW/PRL*3/6/WRM, Dorokhshan/Darukhshan-08, Lalmi-2, Rana-96, Sheshambagh-08.
   - A total of 59 varieties were identified using this criteria.
2) The farmers' variety was observed identical to several reference varieties, one of them being represented several times with the same naming/genetic profile in the reference library. This reference variety was considered to be the most likely.
   - This was the case for the farmers varieties identified as Gul-96 (the Gul-96 reference variety was represented eight times in the reference library, six of them were identical among themselves and identical to farmers varieties), HD 2285 (represented three times, two were identical), Mazar-99 (represented four times, three were identical), Roshan-96 (represented seven times, six were identical), Sohl-02 (represented 12 times, four and two times were identical).
   - A total of 91 varieties were identified using this criteria.
3) The farmers' variety was identical to one reference variety represented twice in the reference library but not identical to each other. The reference variety was still considered to be the most likely reference variety.
   - This was the case for farmers varieties identified as Baghlan-09 and Muqawim-09.
   - A total of 138 varieties were identified through this criteria.
4) The most difficult case observed was when a farmers' variety were identical to reference varieties which were highly inconsistent. Farmers' varieties were identical to reference varities which were represented several times (≥ 4) in the reference library, but these were not at all identical to each other. In these cases and when additionally the farmers varieties were most similar among themselves the farmer predicted name was kept
   - This was the case for field samples identified as Chonte#1. Field samples were identical to reference varieties Daima 99 and MH-97(Attila). Daima 99 is a variety that does not exist and should be corrected to be DAYMA-96. DAYMA-96 and MH-97 were represented six and four times in the reference library and none of those was identical to each other. Many farmers' varieties were more similar to each other than to the highly inconsistent reference varieties and because of this the farmer predicted name was kept.
   - This was also the case for field samples identified as Kunduzi. Field samples were identical to reference varieties Gheshowri Gulram and Sangistan/Tagab soor, both

represented four times in the reference library and none of those identical to each other.
   - A total of 235 varieties were identified through this criteria.
5) The field samples were only identical among themselves and a reference variety with the same naming was not included in the library. In this case the farmer predicted name was also kept.
   - This was the case for field samples identified as Watani Surkhcha.
   - A total of four varieties were identified through this criteria.

Comparing by farmers predicted names and by DNA analyses re-identified variety names

The 560 farmers grown varieties represented 26 different variety names according to the farmers. DNA fingerprinting indicated that only 19 varieties were grown in the respective provinces. Fifteen out of the 19 varieties were officially recorded as Afghan released varieties, released between 1993 and 2013. Fourteen varieties were direct releases from CIMMYT or included a CIMMYT parents. Varieties identified as Kunduzi, Watani Surkhcha, AFGHAN Wheat Collection #53, BOW/PRL*3/6/WRM, and CHEN/AEGI10PS5QUA were not in the official variety list. Of the 560 unique farmers' varieties, 98% were improved lines in comparison to 91% predicted by the farmers. The presence of landraces decreased. The most common varieties identified using DNA analyses were Chonte#1 (225 genotypes) and Muqawim-09 (108 genotypes) followed by the older variety Roshan-96 (62 genotypes) and a new variety Bakhtar 013 (39 genotypes).

Seven varieties observed by the DNA analyses had not been documented by the farmers (Solh-02, Sheshambagh-08, Balkh Dehdadi 013, Bakhtar 013, AFGHAN Wheat Collection #53, BOW/PRL*3/6/WRM, CHEN/AEGI10PS5QUA) accounting for 50 genotypes. From these, 47 genotypes were released after year 2002, indicating that older varieties were unknowingly replaced by newer releases. Overall, 75% of the varieties were released after year 2000, in comparison to 67% predicted by farmers. In 318 cases (60.3 %) farmers were able to predict the growing cultivar name correctly, while in 209 cases (39.7 %) the farmer did not know what genotype he was growing.

Varieties grown in the four different provinces.

Table 8 shows the farmers varieties distributed across the four Afghanistan provinces, Balkh, Herat, Kabul and Nangarrbarr. Ten varieties were grown in the Herat province, nine in the Kabul province and seven in the Balkh and Nangarhar provinces, respectively. Some varieties were only grown in one specific province e.g., Baghlan-09, Dorukhshan-08, Lalmi-2, Sheshambagh-08, Watani Surkhcha and Kunduzi. The most frequent varieties (Chonte #1, Muqawim-09 and Roshan-96) were grown in all four provinces. In the Kabul and Nangarhar provinces different varieties were grown, although the two provinces belong to the same agro-ecological zone.

Table 8. Farmers' varieties identified via DNA analyses grown in the four Afghan provinces

Varieties based on DNA finger printing	Type	Province				Total
		Balkh	Herat	Kabul	Nangarhar	
Baghlan-09	released variety				30	30
Bakhtar 013	released variety		13	26		39
Balkh Dehdadi-013	released variety				1	1
Chonte #1	released variety	81	5	67	72	225
Dorukhshan-08	released variety			3		3
Gul-96	released variety		1	2		3
HD2285	released variety	1				1
Lalmi-2	released variety				9	9
Mazar-99	released variety	2	9	5	4	20
Muqawim-09	released variety	23	58	5	22	108
Rana-96	released variety	1				1
Roshan-96	released variety	5	40	17	1	63
Sheshambagh-08	released variety		3			3
Solh-02	released variety		1	3		4
Watani Surkhcha	landrace	4				4
AFGHAN Wheat Collection #53	landrace		1			1
BOW/PRL*3/6/WRM	breeding line		1			1
CHEN/AEGI10PS5QUA	breeding line			1		1
Kunduzi	breeding line	10				10
Total		127	132	129	139	527

Trait-based marker results

The results of the trait-based markers were addtionally aligned to the farmers varieties to inform CIMMYT and NARS about some key genes these varieties carry. Results for 15 different genes related to rust resistance and plant growth are shown in ***Appendix V***. Variety 'Baghlan' carried the two adult-plant genes (*Lr68* and *Sr2*) for rust. Most varieties carried one of the major *Rht* genes, *Rht1* or *Rht2*, except the varieties Rana-96 and the landrace Watani Surkhcha. Only variety Gul-96 was identified to be a true winter type. All other cultivar had one or two spring alleles at the most relevant vernalization loci. All culivars were additional photoperiod insensitive except the landrace Watani Surkhcha.

Rainfed wheat

We found only 15 farmers growing seed chain rainfed varieties in our survey. 12 of these farmers were in Nangarhar and three in Herat. Since three is a very small number, we chose to study the socio-economic parameters of these 12 farmers as compared to remaining 78 control farmers in Nangarhar. These farmers differed from irrigated farmers in education level, annual household expenditure, livestock units, manure application etc., (Fig 20, Table 9). Manure application seems to be more of a result than a factor causing rainfed cultivation, since farmers tend to invest less in a rainfed

Rainfed farmers were observed to possess more land so perhaps some of it does not get irrigation making them rainfed grower. They spend more perhaps because they earn more from larger acreages they possess. Compared to irrigated farmers, many of them are members of farmer organization so perhaps getting more info on varieties/ technologies, however training participation did not cause any difference between irrigated and rainfed farmers.

