Australian Government
Australian Centre for
International Agricultural Research

Final report

project	**Forage options for smallholder livestock in water-scarce environments of Afghanistan**
project number	AH/2012/021
date published	1/06/2019
prepared by	Mounir Louhaichi (ICARDA – Jordan) Shinan Kassam (CARITAS – Switzerland) Serkan Ates (Oregon State University – USA) Sawsan Hassan (ICARDA – Jordan)
co-authors/ contributors/ collaborators	Aziz Niane (ICARDA – Lebanon) Hayley Norman (CSIRO – Australia) Bradley Nutt (Murdoch University – Australia) Soofizada Qudratullah (ARIA/MAIL – Afghanistan) Remco Mur (KIT – The Netherlands)
approved by	Barbara Rischkowsky (Program Director – ICARDA) Jacques Wery (ADG-R – ICARDA) Werner Stur / Anna Okello (ACIAR)
final report number	FR2019-32
ISBN	978-1-925747-08-9
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

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1 Acknowledgments

The authors would like to acknowledge the great support of the Afghanistan Ministry of Agriculture, Irrigation and Livestock (MAIL) and Agricultural Research Institute of Afghanistan (ARIA), and the two development organizations: the Aga Khan Foundation (AKF) and Action Aid based in Afghanistan. Special thanks go to Bahri Dagdas International Agricultural Research Institute (Konya, Turkey) for collaboration on research and training courses. We also would like to thank NARS outside of Afghanistan including NCARE (Jordan), ARC (Egypt), and LARI and AUB (Lebanon) for their support and in-kind contribution for hosting our training events.

Appreciations are due for the Program Oversight Group (POG) members as well as the forage working committee for their endorsement and support to the forage project.

Last but not least, many thanks go to CSIRO and Murdoch University for facilitating the trainings of Afghan nationals in Australia and their financial support for unplanned activities as well as to Simon Tighe who hosted the mirror trial work in Australia. The logistic support of the ICARDA regional offices in Dubai and Delhi for hosting POG meetings and other workshops is highly appreciated. Without the generous financial support of the Australian Government (DFAT/ACIAR) this project would not have been possible.

2 Executive summary

This four-year research project aimed at reducing the gap in feed supply for ruminants especially in winter through increased forage production and availability of seeds of improved forage species/varieties in Baghlan and Nangarhar Provinces of Afghanistan. The project was implemented as a part of the Afghanistan Agricultural R4D Program funded by the Department of Foreign Affairs and Trade (DFAT) and managed by ACIAR. The project tested and evaluated a large number of forage crops of various origins to identify varieties with superior biomass production and to produce and disseminate 'best practices' packages for forage production. To achieve the projected outcomes, the technical components aimed at increasing forage productivity per unit area of land and water through on-station and on-farm research using participatory approaches with all stakeholders. The specific objectives of the project were to:

- Assess the main climatic, edaphic, and agronomic constraints leading to nutritional gaps and identify appropriate technologies (new species, varieties, and/or management practices) to overcome or reduce constraints.
- Evaluate forage and fodder production options for smallholder livestock systems.
- Expand the scope of existing community-based seed enterprises to include feed and forage seeds, vegetative propagation of shrubs, and planting materials.
- Develop capacity of Afghan researchers in forage and livestock systems research.

An overarching objective of this project was to foster the development of inclusive and sustainable forage production systems within the water constrained provinces with processes for broad (national) uptake. This was achieved through:

- Evaluating adaptability of promising forage genotypes and accessions.
- Demonstrating the validity and potential of these to farmers that are interested in cultivating forage, thereby reducing seasonal gaps in access to feed resources.
- Identification of avenues to support an enabling environment for varietal introduction and release of forage varieties as well as broad uptake by farmers.

Over the course of the project, 97 improved forage and crop genotypes were evaluated for adaptation and/or productivity (measured by biomass and grain yield). Based on the preliminary results, nine promising genotypes were further evaluated on-station and on-farm to generate data to support varietal registration/introduction and to provide guidelines for their agronomic management. Some varieties produced up to 30% more biomass than existing lines. Eighteen forage shrub accessions/ecotypes were multiplied on-station for distribution to public agencies, international and national developmental agencies, as well as private farmers. Concerted efforts were made in fostering ownership and oversight of national systems of research, international developmental agencies, and civil society organizations. A project working committee comprising ICARDA and representatives from five departments from the Ministry of Agriculture, Irrigation, and Livestock (MAIL) was constituted. Despite challenges inherent within a complex and unstable environment, the committee was functional in terms of joint planning, implementation, and monitoring of project activities. Equally important was participation of the seed certification directorate within the project working committee to ensure that the process of varietal registration/introduction of the nine genotypes was in accordance with existing regulations. Security concerns and instability limited the range of research and development activities, as well as the intensity with which activities were undertaken. Mirror trial sites in Western Australia and Turkey therefore provided safe environments for more intensive measurements of productivity and adaptability of tested genotypes; and effectively hosted close to 450 Afghan partners (private, public, and civil society) for approximately 20 training and orientation sessions. Representation of international developmental organizations within the committee was equally constructive, leading to the distribution of seed to the Aga Khan Foundation for collaborative on-station and on-farm research trials within three provinces (Takhar, Badakhshan, and Bamyan) that were outside the project target area of Baghlan and Nangarhar Provinces; thereby showing

significant promise for scaling-out through effective partnership with an international development organization.

Some of the tested varieties proved to be highly adaptable and offer potential to reduce the winter-feeding gap. Through exposure visits and access to global lessons learned, the national research and innovation systems in Afghanistan were effectively exposed to arguments for why forage crops ought to be treated differently from cereal crops – specifically within the framework of national regulations for varietal introduction and release. Mutually beneficial interactions between international development organizations, civil society organizations, and the national research system were enhanced, within the spirit of an innovation systems approach, where matters related to gender are now better understood; although there is a need for continuous improvement in this area.

The baseline survey related to the assessment of the seed systems and markets in Baghlan and Nangarhar Provinces resulted in two major findings and recommendations: (1) farmers' knowledge on seed production standards is very poor and the need for strong extension efforts for raising farmers' awareness is evident. Mass communication tools and hands-on training on seed standards could support this effort; and (2) farmer-to-farmer (community) exchange is the common source for seed and information on many crops in Afghanistan and therefore access to quality seed needs to be enhanced and crop-specific strategies for seed production need to be developed.

The gender study led by the Royal Tropical Institute (KIT) identified both challenges and opportunities for women to create space to innovate and exert agency to mobilize support from their informal networks, both as members of a male-headed household and as female heads of households. For example, women are, to a greater extent than men, reliant on their informal network of (female) family and friends to access information about agricultural innovations that can help them to increase forage production. Related to this, the study found that gender norms around the 'appropriateness' of female–male interactions can greatly inhibit women from interacting with a number of (male) actors. These challenges and opportunities are mediated by gender norms, roles, and relations produced and reinforced by the forage system, i.e. the network of organizations, enterprises, and individuals focused on bringing about change related to forage production and forage value chains, as well as the institutions and policies that affect their behavior and performance (adapted from De Klerk et al. 2012a). It is imperative that these norms, roles, and relations are considered when attempting to introduce new forage varieties into the forage system in Baghlan and Nangarhar as they might effectively prevent women from both adopting and benefiting from the new varieties.

Based on positive experiences attained through sustained engagement and interaction, the project produced a number of valuable results within an environment plagued with limited national capacity (budgetary and other) as well as significant instability. Whether or not national systems amend existing policy on varietal release, excluding forage varieties from a formal release system is a matter of political economy and will.

3 Background

Afghanistan is an extremely poor and conflict-ridden country with more than half of its population of 30 million living below the poverty line of $US1 day^{-1}. In recent years, the number of poor and undernourished has been increasing by 10–15% per year, a result of frequent droughts and increases in the price of food and feed, all of which were compounded by the global food and economic crisis (FAO 2008; WFP 2009). Calorie deficiency rates vary from less than 15% in Parwan, Nangarhar, Sar-i-Pul, and Jawzjan to more than 60% in Badakhshan and Laghman (World Bank 2011). In Afghanistan, about 80% of the population is concentrated in rural areas and most are subsistence farmers. Agricultural production is quite often insufficient to meet family requirements (Groninger et al. 2013). Therefore, the priority crops for meeting day-to-day needs and for generating farm income are wheat, vegetables, and fruits (Walters et al. 2012). In rainfed areas, farmers depend mainly on common land resources to support fodder needs. Agriculture is largely rainfed and droughts are frequent (ICON Institute 2009).