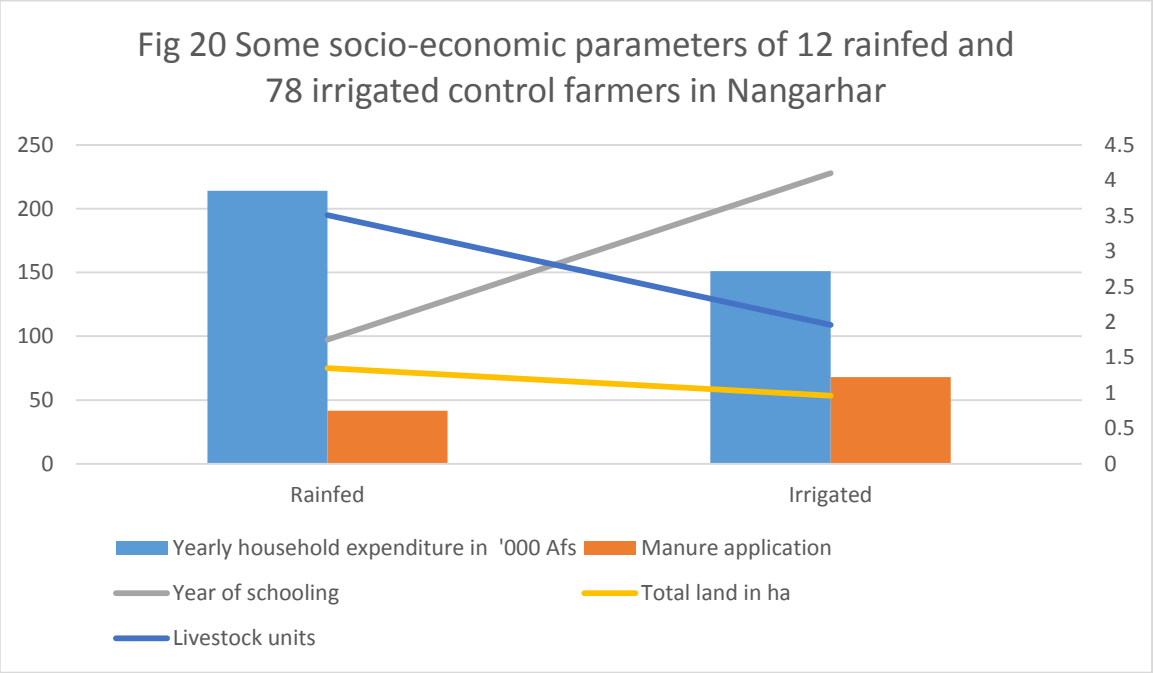


Table 9. Characteristics of 12 rainfed control farmers in Nangarhar

No. of farmers	Cultivated other than Lalmi 02	Cultivated Lalmi 02	Mean differences
	a	b	a-b
	78	12	
Age, household head	43.72	43.3	0.74
	(8.31)	(10.3)	(0.31)
Years of schooling, head	4.09	1.75	2.49**
	(4.92)	(3.19)	(1.70)
% Tajik and Pashtun ethnic group	91.0	75.0	11.2
	(28.8)	(45.2)	(1.05)
Household size (no. of family members)	8.73	9.0	-0.20
	(1.48)	(1.34)	(-0.36)
Total land owned (ha)	0.96	1.35	-0.22
	(0.46)	(0.65)	(-0.95)
Total livestock unit	1.96	3.51	-1.46***
	(0.99)	(1.99)	(-4.06)
Yearly household expenditure (000, AFS)	150.65	214.4	-44.9**
	(62.9)	(111.9)	(-1.87)
% Member of farmers organization	3.8	25.0	-21.4***
	(19.4)	(45.2)	(-3.25)
% Attended wheat farming training	92.3	91.7	3.26
	(26.8)	(28.9)	(0.48)
% Hired labor for farm work	84.6	91.7	-6.8
	(36.3)	(28.9)	(-0.64)
% Applied manure in the crop field	67.9	41.7	30.0**
	(47.0)	(51.5)	(2.19)
Distance to local market (km)	2.72	2.3	0.39
	(1.09)	(0.45)	(0.89)
Distance to main road (km)	1.35	1.0	0.29*
	(0.81)	(0.0)	(1.44)
Distance to agricultural extension office (km)	7.5	8.17	-0.47
	(1.69)	(1.11)	(-0.86)

Note: Standard deviations /t-values are in parentheses. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

7.1 Scientific impacts – now and in 5 years

Delineation of wheat agro-climatic zones: Grouping of iso-climatic Afghan regions into four wheat climatic zones (Table 3; Obaidi *et al.*, 2017) will help make sustainable gains in crop productivity as has been shown elsewhere (Wart *et al*., 2013). Afghanistan wheat varietal testing and release system achieved a milestone during the project tenure when for the first time it released a variety for irrigated conditions of Northern Zone (NZ). It is interesting to observe that zone wise testing could provide Afghan farmers a promising genotype which otherwise would have been lost as this variety produced only 92% yield of average of check varieties in first year at national level. However, since genotype was disease resistant was therefore scrutinised further. It was discovered that the variety produced six percent higher than checks in North Zone in the first year. The variety was then promoted in North zone to advance testing in second and third year. This genotype yielded up to 11% higher than average of checks in advance testing in NZ. Overall variety brings diversity to farmer fields and an yield higher or at par to checks.

Hybrid Maize: First ever maize hybrids have been released in the country. However, efforts so far did not succeed in streamlining their seed production. It is a common knowledge that some imported maize hybrids are selling in the country. ARIA seed production team can continue working on the seed production aspects of inbreds and their hybrids to make available legally released maize hybrids to Afghan maize growers.

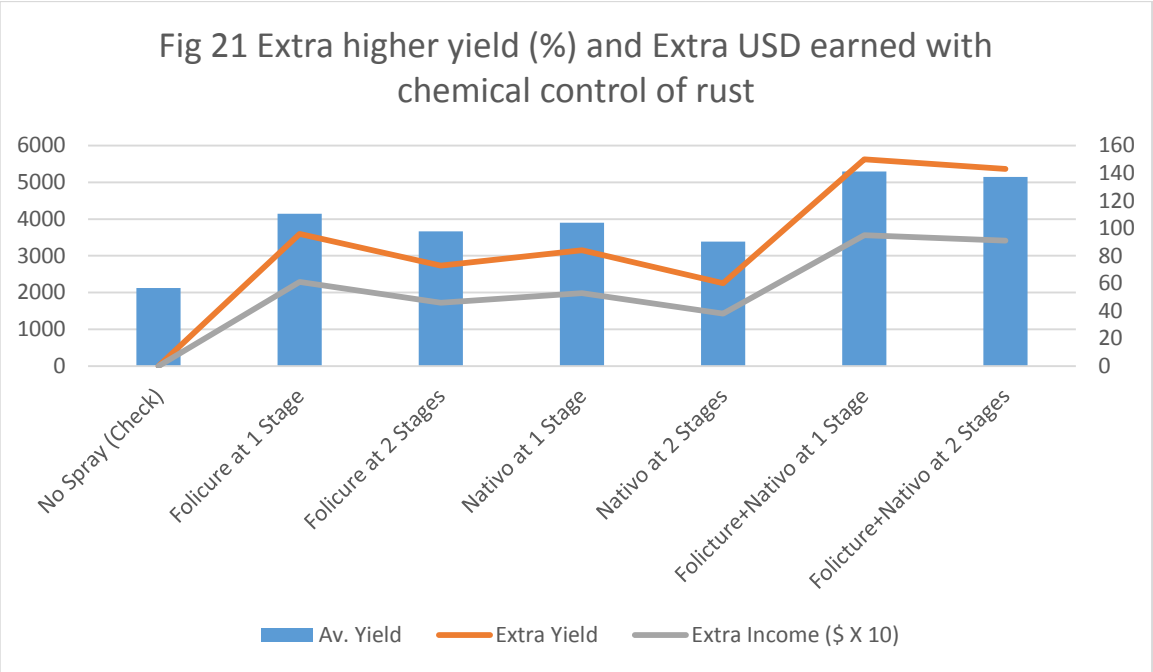
7.2 Capacity impacts – now and in 5 years

A total of 65 Afghan researchers / MAIL staff were sponsored to attend trainings/ workshops abroad and 640 attended in-country trainings/workshops during the project life. Impact of on job training and other efforts is visible in the way the experiments are conducted and reported (Fig 8). Annual crop workshops are now established platforms for Government staff to analyse, interpret and report their work. The 2017 wheat workshop was entirely managed by ARIA. If expanded to other locations, NPhN would lead to further fine tuning of wheat climatic zones. NDSN is already an established instrument to proactively manage wheat rust disease. This year's NDSN reveals that varieties accounting for about 50% of certified seed have fallen susceptible to new/old races of yellow rust. ARIA would use this and other such information in future to manage seed chain varieties effectively to keep Afghan wheat rust free.

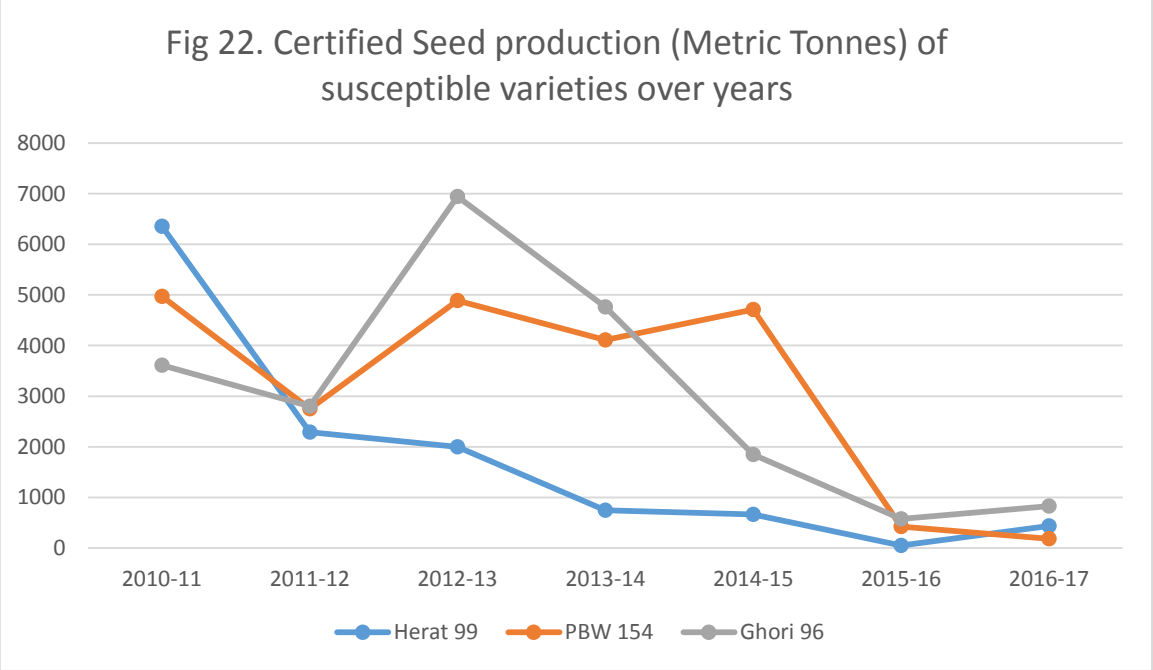
7.3 Community impacts – now and in 5 years

7.3.1 Economic impacts

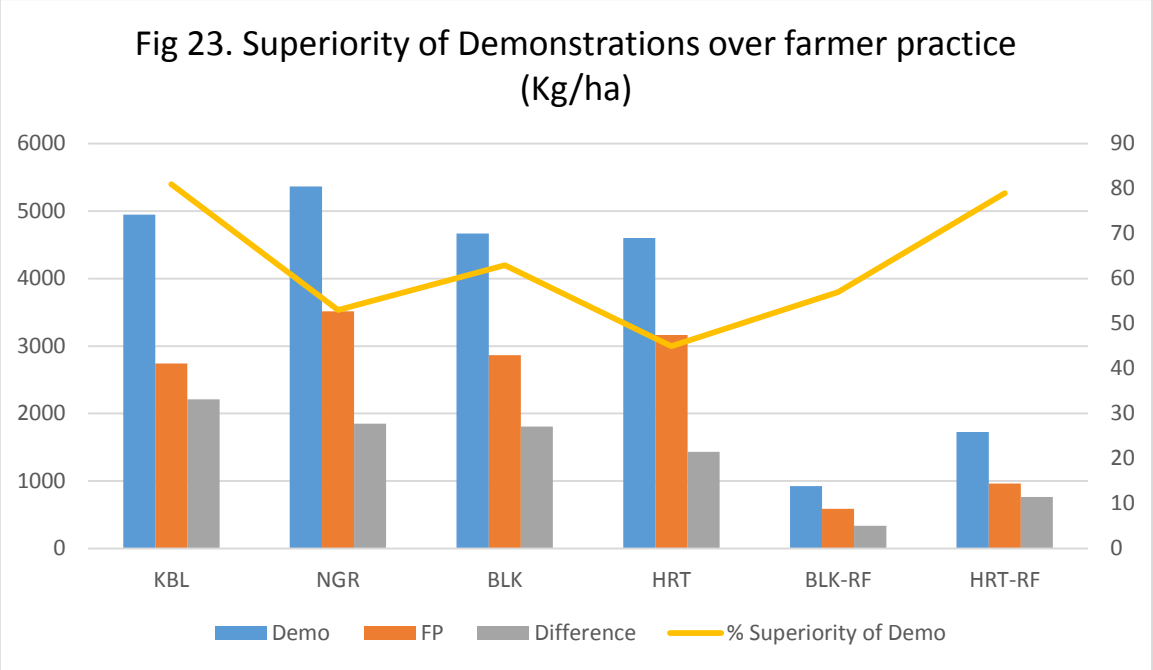
Higher yield and income from resistant wheat varieties: A major economic impact of project has been a reduction in seed production of susceptible varieties. An exploratory study which made use of two fungicides individually and jointly, conducted during 2012-13 and 2014-15, revealed that a fungicide-protected (therefore disease free) crop offers up to USD 950/ ha advantage (Fig 21) over a susceptible variety.



Graph below (Fig 22) shows that susceptible varieties accounted for about 48% of total seed production in 2010-11, and this had been reduced to about 10% in 2015-16 and even less than 10% now in 2016-17. However, MAIL/ARIA cannot afford to be complacent about the achievement as the number one enemy of wheat viz., rust never sleeps. This year's NDSN shows that many varieties hitherto resistant have become susceptible. Therefore a regular vigil and action is needed to keep Afghan wheat fields rust free.



Higher yield from new improved varieties: Farmer field demonstrations made use of new seed of improved varieties and compared with adjoining field with farmer practice. The average of over 2700 such demonstrations conducted in four provinces from 2012-13 to 2016-17 revealed that demonstrations yielded 45 to 81% higher than farmer practice which in absolute terms translated to an yield superiority ranging from 1.4 tonne/ha to 2.2 tonne/ha under irrigated conditions and 0.3 tonne/ha to 0.76 tonne/ha under rainfed conditions (Fig 23).