Agriculture is the main livelihood of the poor rural people and a major contributor to the Afghan economy but the availability of land and water resources for vulnerable smallholder farmers is limited and marginal at best. The Afghan rural population subsists by crop and/or livestock farming (GIRoA 2009). Livestock are essential for the livelihoods of rural Afghan families who keep small ruminants and dairy cows as a source of food, income, and a ‘safety-net’ in times of need. Livestock production is a significant contributor to the Afghan economy, accounting for about half of the agricultural GDP (ACIAR 2011; AusAID 2011). Insufficient feed availability and production for ruminants is the key constraint for the livestock sector (GIRoA 2009). Lack of forage of sufficient quality limits productivity, and the effects worsen during years of drought or in regions where fodder imports from neighboring countries are restricted.

The demand for livestock products within Afghanistan and neighboring countries is likely to rise as populations and incomes grow. This presents a significant opportunity for livestock farmers in Afghanistan to improve household income and food security. Livestock production already plays a key role in economic development of Afghanistan and is an important priority for farmers. The livestock sector provides income, food, employment, and other contributions to rural development. Out of the 75% of Afghans who live in rural areas, 85% keep some livestock (GIRoA 2009). Currently, it is estimated that there are more than 22 million ruminants in Afghanistan, predominantly cattle, sheep, and goats (Fig. 1).

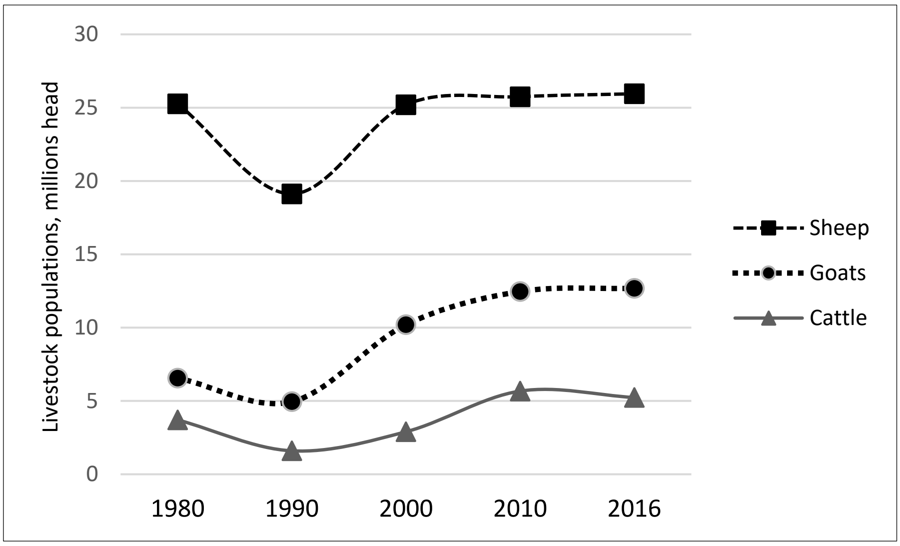

Fig. 1. Changes in livestock numbers over a 30-year period in Afghanistan.
Source: FAOSTAT 2018.

Despite the fact that even the poorest farmers have at least one cow and a few goats or sheep to satisfy their basic needs for meat and dairy products, the levels of productivity are not high enough to provide sufficient meat and milk for the growing population (FAO 2012). The lack of fodder, especially during winter, is one of the major limiting factors for ruminant production in Afghanistan. The need for increased fodder production was also highlighted by the Afghan Livestock Workshop, organized by the Advancing Afghan Agriculture Alliance (A4), (Motamed 2008) and further supported by the USAID Afghan Water, Agriculture, and Technology Transfer (AWATT) program, where ‘Forage Improvement, Demonstration, and Technology Transfer’ was one of the key activities recommended to support the focus on ‘Integrated Water Resources Management, Technology Transfer, and Policy Analysis’ (AWATT 2009). The IFAD-funded ICARDA project on improving women’s livelihoods through raising small ruminants in the marginal areas of Afghanistan and Pakistan concluded that availability of forage/fodder was critical for keeping animals during winter, and unavailability of forages forced poor people to sell their assets. The final report reiterated that “Further research-for-development intervention is needed to increase feed resource base with varieties suitable for resource poor farmers” as one of the lessons learned (ICARDA 2009).

Most of Afghanistan’s forage seed and planting materials were lost during the long period of conflict and most fodder seed comes either from on-farm production or bartering among farmers. The seed of the two most common forage crops, alfalfa and berseem clover, is available in the local market but tends to be poor quality and often contaminated with weed seeds. Although some crop seed-related projects operate in Afghanistan, a forage seed sector is absent (Oushy 2011). Furthermore, farmers follow traditional practices for cultivation of various crops, and fodder crops are no exception. During the period of crisis, the agriculture sector remained neglected, and development of improved technologies and their dissemination by extension agencies could not be pursued vigorously. Farmers usually adopt cropping systems based on their requirements and economics without any consideration for maintaining soil health and sustaining crop productivity. Therefore, productivity of crops in general, and fodder crops in particular, is low. Most agricultural products produced by farmers are consumed by their families or other villagers (Groninger et al. 2013).

In the context of growing concerns about global food security, Australian development assistance has increased to address the root causes of food insecurity in developing countries. This support includes programs to enhance productivity and market development. The overall aim and objectives of the proposed project are consistent with the priorities outlined in Australia's humanitarian and development assistance program in Afghanistan and contribute to their achievement. Australia's assistance to Afghanistan supports the development objectives and reconstruction efforts outlined by the Government of Afghanistan. These development objectives were taken into account in the design of the project. Australia has also made a strategic commitment to support rural development and livelihoods in Afghanistan particularly in the context of dryland agriculture (AusAID and ACIAR 2011b).

Through a recent ‘desk review’ AusAID and ACIAR identified “Integrated crop–livestock farming systems for dryland production areas” as one of the key areas where Australia is considered to be one of the leaders. The review emphasized a focus on improved productivity and intensification of agricultural production systems (including the diversity of wheat-based production systems) for both food security and local markets. It is also stressed that small livestock must be considered as an integral part of the wheat-based farming systems (AusAID and ACIAR 2011a). The ICARDA-Afghanistan office actively participated and contributed to the desk review. As forage/fodder shortage has been identified as one of the major constraints for the growth of the livestock sector (cattle and small ruminants), the proposed project is in line with the recommendations of the desk review.

The forage project is well aligned with MAIL's National Strategy. In particular, it contributes to the following priorities articulated by MAIL:

- Increase forage production and productivity through the development and dissemination of improved varieties, seed, and production practices.
- Combat drought.
- Support research and extension activities, all within the broader context of the government policy to phase out agricultural input subsidies.

The project is also in line with the Government of Afghanistan's priorities. Livestock production is central to the country's National Priority Program 2; the project particularly complements MAIL's Horticulture and Livestock project. Livestock needs also feature prominently in Afghanistan's:

a. National Agricultural Development Framework. The project would contribute to agricultural development in Afghanistan through more efficient use of natural resources in crop–livestock production and improved availability of fodder for livestock and forage seed for the resource poor farmers. The increased availability of forage is crucial for development of a more sustainable and efficient animal production sector. The project will also have a significant impact on capacity development of national research staff and farmers, which will directly contribute to development of the agricultural sector in Afghanistan.
b. MAIL Natural Resource Management Program. The project can directly help this program through better integrated crop–livestock production and introduction of forage legumes in cropping systems that would improve the soil quality and efficiency of water and land use, while indirectly helping reduce pressure on rangelands. The activities designed on the basis of sustainable intensification of fodder production can help agriculture-based economic development in rural areas.
c. MAIL Agricultural Production and Productivity Program. The project can contribute to agricultural development in Afghanistan through increasing the availability of forage dry matter (DM) and seed production, and indirectly increasing livestock production and reducing livestock mortality caused by feed shortages during critical periods. Thus, the project will directly or indirectly contribute to Sub-program C: Livestock, and Sub-Program E: Kuchi support.

4 Objectives

The overall aim of the project is to improve the livelihoods of smallholder livestock farmers in the mixed crop–livestock areas of Afghanistan, which have limited access to water resources. The project aims to increase the availability of feed resources adapted to low water use as supplementary feed in crop–livestock systems of Afghanistan, which are increasingly constrained by water.

To achieve this aim, the project was set to deliver the following four objectives and derived sub-objectives:

1. Assess the main climatic, edaphic, and agronomic constraints leading to nutritional gaps. Identify appropriate technologies (new species, varieties, and/or management practices) to overcome or reduce constraints (Years 1–2, 10% of resources).

1.1 Characterize current constraints and potentials of the forage production systems; update and expand needs assessment.

1.2 Establish and manage a development and communication network with active involvement of other project teams and end-user organizations.

2. Evaluate forage and fodder production options target smallholder livestock systems (Years 1–4, 60% of resources).

2.1 Test current (Afghanistan) and commercially available (international) forage and shrub species and identify key selection traits as a basis for sub-objective 2.2. (Years 1–2).

2.2 Undertake adaptive research on-station and participatory research with farmers to test candidate forages and associated conservation options (Years 1–4).

3. Expand the scope of existing community-based seed enterprises to include feed and forage seeds, vegetative propagation of shrubs and planting materials (Years 2–4, 20% of resources).

3.1 Understanding of village-based seed enterprises (VBSEs) and private seed enterprise PSE forage seed/planting materials system and markets for the products in target districts of the two provinces (Year 1).

3.2 Develop sustainable seed and planting material (nurseries) production and marketing by VBSEs and PSEs (Years 2–4).

3.3 Assess the profitability of VBSEs in forage seed and planting materials production and marketing (Years 2–4).

4. Develop capacity of Afghan researchers in forage and livestock systems research (Years 1–4, 10% of resources)

4.1. Short-term capacity building in measurement and assessment of forage production, seed production, rhizobiology, and socioeconomic survey techniques (Years 1–2).

4.2 Medium-term capacity building in scientific methodology, legume and shrub research, and basic assessment of nutritive value (Years 1–2).

4.3 Capacity building for next users (development partners and farmers) in new forage options (Years 3–4).

5 Methodology

This four-year project was implemented within small-scale crop–livestock production systems in Baghlan and Nangarhar Provinces. In collaboration with the allied watershed initiative, funded by ACIAR, Mazar-i Sharif Province was also utilized as a rainfed testing site for multi-location trials, giving a representative dryland/rainfed region, together with a relatively more secure environment. Key activities included scientific (on-station) research and applied (on-farm) demonstrations, socioeconomic research engagement inclusive of gender as a scientific area of enquiry, and policy-oriented engagement within the larger area of varietal introduction and release.

An initial baseline study was undertaken prior to initiation of research for development activities for characterization of the project catchment area as well as existing challenges and entry points. There were 210 farm households surveyed in Baghlan and Nangarhar Provinces.

Variety evaluation and agronomic management trials

Cultivars of local (11) and introduced (97) forage/range legumes, grasses, and food–feed crops, with superior yields and feeding value were evaluated through replicated, multi-location trials to widen the feed resource base in Nangarhar (Shesham Bagh), Baghlan (Poza-e Shan), and Mazar-i Sharif in 2014–2017. Special attention was given to selection of promising species and cultivars with high water and nutrient use efficiency; and under-utilized forage species and persistent local ecotypes.

In addition to trials in Afghanistan, on-station experiments on the forage-based lamb feeding, dual-purpose winter annuals, and agronomic management of legumes were undertaken at the mirror trial sites in the mixed crop–livestock zone of Western Australia and Turkey. These mirror trial sites provided an environment of relative calm and reduced security risk, thereby providing an avenue for reliable benchmark data as well as an enabling environment for Afghan researchers and national staff to engage in skills-upgrading initiatives as well as introduction to demonstration sites in similar agroecological environments. The mirror trials were located at Bahri Dagdas International Agricultural Research Institute (designated as a drought research center) in Konya, Turkey. The institute is located in Central Anatolia and operates under the mandate of the Ministry of Food, Agriculture and Livestock and has a long history of collaboration with international institutes or organizations such as ICARDA and CIMMYT. In Australia, mirror trial sites were maintained under the aegis of senior scientists at Murdoch University and CSIRO. Site descriptions are presented in Section 7.4.2.

The replicated trials in three locations in Afghanistan assessed a total of 97 (68 legume, 11 cereal, and 18 shrubs) introduced forage/range genotypes for seasonal DM and seed production (see Table 1, Section 7.1 for the complete list). Furthermore, 20 cactus accessions were evaluated for adaptability and tolerance to frost as an alternative feed source. The project conducted a total of seven on-station variety evaluation trials, six forage agronomy and management trials, and eight on-farm demonstrations. Agronomic management options for the integrated and sustainable use of land, water, and nutrients were demonstrated on-farm to optimize forage production from the existing seasonal cropping systems. Each package was demonstrated in 4–6 farms in both locations. Agronomic interventions focused on proper seeding and fertilizer rates and optimization of forage yield and quality through intercropping of annual legumes with cereals. In these studies, forage and grain yields were quantified. Fodder samples from studies in which monocultures and mixtures of legume and cereal were evaluated at three seeding rates were analyzed for concentrations of crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and in vitro organic matter digestibility (IVOMD) characteristics using near-infrared spectroscopy. Farmers' perceptions and preferences for introduced forage species and agronomic management techniques were monitored where possible.

For all activities, field days and travel workshops were organized for farmers and policy makers during the cropping cycle to promote information exchange and encourage adoption.

Shrubs/trees are important forage resources and essential for dryland production systems in Afghanistan. One of the main constraints in production and adoption of improved and integrated forage and shrub production is the lack of native seed and plant material. Targeted species included most promising shrubs/trees. The seeds were collected, properly identified, and established in local research stations and evaluated for persistence and production (biomass). Establishment and growth of four rangeland species (*Atriplex halimus*, *A. nummularia*, *A. lentiformis*, and *Maireana brevifolia*) were evaluated under two establishment treatments (direct seeding and seedling transplanting) in Mazar site. Both treatments were implemented using semi-circular bunds aimed at alleviating soil erosion and promoting water harvesting. The source of the plant materials (seeds and seedlings) was the Agricultural Research Institute of Afghanistan (ARIA) research stations in Baghlan and Nangarhar where the project established mother plants for seed multiplication. On February 2017, the trial was laid out as a factorial split plot design with two establishment treatments (direct seeding and seedling transplanting) as the main plots and shrub species as subplots. The trial was replicated three times. Survival rate, plant height, plant width, plant length, and plant cover were recorded regularly. Plant cover (%) was estimated using a digital vegetation charting technique which relies on image processing of straight-down vertical images.

Twenty promising cactus (*Opuntia ficus-indica*) accessions were introduced to Afghanistan. These accessions originated from Tunisia, Mexico, Ethiopia, Morocco, and Algeria. The cactus cladodes were first transplanted to the farm e-Hada in Nangarhar on the 27 April 2017. The trial was implemented using a randomized complete block design in which cladodes of each accession were planted 2 m apart along the same row, with 3 m between rows.

The initial assessment of forage seed systems along the seed chain showed a need to understand the system in Afghanistan and identify critical gaps. This involves collection and analysis of secondary data from key stakeholders and primary data from farmers in target provinces. Based on the outcome of these studies, forage seed production and marketing was initiated working with existing village-based seed enterprises (VBSEs) and PSEs in target provinces. The VBSE and PSE members were provided with seed of forage varieties/planting materials and necessary inputs and trained in both technical skills of forage seed/planting material production and financial and enterprise management. Each year the technical performance (in terms of the quantity and quality of seed/planting materials produced) was measured to assess the sustainability of forage seed production in Afghanistan (Srinavas et al. 2010).