Distribution of improved seed means higher income for farmers: Using seeds of new improved varieties on an average gives one tonne extra production per hectare (Fig 22) which earns an extra USD 300 for the farmer. At a larger scale, the Government distributed certified seed among farmers and calculated at just 0.5 tonne per hectare, farmers harvested an extra 165102 tonnes of wheat for Afghanistan and earned an additional income of about 49 million USD for the farmers as explained in the table 10 below. This earning stood at over 220 million USD for last three years.

Table 10. Extra economic benefits from Government distributed seed.

	Four times of			**2017-18 Dist'n**	**2017-18 Total***	**Last 3 years Total**
Parameter	**2014-15**	**2015-16**	**2016-17**			
Seed (Tons)	18382.2	11620	20816.4	7367	58185.6	203959
Area (ha)	147057.4	92960	166531.2	58936	465484.6	1631672
No. of households	367643.5	232400	416328	147340	1163711.5	4079181
Women beneficiaries @ 50%					581855.8	2039590
Extra Production @ 0.5 ton per ha					165102.1	735706
Extra income @USD 300 per ton					49,530,643.2	220,711,834

- One farmer shares with 3 more in 2nd year. Number of farmers and area remains same in 3rd and 4th year. Each farmer was given 50 Kg seed, sufficient for 0.4 ha. Source: MAIL

Similarly, project also distributes seed to farmers to conduct farmer field demonstrations. This seed is also expected to produce about 1356 tonne extra wheat for Afghanistan and a total income of 0.40 million USD (Table 11) as explained below. Adding these earnings

for last three years, farmers earned over 1.1 million USD extra, courtesy project intervention.

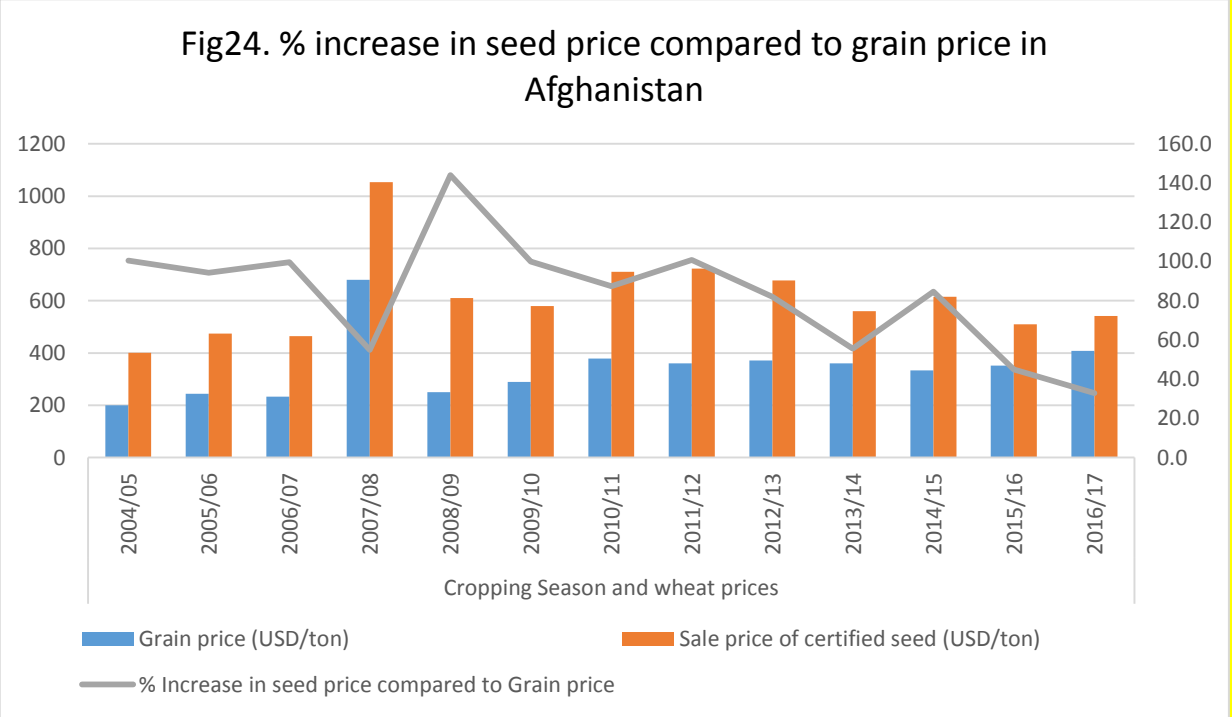
Table 11. Extra income for farmers from project distributed seed.

	Four times of			2017-18 Distribution	Total* 2017-18	Last 3 years total
	2014-15	2015-16	2016-17			
No.	2224	2160	2124	540	7048	19683
Area (ha)	889.6	864	849.6	108	2711.2	7551
Extra production @ 0.5 ton per ha	444.8	432	424.8	54	1355.6	3775.5
Extra income @ USD 300/ton	133440	129600	127440	16200	406680	1,132,650

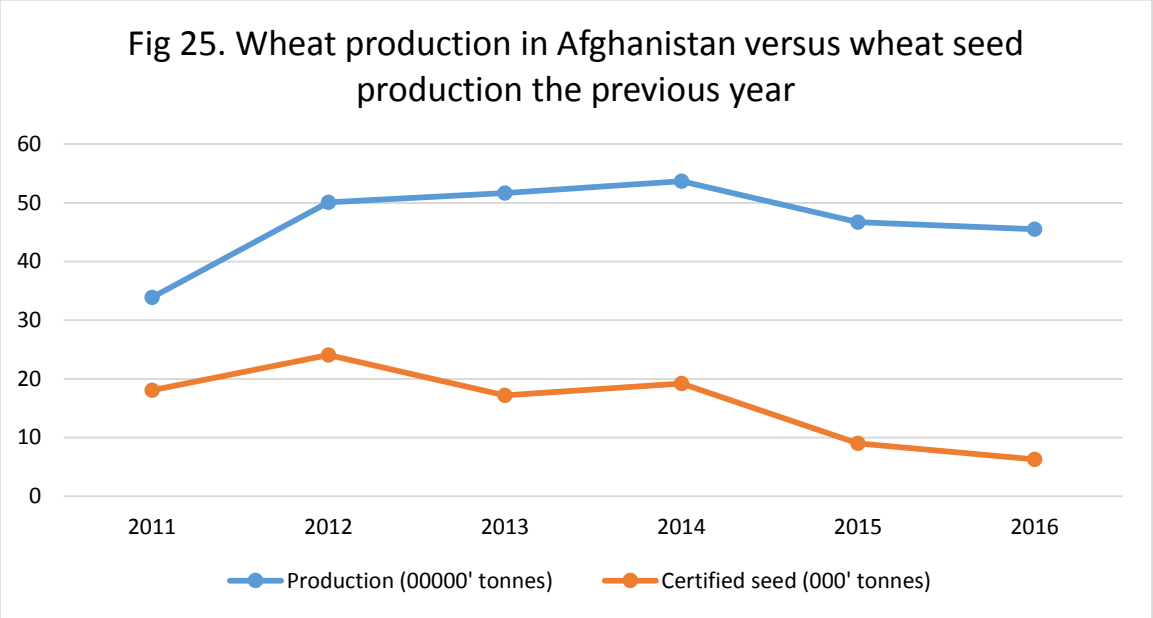
- * One farmer shares with 3 more in 2nd year. Number of farmers and area remains same in 3rd and 4th year. Each farmer was given 25 Kg seed, sufficient for 0.2 ha.

These conservative figures estimate benefits of up to over 220 million USD for Afghan farmers if they continue to use new improved high yielding disease resistant varieties. These benefits would multiply if system could produce more seed.

Increased availability of improved varieties leading to more seeds, more competition, price correction and more production: Since present seed system has not been able to deliver and whatever little quantities are being produced are fairly expensive. The downward trend in seed price during last couple of years indicates a market correction happening (Fig 24). This realistic price coupled with allowing truthfully labelled (TL) seed hold promise and would contribute to demand for wheat seed in actual market place.



This has also been observed that a higher seed availability contributed to better harvests (Fig 25). However, it is imperative to strengthen supply of other inputs as well as an assured output market to give a real push to wheat production in the country.



It is a different scenario when we look at maize seed production and availability. Private companies are expected to engage more with maize seed, however this has not been the case. One major reason seems to be less acreage and perhaps maize is produced more for fodder than grain. We utterly failed to successfully demonstrate maize varieties mainly because they were always harvested for fodder and cobs stolen. Therefore, unless demand grows, maize seed production will remain stagnant as of now.

7.3.2 Social impacts

Agronomy experiments of project concluded line sowing to be higher yielding compared to broadcast sowing and project started demonstrating line sowing to farmers. This technology has demonstrated extra yield benefits ranging from 20 to 25%. Similar results were reported by Pakistani researchers (Attaullah Khan *et al*., 2007). Farmers have taken fancy for the technology and demanded more. Project imported 12 new seed drills and efforts were made to line sow all the demonstrations in 2016-17 season. 467 of 540 demonstrations in 2016-17 were line sown with a success rate of 86%. Similarly, all demonstrations in 2017-18 were line sown. Project made efforts to initiate local ag-machine makers into manufacturing seed drills for line sowing. Project took them to an ag-machine fair in India, made them interact with several manufacturers at the fair, and also took them to a manufacturer's facility at Ludhiana in Punjab, India. In spite of the project offer of assured purchase of such drills, they were not inclined. Here also a situation similar to seed industry prevailed. They were interested in big money and only wanted to supply bulk quantities if someone ordered. May be only if Government or some project decides to supply to communities in bulk, or if some enterprising farmers start renting out to farmers, like they rent out tractors, the situation would improve. The seed drills available with project are being donated to provincial DAILs and these agencies will have to take lead to get these machines into country for their widespread use by farmers.

Our demonstrations have also resulted into farmers sharing harvest of a demonstration with fellow farmers/ neighbours/ friends for use as seed in the following season. We have estimated that on an average a farmer shared his harvest with 3.07 farmers resulting into a multiplication ratio of 1:4. Overall, seed of new varieties and line sowing led to higher production, higher income for growers and associated social benefits like good health and a general social wellbeing. This will potentially contribute to peace and stability in the country and faith in Governmental agencies like ARIA working for the welfare of Afghan people.

7.3.3 Environmental impacts

The project successfully contributed to release of 24 new high yielding and disease resistant varieties/ hybrids of wheat and maize. This contribution has successfully supported MAIL to keep Afghan wheat free from any rust epidemic and thus protected environment from the harmful effects of fungicides and other pesticides. Increased production on account of resistant varieties contribute to food security (Joshi et al., 2011) and higher income levels that would also prompt more investment in conservation agriculture technology and soil health which will ultimately not only protect environment but will also draw less from already strained natural resources like water. The road ahead for MAIL/ ARIA is to maintain the tempo not just by growing NDSN but sincerely acting on NDSN results and advising seed production agencies accordingly.

7.4 Communication and dissemination activities (CDA)

Insecurity is the biggest hurdle in communicating with farmers and reaching out to them. One has to fully rely on local staff. Our 2016 survey revealed that training participation (Table 6; Fig 14) was one of the factors that positively influenced adoption of new varieties. Similarly, factors like distance from the market (Fig 11) and main road (Fig 12) also positively influenced adoption. The table 12 below lists means of communications adopted to disseminate information among farmers:

Table 12. Events organised to disseminate information/ technology among farmers.

Topic of extension messages	Province	Number of prints	Distribution	Events
Optimum sowing time for Kabul	**Kabul**	1000	Farmers (Bagrami, Charasyab, Paghman and Dehsabz districts), ARIA, DAIL staff	Field day, Training, coordination meeting, field visits
Seed Selection or Choice of variety		1000	Farmers (Bagrami, Charasyab, Paghman and Dehsabz districts), ARIA, DAIL,	
Wheat weed management and common Kabul weeds		1000	Farmers (Bagrami, Charasyab, Paghman and Dehsabz districts), ARIA, DAIL. Villages (Qalai Agha, Qalai Hakim, Golbota, No Borja, Elias Khail, Galzar, Charsoq, Karizak, Khoja Mosafer, Shina, Alokhail, Bagrami, Qalia Ahmad khan, Shewaki.	
Wheat weed management for Nangarhar	**Nangarhar**	1000	Nangarhar DAIL, Extension dept. Farmers (Surkh Rod, Behsood and Khewa) districts and ARIA staff. Villages (Qalai Per Sahib, Soltan Por olya, Soltan Por Sofl, Qalai Ahmad Zai, Naring Bagh, Nazar Abad, Sabzabad, Bagrami, Naghrak, Amarkhail.	Field day, Training, coordination meeting, field visits

Wheat seed and fertilizer rate, seed treatment	**Balkh**	1000	Farmers of (Nahre Shahi, Dehdadi, Chimtal and Marmol extension department and ARIA. Villages (Yaka Bagh, Yaka Toot, Sarasyab Bala and Sarasayb payeen, Megen Tepa. Langar khana. Dashti Marmol.	Field day, Training, coordination meeting, field visits
Wheat sowing time for Balkh		1000		
Wheat sowing method (Broadcast and Line sowing)		1000		
Good seed results in good yields		1000		
Wheat Weeds Management for Balkh		1000		
Optimum sowing time for Herat	**Herat**	1000	Farmers of Injil, Gozara, Robat Sangi districts of Herat, Extension department, ARIA. Villages, Qalai Dasht, Qafaslan, Qalai Mergul, Mahle Dasht, Robat Sangi sofla and Olya. Shokor khani, Qasri yahya.	Field day, Training, coordination meeting, field visits
Wheat seed and fertilizer rate, seed treatment		1000		
wheat irrigation and critical time of wheat irrigation		1000		
wheat weed management		1000		

8 Conclusions and recommendations

8.1 Conclusions

CIMMYT-bred wheat and maize genotypes are adapted to Afghan conditions. Agencies need to speed up their seed production efforts so that farmers could realise full benefits of higher yields of these varieties. However, it is crucial that not just seed but other critical inputs like fertilizer, irrigation, weedicides etc., should also be available in right quality, quantity at right price and at the right time. Also, the system needs to be very careful to protect farmers' interests by not letting grain price go low during post-harvest season.

Employing phenology was successful in delineating Afghan wheat acreage into various wheat climatic zones, though this needs to be fine-tuned by expanding nursery to cover the entire country. The project conducted this nursery at fewer locations. We had only one location for zones like East, North-east etc. As ARIA adds more research stations to the list of functioning stations, this nursery should be conducted at all possible locations to map the country more precisely.

A proactive approach to assess rust race scenario helped in removing susceptible varieties from seed chain well in time before they caused any noticeable damage in farmer fields. The project conducted a National Disease Screening Nursery (NDSN) to achieve this. As mentioned for above point, NDSN should also cover all possible locations in the country.

Training and working with Afghan researchers helped build their capacity. This is evident from increase in accepted experiments (Fig 8). Also, ARIA has started conducting crop workshops on its own.