The activities related to capacity building (Objective 4) targeted directly involved project partners but aimed at specifically strengthening the capacity of forage production at a wider scale, involving farmers and national staff of the Government of Afghanistan. Thus, the project conducted short-term technical courses for researchers and extension agents focusing on topics directly relevant for the project implementation so that the knowledge gained could be directly applied on the ground. Project staff were trained in measurement techniques of forage production and to assess the effectiveness of rhizobial nodulation of forage and crop legumes in fields.

Strengthening innovation systems

One important objective was to develop scaling approaches and methodologies and test these for proof of concept. Normatively, this is very different to that of scaling the adoption of new practices and knowledge (embodied in seed or equipment; or supportive). While the latter continues to have global success in the dissemination of seed and equipment within enabling (social, economic, and policy environments), it has been less successful within more complex environments such as war-torn Afghanistan. As such, there is a need for shifting away from conventional (linear) approaches for technology development and dissemination, toward a focus on networks of relations and interactions to support the participatory development of new practices and widespread use (broad uptake). This requires a framework that embodies innovation as an interlinked process of technical change, new or improved organizational arrangements and institutionalization of processes and norms related to production practices, regulatory mechanisms, and incentive mechanisms.

Innovation systems are social systems insofar as interactions between human beings are concerned – individually, as well as within and between organizations. A key focus of endeavor within this project initiative related, therefore, to strengthening the range of mutually beneficial relationships between private individuals (farmers, value chain intermediaries, and researchers) and individuals working with public (regulatory and administrative organs) and civil society organizations (NGOs and international organizations). Improved interactions between stakeholders, joint experimentation, and more demand-responsive research were an avenue sought to increase the propensity for new practices and technologies to be adopted at scale and outcomes to be realized outside of the immediate provinces within which the project engaged directly.

Fostering mutual beneficial relationships and partnerships was undertaken through:

1. Creation of a project steering committee comprising key staff within national research systems, national regulatory bodies (including the seed certification directorate), and international organizations (Aga Khan Foundation, Action Aid, and World Vision), as well as key ICARDA project staff.
2. A working tri-partite agreement between ICARDA, MAIL, and the Aga Khan Foundation in relation to the development and functioning of seed multiplication plots within provinces outside of direct project implementation.
3. Joint socioeconomic research undertaken through a collaborative effort between ICARDA, the Royal Tropical Institute (KIT), and ARIA.
4. Direct engagement with farm households within the three provinces targeted in on-farm trials of tested forage varieties and species as well as in socioeconomic research.

Gender concerns

Attempting to ensure equality in access to knowledge, forage varieties, and species tested for adaptability, as well as equity in opportunity to access resources, was undertaken through measures to understand existing social and cultural constraints and entry points for addressing these concerns. Three notable activities were undertaken in this regard:

1. Workshop facilitated by KIT and ICARDA on 3–5 July 2017 in Dubai aimed at identifying opportunities and constraints in Afghan forage innovation systems:
    a. Developing an analytical framework
    b. Mapping the forage innovation systems and key value chains
    c. Understanding the roles of public/civil-society/private organization roles within existing and transitioning forage production and marketing systems
    d. Assessing opportunities and constraints related to regulations on varietal introduction and release
    e. Analysis of gender dynamics within each of the above
    f. Identifying opportunities and constraints to facilitate gender equality in access to opportunities within profitable forage systems nationally.
2. Household study. Intra-household dynamics related to forage production (ICARDA and KIT) July 2017 to July 2018:
    a. Analytical framework and research methodology based on four dimensions of social relations:

        i. Division of labor
        ii. Access to and control over resources and benefits
        iii. Norms and values
        iv. Decision making processes
    b. Exploratory study on household dynamics
    c. In-depth study on household dynamics.
3. Case study. Understanding cultural and social norms related to knowledge transfer among women farmers (ICARDA and KIT), July 2017 to July 2018:
    a. Analytical framework and research methodology
    b. Interviews and focus group discussion with women farmers, agricultural extension officers, and key staff within international organizations and national institutions.

Policy influence

The legacy of this project was defined by how national systems of innovation have fully understood the need for treating forage crops differently from existing cereal crops – specifically within the framework of national regulations for varietal release/introduction. This understanding was fostered through regular interactions between ICARDA scientists and specifically the seed system specialist based in Beirut, as well as the three project managers overseeing the initiative. More specific information and knowledge exchange was fostered over the course of dedicated international exchange visits to Egypt, Jordan, and Turkey, where ARIA and MAIL staff were exposed to seed system polices and regulations within different contexts; with lessons taken back for consideration of policy reform or promulgation in Afghanistan.

Legacy, in terms of policy influence and sustainability, was also defined by the current interactions between international and national system research staff that have impressed the need for addressing issues of efficacy in research, appropriate planning, and effective budgeting – and equally importantly, the need for stronger linkages with civil society organizations for out-scaling of research outputs toward the attainment of desired research and development outcomes. Here, closer integration and ties fostered with the Aga Khan Foundation and World Vision, in the development of demonstration sites and farmer field days within provinces outside of the project catchment area served as a potential long-term approach for large-scale validation; and uptake of varieties amenable and adapted to broad uptake at a national level.

Taken together, both of these legacy relevant aspects were within the scope of a functional innovation systems approach that now needs to be owned by national partners (governmental as well as international organizations and civil society) who have been exposed to effective approaches for collaboration. Whether this is taken up, and to what degree, is a matter of political economy.

6 Achievements against activities and outputs/milestones

Objective 1: Assess the main climatic, edaphic and agronomic constraints leading to nutritional gaps and identify appropriate technologies (new species, varieties and/or management practices) to overcome or reduce constraints

PC = partner country, A = Australia

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
Objective 1.1 Characterise current constraints and potentials of the forage production systems, update and expand needs assessment.				
1.1a	Review existing literature and reports on forage and livestock production to summarize feeding systems in each province. Review biophysical characterization of target areas.	• Updated knowledge of small-scale crop–livestock systems documented for each target province • Biophysical environment and existing forage and livestock production characterized and documented • Reports published and available to stakeholders	Completed: Two reports completed and shared with ARIA in early 2018: Status of forage production in Afghanistan http://repo.mel.cgiar.org/20.500.11766/8307 Characteristics of Baghlan and Nangarhar Provinces http://repo.mel.cgiar.org/20.500.11766/8314	The status report describes the dynamics of seasonal forage supply and demand and the gap in supply. It highlights constraints, solutions, and opportunities to improve forage production. The second report provides an updated status of the biophysical environment targeted by the project.
1.1b	Field observation of current endemic forage/range species and nodulation (legumes).	• Endemic forage/range legumes documented and existence of nodulation	Completed: Data were acquired on endemic forage/range legumes and the most commonly used local forage legumes included in the varietal comparison trials with newly introduced forage crops. A study on root nodulation of the legumes as an indication of nitrogen-	The nodulation study was carried out by one of the national Afghan trainees who visited Australia in 2016 for a six-week training course implemented by CSIRO and Murdoch University partners. Having an Afghan national undertaking this work also serves as capacity development. Extra material (e.g. seed and inoculants) as well as technical

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
			fixation potentials was carried out including local and introduced varieties.	backstopping to support to the study were provided by Murdoch University.
1.1c	Survey of feed base for baseline production data (forage, shrubs, trees, and concentrates). Study fodder and forage seed and identify constraints and opportunities.	• Feed base and fodder technologies baseline production data are documented • Papers published and available to stakeholders	Completed: - 210 farmers selected using multi-stage random sampling were surveyed to characterize the current status of crop–livestock production systems in Baghlan and Nangarhar. The report is available, also a proceeding paper was submitted to present the data http://repo.mel.cgiar.org/20.500.11766/8305 http://repo.mel.cgiar.org/20.500.11766/8304 http://hdl.handle.net/20.500.11766/4910 - One paper based on survey results submitted (PDF copy is shared).	The survey included Afghan farmers' choice of forage seed sources and the factors affecting their choice. A manuscript "Factors affecting farmers' choice of seed sources: case of Afghanistan farmers" was submitted to the Agribusiness Journal (under review). Information from this survey supported engagement on gender within forage production systems in Afghanistan. In addition, it was closely linked to mapping out forage value chains in the provinces of direct project engagement (Baghlan and Nangarhar) providing a baseline for future work.
1.1d	Study on seed markets within the project catchment area and Afghanistan more generally.	• Report identifying the multiple channels for seed acquisition and distribution • Catalog of main actors within the seed value chain (report)	Partly completed: A study initiated in September 2016 was completed in December 2016 http://repo.mel.cgiar.org/20.500.11766/8242 Report on variety introduction http://repo.mel.cgiar.org/20.500.11766/8241	