Disseminating technology through farmer field demonstrations (FFD) empowered farmers and helped them adopt new technology. These FFDs have shown farmers that much higher yields could be harvested by adopting new varieties and improved practices (Fig 22).

Genotyping and phenotyping all available Afghan wheat germplasm helped remove duplicates and helped develop a reference wheat population for Afghanistan. However, this reference population needs to be refined by including accessions from confirmed sources and removing duplicates.

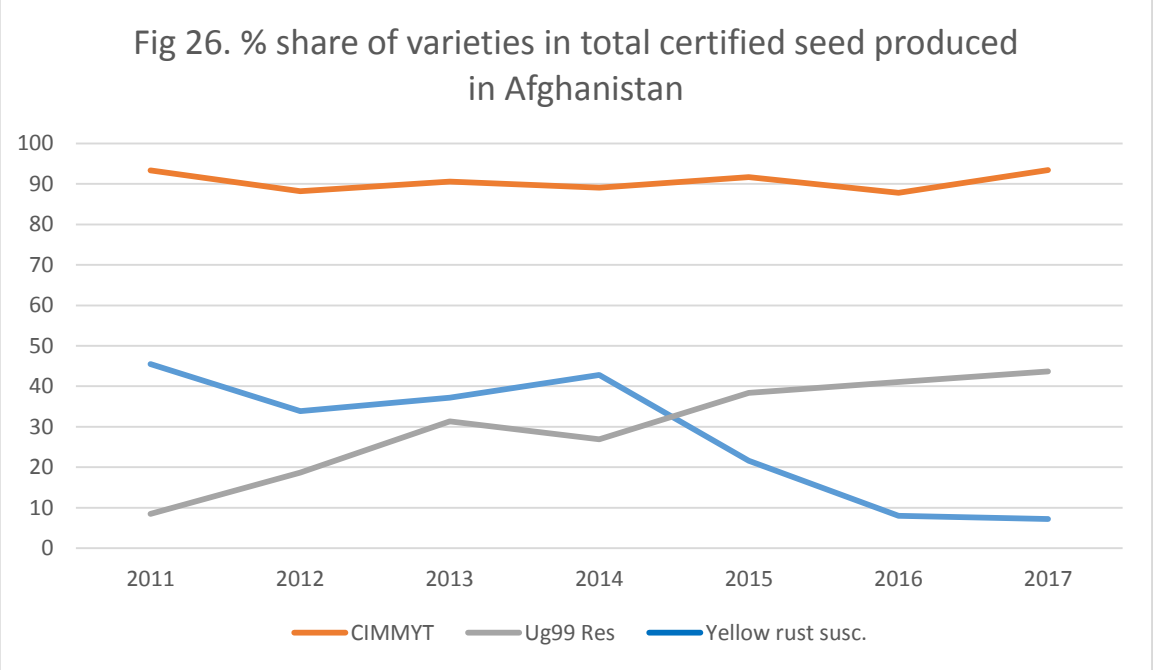
DNA profiling showed that farmers around the hubs grew preferentially modern (but not necessarily very recent) varieties, and the majority were aware of the variety they had grown. The study revealed that more than 85% of the sampled farmers grew less than 20 year-old variety (Table 8).

8.2 Recommendations

Farmers should use only new improved varieties for raising wheat crop. Our demonstrations revealed that farmers harvested up to 2.2 tonne/ha more in FFDs compared to FP fields (Fig 22).

ARIA may continue import new trials and nurseries from CIMMYT for releasing new varieties in the country. Though several other agencies have been working in country but CIMMYT material has been found to be the best adapted. This is evident from the fact that even today more than 90% of wheat certified seed is accounted for by CIMMYT varieties (Fig 26).

MAIL should strengthen seed chain. The needed steps have already been initiated as is evident from price correction that wheat certified seed is currently going through (Fig 23).



Introduction of TL seeds is another intervention that will aid to the availability of affordable quality seed.

ARIA/ MAIL should further fine-tune wheat climatic zones. The current proposed zones were limited by non-availability of sufficient number of testing sites. Project believes that zones like North-East and South-West need to be further subdivided by generating more data from locations within these zones.

ARIA/ MAIL should continue with NDSN for the purpose of wheat rust surveillance. Yellow rust continues to remain a big threat. It looks under control but even in 2017-18 season, half of the varieties under seed production are yellow rust susceptible (disease score of 20S or more)

Agriculture Technology Information Centres should be established in all districts of the country. These can be housed in Extension offices and should be linked with local ARIA wheat researchers. The centres should reach out to farmers with all available technologies to increase wheat production.

MAIL should provide access to market for farmers and especially on making available quality inputs including seed. Our survey has shown that distance to market was a factor in adoption of technology (Fig 11). So, creating infrastructure and supportive policy framework will definitely boost availability and adoption of technology.

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10 Appendixes

10.1 Appendix I: Varieties released by the project

NO	Variety given Name	Pedigree	Seed Source Origin	Trial/ Nursery	Year of Release	Variety Type	Crop	Yield Benefit in Kgs/ha (check)	Yield Benefit (%)
1	Lalmi-04	SLVS*2/PASTOR	CIMMYT	14th SAWYT#324	2013	Rainfed/ Spring	Bread Wheat	363 (Lalmi-02)	6
2	Kabul-013	WAXWING*2/ TUKURU	CIMMYT	29th ESWYT#124	2013	Irrigated/ Spring	Bread Wheat	1386 (Darulaman-07)	29
3	Bamyan-013	VORONA/KAUZ /4/URES/BBL //KAUZ/3/BCN	Turkish CIMMYT	10th WON-IR # 278	2013	Winter Wheat/ Irrigated	Bread Wheat	505 (Solh-02)	8.2
4	Durum#1	AUK/GUIL// GREEN/3/ PATKA_7/ YAZI_1	CIMMYT	36th IDYN #41	2014	Spring	Durum Wheat	924 (Parva-02)	17
5	Durum#2	R143/RUFF/STIL/3/ YAV79/4/ SHWA/MALD /5/ ALTAR84/6/ TILO_1/LOTUS_4	CIMMYT	36th IDYN #47	2014	Spring	Durum Wheat	748 (Parva-02)	21
6	No Name Given yet	ZM523A-16-2-1-1-B*4/ [CML312 /CML445// [TUXPSEQ] C1F2 /P49-SR]F2-45-3-2-1-BBB]-1-2-1-1-2-BBB // [INTB-F2-90-2-1-1-BBB /CML395]-B-1-1-1-1-BB	CIMMYT	PYT – Hybrid Maize#1	2014	Hybrid Maize	Hybrid Maize	2766 (Shamal-08)	37
7	No Name Given yet	CML537// CML312 //[CML444/ DRB-F2-60-1-1-1-BBB // [LZ95441/ LZ966205]- B-3-4-4-B-5-B*7] -5-2-2-1-1-BBB	CIMMYT	PYT – Hybrid Maize#8	2014	Hybrid Maize	Hybrid Maize	2865 (Shamal-08)	39