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
		• Uncovering of options for how to more effectively introduce forage seed varieties and shrubs through public, private, and civil society institutions (report)		
1.1e	Gendered and systemic constraints and opportunities to fodder production systems (additional activity following mid-term review recommendations)	• Analyze and document intra-household dynamics related to forage production. Describe cultural and social rules related to forage systems knowledge transfer	Completed: 68 surveys for women (female-headed households) and for men (male-headed households) were conducted in Nangarhar and Baghlan Provinces. A total of 12 focus group discussions/ mini-workshops in two selected villages in Nangarhar and Baghlan Provinces took place in March 2018. The intra-household dynamics related to forage production were analyzed and documented. Dataset available (with KIT). Gender norms, roles, and relations related to forage systems knowledge transfer among women farmers were documented (report in preparation by KIT). Six Afghan women, together with KIT, wrote several research diaries over a period of 8 months in which they shared their life stories and reflections on	Note: These activities were not part of the original proposal but a very useful addition and respond to the mid-term review recommendations A collaborative research agreement between ICARDA and the KIT was signed to support this additional activity. Knowledge of the NARS involved in this study was enhanced.

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
			gendered opportunities and challenges for innovation in the forage system (report in preparation by KIT).	
Objective 1.2 Establish and manage a development and communication network with active involvement of other project teams and end-user organisations				
1.2a	Identify sites with potential to collaborate with other programs that are addressing livestock production constraints. Participate in joint training, workshops, and field days.	• A well-established collaboration with other programs and ongoing projects	Achieved through: Collaboration with Aga Khan Foundation (AKF) through an agreement between ICARDA, ARIA. and AKF to support the demonstration of forage seeds and develop capacity of AKF staff. - Eight species were cultivated through AKF in Baghlan, Bamyan, Takhar, and Badashan Provinces: 1. Sainfoin (*Onobrychis sativa*) cv Ozerbey 2. Oat (*Avena sativa*) cv Syedisehir 3. Common vetch (*Vicia sativa*) cv Baraka 4. Narbon vetch (*V. narbonensis*) cv Velox 5. Berseem clover 6. Common vetch (*V. sativa*) cv Rasina 7. Forage pea (*Pisum sativum*) cv #40-10 8. Triticale (*Triticosecale*) cv Alperbey - Three AKF women (Lana Roish, Bomani Afzali, and Sayli Khusravbekova) participated in the Jordan training and enhanced their	The partnership with AKF opened new avenues for the scaling up and out of varietal development and distribution systems for forage seeds. Large-scale uptake will take some time given regulations on varietal introduction/release: - Larger quantities of seeds are available for multiplication - Farmers in provinces outside Baghlan and Nangarhar are knowledgeable on production practices for forages and have been introduced to improved forage species - Capacity development of three AKF female staff will help increase the capacity of women within Afghanistan, providing hope for a future cadre of women to receive technical training, gain experience, and be well positioned to take a role in agriculture in the country.

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
		• Conduct a series of transition workshops involving concerned stakeholders	knowledge about social and cultural norms of females. Collaboration with Action Aid NGO: Action Aid staff in Mazar (two female and 11 male) and in Bamyan (two female and 13 male) were trained on *Atriplex* plantation and seed production. Collaboration with ACIAR-funded watershed initiative in Mazar-i Sharif: 1200 *Atriplex* saplings dispatched for planting in the research site and to evaluate various shrub propagation techniques including direct seeding, cuttings, and transplantation of seedlings on shrub performance under semi-circular water conservation technique.	Capacity development of staff of NGOs will help to speed up uptake of innovations. *Atriplex* saplings obtained from the Dhadadi farm in Mazar to which *Atriplex* seeds had been provided earlier by the project. This trial was added to the project in 2017. Mr. Safi (field coordinator based in Mazar under the ACIAR watershed project) is monitoring shrub establishment and growth. Evaluation of perennial species (shrubs) needs more time than annual forage crops and so ARIA needs to continue monitoring these plantations. This milestone was added to the project document at Variation 2. The project did very well in this regard and the workshops helped in getting ARIA and MAIL engaged in the project.
1.2b	Monitoring and evaluation.	• Impact of activities is monitored	Achieved through:	By establishing the M&E framework early in the process,

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
			A monitoring and evaluation (M&E) framework developed by R. Telleria and S. Ates soon after the inception workshop in March 2014. Specialized training in M&E with specific attention to ACIAR reporting requirements was undertaken in late 2016, through engagement of a Kabul-based ACIAR consultant, and in collaboration with other ACIAR initiatives. Monthly progress reports were submitted to ACIAR M&E as well as to ACIAR focal point. Regarding phasing out of the project: A working committee within the Ministry of Agriculture was established in 2017 to take over monitoring of the forage project involving all concerned departments. In late 2017 and 2018, reviewing transition plans and monitoring progress transition workshops were conducted involving ARIA and ICARDA scientists. Mr. Moussaoui (ACIAR M&E) attended these workshops. http://repo.mel.cgiar.org/20.500.11766/8315 http://repo.mel.cgiar.org/20.500.11766/8302	providing training, and setting up the appropriate committees to monitor the work, ARIA capacity to undertake and continue the project activities beyond the project lifetime has greatly improved. It is hoped that this will have provided a foundation for future projects and work.

Objective 2: Evaluate forage and fodder production options for smallholder livestock systems

No.	Activity	Outputs/ Milestones	What has been achieved?	Comments
Objective 2.1 Test current (Afghanistan) and commercially available (international) forage and shrub species and identify key selection traits to inform 2.2. (Yr 1-2).				
2.1a	Assemble germplasm and initial screening of potential legume species at mirror trial sites (Perth and Turkey). Mirror sites selected to match climatic, edaphic, and systems constraints in-country (aridity, frost, and opportunistic cropping in summer).	• New forage/range species, technologies, and systems established • Native forage/range species collected and/or purchased	Completed: Konya, Turkey: A total of five experiments conducted in the mirror trial site in Konya, testing selected forage species suitable for Afghanistan as well as dual-purpose use of cereals and feeding systems incorporating these fodder sources: - Effect of planting sainfoin either with forage legumes or cereals at different seeding rates on establishment and subsequent production of sainfoin. Completed June 2016. - DM production and feeding value of cereal crops under dual-purpose management. Completed March 2016. - Determination of dual-purpose potentials of cereal crop varieties for integrated crop–livestock farming in irrigated and rainfed conditions. Completed June 2016. - Determination of fattening performance and meat quality of the weaned Anatolian merino and Akkaraman lambs under different feeding systems. Completed August 2017.	The mirror trials sites in both countries were very important in providing a good research environment for training of national Afghan research staff. They received technical training on alternative forage production systems and are applying lessons learned in the field as best as possible (given resource constraints). A series of papers resulted from testing new technologies and feeding systems in the mirror trials in Turkey: - One peer reviewed paper published: Biomass yield and feeding value of rye, triticale, and wheat straw produced under a dual-purpose management system. Journal of Animal Science, 95(11), 4893-4903. http://dx.doi.org/10.2527/jas2017.1888 http://hdl.handle.net/20.500.11766/8317

			- Dual-purpose grazing of triticale–legume mixtures. Second year data being collected in 2017/18.	- One peer reviewed paper is in press: Bio-economic analysis of dual-purpose management of winter cereals in high and low input production systems. Field Crops Research http://onlinelibrary.wiley.com/doi/10.1111/gfs.12291/full http://dx.doi.org/10.1111/gfs.12291 - One abstract titled "The effects of forage-based and a concentrate feeding system on lamb production" was submitted to 2018 ASAS-CSAS Annual Meeting & Trade Show in Vancouver, Canada (an oral presentation). - First draft of the sainfoin paper is ready.
			Perth, Australia: - Yield and forage quality of mixtures of vetch and cereal mixtures.	Three species of vetch, common (*Vicia sativa*), purple (*V. bengalensis*), and woolly pod (*V. villosa*) were sown alone or in 1:1 mixture with forage oats or barley.