8	No Name Given yet	CML536/CML312 //[INTB- F2-90-2-1-1-BBB /CML395]-B-1-1-1-1-BB	CIMMYT	PYT – Hybrid Maize#10	2014	Hybrid Maize	Hybrid Maize	2164 (Shamal-08)	28
9	Takhar-13	PETUNIA1/CAL192//BLLU	CIMMYT	27th IBYT#15	2013	Spring	Barley	1251 (Jaw Turkey)	60
10	Darulaman -13	STIPA/3/M9878/CARDO//QUINA /4/CIRU	CIMMYT	28th IBYT#906	2013	Spring	Barley	1365 (Jaw Turkey)	77
11	Wahdat-15	KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ	CIMMYT	4th EBWYT#503	2015	Facultative/ Spring	Bread Wheat	729 (Mazar-99)	15
12	Afghan-15	WHEAR//2*PRL/2*PASTOR	CIMMYT	4thEBWYT#530	2015	Facultative/ Spring	Bread Wheat	1149 (Mazar-99)	26
13	Waafer-15	BABAX/LR42//BABAX*2/3/TUKURU	CIMMYT	2nd STEMRRSN#6012	2015	Facultative/ Spring	Bread Wheat	711 (Chonte#1)	14
14	Lalmi-15	MTRWA92.161/PRINIA/5/SERI*3 //RL6010/4*YR/3/PASTOR/4/BAV92	CIMMYT	18th SAWYT#36	2015	Spring	Bread Wheat	1332 (Lalmi-02)	44
15	Bahaar-15	CAL/NH//567.71/3/SWRI/4/CAL/NH//. . .	CIMMYT	25th ESWYT#8	2015	Facultative/ Spring	Bread Wheat	519 (Ariana-07)	17
16	Elhaam-15	STARSHINA	CIMMYT ICARDA	1st IWWSRRN#7	2015	Winter Wheat	Bread Wheat	163 (Solh-02)	3
17	Lalmi-17	MTRWA92.161/PRINIA/5/SERI*3 //RL6010/4*YR/3/PASTOR/4/BAV92	CIMMYT	30th SAWSN#56	2017	Spring	Bread Wheat	408 (Lalmi-02)	11.2
18	Durum-3	PLATA_7/ILBOR_1//SOMAT_3/3/SORA/ 2*PLATA_12//SRN_3/NIGRIS_4 /4/BCRIS/BICUM //LLARETA INIA/3/DUKEM _12/2*RASCON_21	CIMMYT	45th IDYN#136	2017	Facultative/ Spring	Durum Wheat	903 (Parva-02)	17.4
19	Daima-17	KA/NAC//TRCH/3 /DANPHE #1	CIMMYT	31st SAWYT#110	2017	Spring	Bread Wheat	319 (Lalmi-02)	9.7

20	Shamal-17	KANCHAN*2/JUCHI	CIMMYT	45th IBWSN#130	2017	Facultative/ Spring	Bread Wheat	42 (Mazar-99)	0.7
21	Ariana -97	CZP132004	CIMMYT	14 EPOP#11	2018	Maize	OPV Maize	5915 (Zodras)	56
22	CIMMYT - 97	ZM309	CIMMYT	14 EPOP#22	2018	Maize	OPV Maize	2905 (Zodras)	55
23	Kabul - 97	ZM521	CIMMYT	14 EPOP#124	2018	Maize	OPV Maize	2702 (Zodras)	52
24	Bolan - 97	SC513	CIMMYT	14 EPOP#26	2018	Maize	OPV Maize	3077 (Zodras)	59
25	Wheat 2018-1	4WON-IR-257/5/YMH/HYS// HYS/TUR3055/3/DGA /4/ VPM / MOS	CIMMYT	21st FAWWON-IR#44	2018*	Winter wheat	Bread Wheat	975 (Pamir 94)	16
26	Wheat 2018-2	BCRIS/BICUM//LLARETA INIA/3/ DUKEM_12/2*RASCON_21/4/ SORA/2*PLATA_12//SOMAT_3/3/AJAIA_12/ F3LOCAL(SEL.ETHIO.135.85)//PLATA_13	CIMMYT	45th IDSN#7041	2018*	Fall sowing	Durum	952 (Parva 02)	18
27	Wheat 2018-3	KACHU/BECARD//WBLL1*2/BRAMBLING	CIMMYT	8th HTWSN#21	2018	Spring	Bread wheat	786 (Lalmi 02)	13

10.2 Appendix II: Trainings conducted in country

NO	Title	Venue	Date	Participants	Participant organizations
1	Project Inception workshop	MAIL	19-Dec-12	40	ARIA, FAO, ICARDA, USAID, AusAID, CIMMYT-Iran, NGOs, and PSE
2	Wheat production brainstorm	MAIL	27-Feb-2013	8	MAIL, CIMMYT, ICARDA, FAO
3	2nd ARIA-CIMMYT Maize workshop	PPQD, MAIL, Badambagh, Kabul	09-10th April 2013	30	ARIA, MAIL, FAO, ANSCO, CIMMYT
4	Training on Statistical Analysis 11, April 2013	CIMMYT Office, Kabul	11th April 2013	10	ARIA, CIMMYT
5	Programme 3rd All Afghanistan Annual Wheat Researchers Workshop	MAIL , Kabul	26-28 Aug 2013	64	ARIA, MAIL, FAO, ICARDA ANSCO, CIMMYT
6	Programme Training Course on "CONSERVATION AGRICULTURE: CONCEPT & APPLICATION	PPQD, MAIL, Badambagh, Kabul	28-29 Sep 2013	35	ARIA, MAIL, FAO, ICARDA ANSCO, CIMMYT
7	PROGRAMME Experimental Designs: Constitution, Analysis & Interpretation January 26th & 29th 2014	MAIL, DAIL Badambagh, Kabul	26-29 Jan 2014	36	ARIA , CIMMYT, JICA
8	3rd ARIA-CIMMYT Maize Workshop	CIMMYT Office, Kabul	10-Mar-2014	33	ARIA, CIMMYT, DAIL, ICARDA
9	Wheat Rust Management Training	HR building , MAIL	06-07 May 2014	47	ARIA, CIMMYT, DAIL, PPQD
10	4th All Afghanistan Annual Wheat Workshop 19-21 October 2014	MAIL, Kabul	19-21 Oct 2014	63	ARIA, MAIL, PPQD, CIMMYT, DAIL, SLDR
11	Training on Maize Breeding Quality Seed Production	Badambagh, Kabul	25- 26 Apr 2015	55	ARIA, MAIL, CIMMYT, AAEP, FAO, ACIAR. JICA, ANSOR, Seed Certification
12	4th ARIA - CIMMYT Annual Maize Workshop	Badambagh, Kabul	27-Apr-2015	39	ARIA. CIMMYT, MAIL

13	5th ARIA - CIMMYT Annual Maize Researchers Workshop, Badam Bagh, Kabul	Badambagh, Kabul	22-Apr-2016	44	ARIA. CIMMYT, MAIL
14	Practical training of research staff of three new included provinces.	CIMMYT Office, Kabul	21-22 Dec 2016	5	ARIA, DAIL
15	Theory and practical data entry and analysis training	Badambagh, Kabul	8-9 Aug 2017	6	ARIA
16	CIMMYT Handover workshop	Intercontinental Hotel	28-Aug-17	45	ARIA, MAIL, ICARDA, AUS-Embassy, GRAIN, AAIP, DAIL
17	6th National Wheat workshop	MAIL	17 - 20 Sep 2017	80	ARIA, MAIL, ICARDA, French Co, GRAIN, AAIP, DAIL