2.1b	**On-station screening** of the most promising forage legumes, shrubs, and dual-purpose crops in Afghanistan. Test simple fodder conservation techniques.	• Native and exotic forage/range species and food–feed crops tested • Appropriate agronomic practices to increase forage production from cropping systems developed	Completed. Forage trials in two provinces were completed in June 2017: Improved genotypes (68 legumes, 11 cereals, and 18 shrubs) obtained from ICARDA, Australia, USA, Canada, and Turkey were evaluated at ARIA research stations in both target provinces. Three winter cereal–forage legume mixtures and sowing rate experiments were established in research stations of Mazari-i Sharif, Sheshambagh (Nangarhar), and Poza-i-Eshan (Baghlan). A database from all forage trials was created and shared with concerned partners; the data were cleaned and analyzed.	The trials led to recommendations to introduce eight cultivars proven to give the highest yield. 1. Oat Yeniceri 2. Triticale Tatlicak 3. *Vicia sativa* Rasina 4. *Vicia sativa* Baraka 5. Narbon vetch cv Velox 6. Forage pea cv #40-10 7. Sainfoin cv Ozerbey 8. Alfalfa cv Sequel ARIA and AKF have endorsed these varieties through putting them into the varietal introduction/release process or further testing in their own research stations. This database will help guide future research. At least one ISI paper is planned to be published together with Afghan colleagues.
Objective 2.2 Undertake adaptive research on station and participatory research with farmers to test candidate forages and associated conservation options (Yr 1-4).				
2.2a	Test promising forage options in on-farm trials to test commercial potential and to aid adoption. Data supports case for	• Ten promising forage species and forage crops tested on-farm	Completed: Nine promising forage species/varieties were identified through the on-station trials. A total of eight forage trials for the nine promising cultivars were established in	While testing the most promising species also in combinations on-farm, the on-farm trials demonstrated effective (contemporary) practices in forage and forage seed production.

	national variety release.		collaboration with 16 farmers in each of the two target provinces (Baghlan and Nangarhar) – 32 farmers in total. Farmers have shown a keen interest in producing these varieties once officially introduced/released.	
2.2b	Establish seedlings of perennials for demonstration of shrubs and trees with the utilization of technologies for water harvesting (in collaboration with other projects in Afghanistan).	• Appropriate agronomic practices to increase forage production from cropping systems developed	Partly completed: Three different techniques for establishing shrubs in Mazar-i Sharif are being evaluated under semi-circular water harvesting as a joint activity with the ACIAR watershed project. Out of the three techniques, two have responded positively.	Trial is ongoing due to having to deal with perennial species. Shrubs need at least 2 years to fully establish; preliminary data are already available; expected to lead to best practices for shrub establishment under Afghan conditions. At the same time an effective source of seed multiplication for future rehabilitation efforts was established at the research station.

Objective 3: Expand the scope of existing community-based seed enterprises to include feed and forage seeds, vegetative propagation of shrubs and planting materials

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
Objective 3.1 Understanding of VBSE and PSE forage seed/planting materials system and markets for the products in target districts of the two provinces (yr 1)				
3.1a	Forage seed system analysis	• Quantitative and qualitative data on forage seed system collected, analyzed, and synthesized • Local knowledge of forage seed production system documented • Papers, flyers, and leaflets on forage seed system published	Partly completed: Opportunities and constraints in Afghan forage innovation systems including local knowledge were identified and accessed; regulations on varietal introduction and release were documented; key value chains were recorded; the roles of different stakeholders (public/civil society/private organization) within current forage production systems were recognized; and gender roles were analyzed and documented http://repo.mel.cgiar.org/20.500.11766/8242 A baseline survey was conducted at the beginning of the project implementation covered all aspects related to forage seed systems in Afghanistan. Main findings were summarized and submitted for publication in a peer reviewed journal. Findings from analysis of secondary data and the survey were verified in a multi-stakeholder workshop held in Dubai.	The take home message is that developing standalone VBSEs for only forages is not a viable option. As an alternative, the solution would be to help the existing VBSEs to diversify by adding forages to the field crops such as wheat, barley and rice. A workshop was conducted in Dubai on 3 July 2017 facilitated by

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
			Information was also disseminated via three blogs: "Improving forage value chains in Afghanistan" published: http://ttps://www.icarda.org/update/improving-forage-value-chains-afghanistan http://hdl.handle.net/20.500.11766/8303 Ulufa* – "From Seed to Feed" published https://www.kit.nl/sed/news/ulufa-seed-feed/ http://hdl.handle.net/20.500.11766/8312 "Fodder seeds: empowering women and closing gaps in Afghanistan" published https://www.kit.nl/sed/project/fodder-seeds-empowering-women-and-closing-gaps-in-afghanistan/ https://www.icarda.org/update/fodder-seeds-empowering-women-and-closing-gaps-afghanistan http://hdl.handle.net/20.500.11766/8316	Dr Remco Mur and Dr Yngve Braaten from KIT in collaboration with Dr Shinan Kassam from ICARDA. Participants in the workshop included farmers, seed enterprises, government representatives (research and extension), and development practitioners. (PDF copy of the factsheets)

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
Objective 3.2 Develop sustainable seed and planting material (nurseries) production and marketing by VBSEs and PSEs (years 2-4).				
3.2a	Establish mother shrub/tree species in research station for seed or vegetative multiplication	• Five most promising shrub/tree species collected, established, and disseminated	Completed: Seedlings were transplanted in 2015 at Sheshambagh (Nangarhar). Planting was delayed until April 2016 at Poza-i-Eshan (Baghlan) Research Station due to security concerns. Of the 18-shrub species sent to Afghanistan, five have survived: four *Atriplex* spp. (*A. nummularia*, *A. canescens*, *A. halimus*, and *A. lentiformis*) and *Brassica prostrata*; the last showing significant potential. In Baghlan, two Australian species (*A. nummularia* #48 and #13) recorded the highest survival rate of 42 and 38%, respectively (see final report). In addition, a total of 140 cactus cladodes of various accessions were dispatched to Afghanistan (seven cladodes each from 20 accessions) in late April 2017 and planted first on Hadda farm at Nangarhar. This activity has two purposes: evaluate adaptation of the 20 accessions and multiplying cactus cladodes for later transplanting to farmers' fields.	Performance of the introduced shrub options was documented. Resources of seeds or plant material of the introduced options for further dissemination were ensured. Forage cactus accessions were evaluated under Nangarhar conditions. The imported cactus cladodes were planted on Hadda farm in Nangarhar. Unfortunately, after successful transplantation and establishment, 40% were damaged by grazing animals and environment effects. Therefore, the remaining live cladodes were moved to Nangarhar Research Station. This trial is ongoing, and the remaining accessions are being monitored and evaluated. Preliminary results show that two accessions are performing well.
3.2b	Assemble and multiply seed and planting materials of	• Limited seed of adapted promising forage/range seeds identified in previous and new projects multiplied and supplied	Completed: Seeds of promising annual and perennial forage crops were multiplied at Baghlan and Nangarhar Research Stations:	Two pathways were pursued for seed multiplication:

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
	adapted forage varieties		1151 kg of foundation seeds were produced in 2016 at Dare-e-Noor and Farm-e-Jadeed Districts of Nangarhar for further multiplication (see internal report on seed production). Based on an agreement between ICARDA, ARIA, and AKF to support the demonstration of forage seeds, eight varieties were cultivated in Baghlan, Bamyan, Takhar, and Badashan Provinces.	- Controlled environment at the Nangarhar Research Station - Propagation through NGO partner (AKF).
Objective 3.3 Assess profitability of VBSEs in forage seed and planting materials production and marketing (year 2-4).				
3.3a	Establish a breeder seed multiplication system in Baghlan and Nangarhar agricultural research centers	• Sustainable source of forage seed supply to VBSEs, PSEs, and other suppliers attained	Data on multi-location adaptation trials consisting of two sites in Afghanistan (Nangarhar and Baghlan) are available for use in future breeding programs.	Adaptation trials identified nine genotypes of common vetch, triticale, oats, and sainfoin with high potential for forage and pasture production. Source seed of these varieties have been produced and used for demonstrations and large-scale verification jointly carried out by ARIA and AKF. Further multiplication and out-scaling is pending formal variety release and registration which is a prerequisite for any variety to enter the formal seed production, certification, and commercialization chain.