10.3 Appendix III: Trainings attended abroad

NO	Title	Venue	Date	Participants	Participant organizations
1	International winter wheat program	TCI, Turkey	02-09.04.2013	2	ARIA
2	BGRI Technical conference	India	19-22.08.2013	4	ARIA , CIMMYT
3	Wheat pathology course	CIMMYT-Mexico	02-16 Aug 2013	2	PPQD, ARIA
4	Administration training	CIMMYT-Mexico	26 Aug - 05 Sep 2013	1	CIMMYT
5	Advanced Wheat Improvement course	CIMMYT-Mexico	16 Aug - 15 Sep 2013	2	ARIA
6	Finance and HR training	Nepal	01-05.08.2013	2	CIMMYT
7	Conservation Agriculture	India	15 - 31 Oct 2013	4	CIMMYT, ARIA
8	Basic wheat improvement course	CIMMYT-Mexico	24 Feb – 04 June 2014	2	ARIA
9	BGRI Technical Workshop	CIMMYT-Mexico	20 Mar 2014 - 1st Apr 2014	2	ARIA
10	Conflict Resolution Training	India	22 - 24 Sep 2014	2	CIMMYT
11	Advanced Conservation Agriculture course	India	06-22 Oct 2014	4	ARIA, CIMMYT
12	Basic Wheat Improvement Course	CIMMYT-Mexico	20 Feb – 02 Jun 2015	2	ARIA, CIMMYT
13	Basic Wheat Improvement Course	CIMMYT-Mexico	18 Febr – 28 May 2016	2	ARIA
14	Rust Surveillance Training in Nepal		16 - 25 Mar 2015	4	ARIA, CIMMYT
15	Impact Analysis Survey Meeting in India	India	01 - 04 August 2015	5	CIMMYT
16	International Agricultural Machinery Exhibition	India	03 - 05 Dec 2015	3	Private seed companies
17	International Winter Wheat Improvement Program (IWWIP) workshop.	TCI, Turkey	12 - 14 Jan 2016	1	ARIA
18	Karnal Bunt Training	IIWBR, India	04 - 06 April 2016	8	ARIA, CIMMYT
19	Basic wheat improvement course	CIMMYT-Mexico	18 Feb -28 Mar 2017	2	ARIA
20	Seed cleaners training	India	21-26 Mar 2017	4	ARIA, CIMMYT
21	Impact analysis training	India	26-28 Sep 2016	5	CIMMYT
22	Rust Surveillance Training in Nepal	Nepal	Feb 22nd to Mar 3rd , 2017		CIMMYT
23	DUS Characterization and Quality Seed Production in Wheat	India	27-29 March 2017	2	ARIA, CIMMYT

10.4 Appendix IV: Range of traits in 1277 wheat germplasm lines

Character	Max	Minimum	Mean
Days to Heading	195	153	161
Days to Maturity	214	188	205
# of spikelet's/spike	29	11	19
Plant height (cm)	135	30	80
TKW/g	50	15	36
Plant Growth habit	Erect, Semi Erect, Prostrate		
Waxiness of the plant	Present, intermediate, Absent		
Flag Leaf Attitude	Erect, Semi Erect, Drooping		
Glume Hair	Absent, Present.		
Stem Solidness	Hollow, Semi Hollow, Full		
Ear Shape	Tapering, Fusiform, Parallel, Clavate, Semi Clavate.		
Ear Color	White, Brown, Semi Brown,		
Ear Density	Dense, Very Dense, Medium, Lax		
Foliage Color	Green, Pale Green, Dark Green		
Awns	Present, Absent,		
Diseases (YR)	TR, 5R, 10M, 20M, 30M, 40S,60S,80S,100S.		
Grain Shape	Oblong, Elliptical, Round, Ovate		
Grain color	White, Red, Amber		
Grain Hardness	Hard, Soft		

10.5 Appendix V: Genes in identified cultivars

Identified cultivar name / Genes	*1B1R*	*1A1R*	*Lr34*	*Lr37*	*Lr67*	*Lr68*	*Sr2*	*Sr25*	*Rht1*	*Rht2*	*Vrn-A1*	*Vrn-B1*	*Vrn-D1*	*Ppd-D1*	*Eps-D1*
Baghlan-09	-	-	-	-	-	+	+	-	dwarf	tall	winter	spring	spring	ins	+
Chonte #1	-	-	-	-	-	- (s)	+	-	dwarf	tall	winter	winter (s)	spring	ins	+ (s)
Dorokhshan/Darukhshan 08	-	-	-	-	-	-	-	-	dwarf	tall	winter	winter	spring	ins	+
Gul-96	+	-	-	-	-	-	-	-	dwarf	tall	winter	winter	winter	ins	+
HD2285	-	-	-	-	-	-	-	-	dwarf	tall	spring	spring	NA	ins	+
Kunduzi	-	-	-	-	-	-	-	-	tall	dwarf	winter	spring	spring	ins	+
Lalmi-2	-	+	-	-	-	-	-	-	dwarf	tall	winter	spring	spring	ins	+
Mazar-99	-	-	-	-	-	-	-	-	dwarf	tall	winter	spring	spring	ins	-
Muqawim 09	-	-	-	-	-	-	-	+	dwarf	tall	winter	spring	spring	ins	-
Rana-96	-	-	-	-	-	-	-	-	tall	tall	winter	winter	spring	ins	-
Roshan-96	(s)	-	-	-	-	-	-	-	dwarf	tall	spring	spring	winter (s)	ins	-
Watani Surkhcha	-	-	-	-	-	-	null	-	tall	tall	winter	winter	spring	sen	-
Sheshambagh-08	+	-	+	-	-	-	-	-	dwarf	tall	winter	winter (s)	spring	ins	+
Balkh Dehdadi	-	-	-	-	-	-	-	-	dwarf	tall	spring	spring	spring	ins	-
Solh-02	-	-	-	-	-	-	-	-	dwarf	tall	winter	winter (s)	spring (s)	ins	+ (s)
Bakhtar 013	-	-	-	-	-	-	-	-	tall	dwarf	spring	spring	spring	ins	+
BOW/PRL*3/6/WRM/…	-	-	-	-	-	+	-	-	tall	dwarf	winter	spring	spring	ins	+
CHEN/AEGI10PS5QUA…, PVN//CAR422/ANA…	-	-	+	-	-	-	-	-	tall	dwarf	winter	spring	winter	ins	+
AFGHAN Wheat Collection #53	-	-	-	-	-	-	-	-	dwarf	tall	spring	spring	winter	ins	-

Caption: **-** : absence of the allele, **+** : presence of the allele, **(s)** : segregation was observed, **ins** : insensitive, **sen** : sensitive

10.6 Appendix VI: Afghan germplasm lines with multiple disease resistance

No.	Name	STBm	TSm	SNBm	KBm	SBm
1	ANOAS-5/STIER-13/5/274/320//BGL.3.MUSX/…	279.0	1.0	1.1	0.2	470.1
2	GAUR-2/HARE-3//JLO97/CIVET/5/DIS B5/3/SPHD/..	217.3	1.2	1.0	0.3	625.2
3	FD-693/2*FAHAD-4//POLLMER-4/3/POLLMER-2.1	213.6	1.2	1.0	1.1	367.9
4	STIER-13/FAHAD-4//MANATI-1/3/POLLMER-1.1	203.7	1.4	1.0	1.0	692.3
5	CMH77A.1024/2*YOGUI-1//CIVET#2/3/JLO97/…	221.0	1.0	1.0	2.0	704.0
6	Nish Shotor	246.9	1.1	1.1	2.7	513.3
7	CROC-1/AE.SQUARROSA(205)//KAUZ/3/SASIA	695.1	1.4	1.0	0.7	654.6
8	FAHAD-5/POLLMER-3	222.2	1.4	1.2	2.3	576.5
9	Parva 2	198.8	1.1	1.0	3.3	692.0
10	Odessa 06/Mesa	177.8	1.2	1.0	4.4	588.0

STBm: Septoria tritici blotch

TSm: Tan spot

SNBm: Septoria nodorum blotch

KBm: Karnal Bunt

SBm: Spot blotch