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
3.3b	Initiate forage seed and planting material production and distribution with existing VBSEs, PSEs, and other suppliers in target sites	• Sustainable supply of quality forage seed to farmers through VBSEs, PSEs, and other suppliers attained	Partly completed: VBSE and PSE forage seed/planting materials system and markets for the forage products were studied and identified. Source seed production of the nine genotypes with high potential for forage and pasture production identified through crop adaptation trials was established in Dare-e-Noor and Farm-e-Jadeed Districts of Nangarhar as well as in Baghlan. In addition to this, small-scale seed processing facilities were purchased from Kimseed. The equipment was handed over to ARIA though a deed donation. (PDF copy)	The process of distributing seed to VBSEs has to be delayed until formal release of some or all of the promising genotypes. Due to compliance requirements of Afghan policies, all new varieties must undergo a formal introduction procedure, which is being undertaken at ARIA research stations. This activity will secure foundation seed for further multiplication by VBSEs and PSEs once varieties have been released. Some seed was used for large-scale demonstrations to create public awareness and effective demand for forage seed to speed up technology dissemination when the varieties are formally released. Capacity of ARIA staff was enhanced see Objective 4). A training course “Data Collection, Experimental Design and Data Analysis in Forage Trials” was conducted for 15 ARIA

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
				participants during 16–18 April 2018 in Kabul.

Objective 4: Develop capacity of Afghan researchers in forage and livestock systems research

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
Objective 4.1. Short term capacity building in measurement and assessment of forage production, seed production, rhizobiology and socioeconomic survey techniques (years 1 & 2).				
4.1a	Capacity building in measurement, monitoring, and assessment of forage production and nodulation surveys	• Afghan scientist are trained on experimental design, methodology, and sampling techniques in forage trials	Capacity of 20 staff (16 males and four females) from the animal health program of MADERA (NGO based in Afghanistan) and MAIL on forage production and forage experiments strengthened. Capacity of 10 Afghan scientists from ARIA (nine males and one female) was enhanced on forage production and forage experiments (course agenda, list of participants, and images taken during the course). Practical knowledge of *Atriplex* plantation and effective seed production practices of Action Aid in Mazar and Bamyan Staff (NGO) enriched for 28 (four males and 24 females) in Kabul.	Course on forage production and forage experiments was given to the animal health program team of MADERA and MAIL on 13–15 January 2015 in Kabul. A one-week theoretical and practical training course on forage production and forage experiments was undertaken on 18–22 May 2015 at the mirror trial site in Konya, Turkey. *Atriplex* plantations and effective seed production practices training course conducted in 2016 at ICARDA offices in Mazar conducted by ICARDA project coordinator.

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
			The capacity of 13 professionals from MAIL on forage production and forage experiments was strengthened (Turkey).	A 5-day theoretical and practical training course on forage production and forage experiments was delivered on 30 May to 3 June 2016 at the mirror trial site in Konya, Turkey.
			Capacity of 22 ARIA staff (16 males and six females), farmers, stakeholders, and NGO staff were enhanced on themes related to measurement, monitoring, and assessment of forage production and nodulation surveys – a testimonial provided by Munir Seddiqi, a member of the forage working committee, was published as a blog. https://www.icarda.org/update/reflections-afghanistan-forage-initiative-event http://hdl.handle.net/20.500.11766/8313	A 6-day practical and theoretical training course on forage biomass and seed production, alley cropping and water harvesting techniques, and the design and management of basic forage experiments was undertaken for NARS staff on 28 April to 3 May 2017 in Amman, Jordan, and Cairo, Egypt.
			Capacity of 16 ARIA staff (15 males and one female) was increased on data collection, experimental design & data analysis in forage trials (Kabul, Afghanistan) http://repo.mel.cgiar.org/20.500.11766/8302)	A group training course on “Data Collection, Experimental Design & Data Analysis in Forage Trials” conducted during 16–18 April 2018 (http://repo.mel.cgiar.org/20.500.11766/8302).
			The capacity of four ARIA staff was enhanced through a review of the forage project experiments, their design, statistical analyses, and interpretation. The	Recently added activity upon request of ARIA.

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
			workshop took place in New Delhi on 24–26 September 2018.	
4.1b	Capacity building in seed production and seed business management	• Capacity of the seed enterprises and stakeholders involved in seed business strengthened	Partly completed: Capacity of one male NARS staff member on seed production and seed business management strengthened through training provided by ICARDA's seed system specialist Aziz Niane.	
			A workshop on seed processing focused on assembling, testing, and use of the Kimseed machines was conducted in Nangarhar.	A mechanic, Mr. Ibrahim, demonstrated assembling, testing, and use of the Kimseed machines which were purchased through project funds and donated to ARIA.
			Capacity of ARIA staff (13 male) on seed processing strengthened with the new seed processing equipment (Kabul, Afghanistan).	A specialized group training course on seed processing (use of new equipment) was conducted for ARIA staff on 13 March 2018 in Kabul (see PDF report).
4.1c	Capacity building in socioeconomic survey techniques and survey data analysis	• Afghan scientists trained on socioeconomic survey techniques and survey data analysis	Capability of 10 NARS staff (males) was enhanced concerning how to conduct baseline surveys and data analysis.	A 2-day training course on baseline survey and survey data analysis was conducted by Dr Roberto Telleria and Dr Serkan Ates during 20–21 October 2014 in Kabul, Afghanistan.
			Through the collaborative engagement with KIT, national researchers and ICARDA staff were trained on concepts related to	A workshop on assessing the systemic and gendered opportunities and constraints for

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
		• Specific training on monitoring and evaluation, with specific attention to ACIAR-defined indicators was provided in Dubai to project partners in Afghanistan	gender as well as intra-household survey design and implementation. This training was an integral part of a multi-stakeholder workshop in Dubai.	innovation in forage value chains in Afghanistan, with a focus on Baghlan Province was held in Dubai on 3 July 2017. The workshop was facilitated by Drs Remco Mur and Yngve Braaten from KIT in collaboration with Dr Shinan Kassam from ICARDA. The workshop brought together 20 stakeholders, including Afghan government officials, researchers, development practitioners, cooperative members, private seed and input suppliers, as well as farmers. It outlined the different functions within the forage value chain, with a focus on innovation, and roles of stakeholders, with a focus on gender, and more specifically on the role of women given prevailing social and custom norms related to female engagement. It also identified the main drivers affecting the development and adoption of new knowledge, technologies, and seed varieties within forage value chains, as well as how these drivers affect women and men differently.

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
Objective 4.2. Medium term capacity building in scientific methodology, legume and shrub research and basic assessment of nutritive value (year 1-2).				
4.2a	Capacity building for two national researchers on scientific methodology, seed production, rhizobiology, plant evaluation, and basic nutritive assessment	• Two trainees trained on experimental design, biological nitrogen fixation, seed increase, rhizobiology, and basic NV analyses	Two Afghan citizens (Abdul Haq Farhang and Himat Sahil) were trained on forage agronomy, animal nutrition, and nodulation surveys for one month in October 2016 in Perth, Australia.	This training was aimed toward better project implementation through enhancing the professional capacity of partners.
Objective 4.3 Capacity building for next users (development partners and farmers) in new forage options (years 3-4).				
4.3a	Capacity enhancement for next users (development partners and farmers)	• Field days organized • Communications established and results disseminated	One field day was organized with the participation of 80 farmers, extension officers, agriculture students, and ICARDA staff at ongoing trial sites in Baghlan on 3 May 2015. One field day was organized with the participation of 65 farmers, extension officers, agriculture students, and ICARDA staff at ongoing trial sites in Nangarhar on 5 May 2015. One field day was organized for 79 farmers, extension officers, agriculture students, and ICARDA staff at ongoing trial sites in Nangarhar on 27 March 2016.	The three field days organized for demonstrating forage trials reached 224 farmers, extension officers, agriculture students, and ICARDA staff. They increased awareness of different stakeholders concerning new forage technologies.

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
			Information about the project and gender roles was published. Information and key findings of the forage project were broadcasted on the national radio in Kabul (local language).	Blog on forage options for smallholder livestock in water-scarce environments of Afghanistan was published https://livestock.cgiar.org/2017/07/05/forage-options-afghanistan/
		• Training of women farmers/ agricultural laborers on effective propagation techniques for forage shrubs was undertaken in Jordan	The capacity of six Afghan women was enhanced to a level to train other people (Training of Trainers) through a training workshop held in Jordan during 7–12 April 2018 on “Plant propagation, nursery management, pasture production and enterprise development training” with a strong component of gender – “Gender initiative and systemic constraints and opportunities to forage systems in Afghanistan and specifically in Baghlan and Nangarhar Provinces through an agricultural innovation system analysis”.	http://hdl.handle.net/20.500.11766/8297) Radio broadcasting was posted on YouTube. https://www.youtube.com/watch?v=kDlD9t3soKc&feature=youtu.be Six Afghan female farmers/extension workers attended a course on seed propagation, nursery management, and enterprise development during 7–12 April in Amman. Upon their return to Afghanistan, one of the women conducted training for Afghan farmers using

No.	Activity	Outputs/ milestones	What has been achieved?	Comments
				the tools and skills she acquired during training in Jordan. The list of participants, training agenda, and blog from the 2018 training event are still to be prepared. http://repo.mel.cgiar.org/20.500.11766/8280 https://www.kit.nl/sed/project/fodder-seeds-empowering-women-and-closing-gaps-in-afghanistan/ https://www.icarda.org/update/fodder-seeds-empowering-women-and-closing-gaps-afghanistan http://hdl.handle.net/20.500.11766/8316

7 Key results and discussion

A number of on-station and on-farm experiments were carried out in rainfed and irrigated conditions in Baghlan, Nangarhar, and Mazar-i Sharif Provinces. In these experiments, biomass and seed production of local and imported varieties were compared to determine any yield advantage of imported varieties. Agronomic trials were conducted to determine optimum seeding rate, intercropping, fertility, and irrigation management of annual and perennial forages. On-station experiments in Afghanistan consisted of variety comparison trials (Section 7.2.1) and agronomic management of introduced forage crops (Section 7.2.2). In addition to the variety comparison trials, underutilized and self-regenerating annual legumes originating from Australia were tested for vigor and adaptation as potential forages in rainfed cropping systems. The baseline survey and the results of these experiments and demonstration activities indicated that the availability of wider selection of forage varieties and overall forage production could be increased a great deal in Afghanistan. Four on-farm trials (Section 7.3) in each of the two target provinces (a total of eight trials) were conducted in collaboration with 16 farmers in each province (32 farmers in total) to introduce the promising forage crops to the farmers and demonstrate basic agronomic packages. Mirror trials (Section 7.4) further evaluated these forages in several agronomic management and animal feeding trials. These provided more in-depth results on their feeding values and potential for crop–livestock farming systems. The findings of the mirror trials were published in ISI journals and conference proceedings.

The baseline survey and on-station activities achieved the following specific outcomes:

Key findings of the baseline survey:

- In Baghlan, the main crops grown are wheat, rice, alfalfa, mungbean, chickpea, and sorghum using local and improved varieties. Alfalfa was the only reported forage crop grown in irrigated farming and most farmers used local cv Rishika or an unnamed local variety. Among different cropping systems practiced by households in Nangarhar, wheat–maize cropping (40%), followed by wheat–maize–clover (15%) and wheat–mungbean systems (10%), were important. Except for wheat and maize, most other crops are irrigated. Forage cultivation was not observed in rainfed areas of Nangarhar due to shortage of cultivated rainfed area. The reported forage yields were extremely low – for example, fodder yield for alfalfa of 3 t ha^{-1} was much below the potential of high-yielding varieties. This indicated a large scope for increasing alfalfa yield in Nangarhar through project interventions such as introducing lines with high biomass potential.
- Composition of livestock holdings at the household level differed significantly between provinces in terms of both species and factors affecting species choice. In Nangarhar households, cattle (71%) formed the majority of livestock holdings, with goats (23%) and sheep (6%) comprising the remainder. In contrast, surveyed households in Baghlan, on average, owned a mix of livestock: sheep (49%), goats (32%), and cattle (19%). For both provinces, production of milk for both home consumption and surplus marketability were mentioned as key incentives for keeping cattle, while asset wealth and marketability of meat were important reasons for keeping sheep and goat herds (and more specifically local breeds).
- Average daily production of cow milk varied significantly between Baghlan and Nangarhar, with 7.2 liters (local breed) and 15.7 liters (cross-breed) per day in Baghlan, and 4.7 liters per day in Nangarhar. One explanation for this variance in productivity, to be confirmed through field investigation, is that most of the irrigated area in Nangarhar is planted with wheat and rice, with little allocation for forage crops, resulting in a feed and nutritional gap for livestock.
- Access to seed from VBSEs was reported to be negligible by respondents in Nangarhar. This is not unexpected, given that there are no functioning VBSEs within the districts sampled for this survey; however, it raises the question of why VBSEs in

relatively close proximity have not been accessed. In Nangarhar, nine VBSEs operationalized through ICARDA initiatives are within close proximity to the provincial capital of Jalalabad and should not pose a significant challenge to access. In contrast, 34% of respondents in Baghlan indicated involvement with a VBSE. This was identified as an area of immediate concern, in terms of a better understanding of access, given that one project output was to make forage seeds and planting material available through two VBSEs and four community-based plantations.

- Farmer-to-farmer knowledge exchange was relatively high in Baghlan and related to improved forage and cereal seeds as well as crop management. This knowledge channel was only used marginally more frequently than public extension, with VBSEs playing a relatively minor role in information exchange. In contrast, radio was a prominent source of information for Nangarhar respondents. Taken together, these results provide some indication on effective channels through which to disseminate information and knowledge, and which are contextually different.

Variety comparison trials:

- Five variety comparison experiments were established under irrigated conditions at Shesham Bagh Research Station, Nangarhar. Imported varieties of alfalfa, common vetch, grasspea, triticale, and oat were compared with the locally available varieties for seed and DM yields in 2014–2016. Introduced alfalfa cvs Aleppo and Sequel provided substantially greater forage DM yield (over 5 t ha^{-1}) than local cv Ghazni. This indicates that forage production from irrigated alfalfa can be substantially increased by replacing cv Ghazni with the improved varieties. Similarly, common vetch cvs Morawa, Rasina, and Vs 2606 were superior to the local variety mainly from the seed production standpoint. Compared to local varieties, oat cv Yeniceri had greater seed yields, and DM yield was 1.3–3.5 t ha^{-1} greater. However, introduced grasspea and triticale varieties did not offer any yield advantage over local varieties. These results indicated a huge need for improved forage varieties in Afghanistan to increase yield. Increasing productivity by using improved varieties can help provide a solution to the winter feed gap.

Agronomic management trials:

- ***Forage legume–cereal bi-crops under irrigated and rainfed conditions:*** The objectives of these studies were to identify the highest yielding forage legume and cereal combinations and optimum seeding rates. Monocultures and binary mixtures of triticale, oat, barley, forage pea, grasspea, narbon vetch, common vetch, and Hungarian vetch were planted at 100, 200, or 300 plants m^{-2} and tested under rainfed (Mazar) and irrigated conditions (Baghan and Nangarhar). The results revealed that sowing small-grain winter annual cereal and legume mixtures at 200 or 300 plants m^{-2} provided similar DM yields in both irrigated and rainfed systems. Reducing plant density to 100 plants m^{-2} caused significant yield penalties. Sowing at high seeding rates is a common practice in most developing countries but this unnecessarily increases seed costs. Moreover, nutritive value analyses indicated that the quality of forages might decrease at higher seeding rates, possibly due to decreased leaf/stem ratios or lower legume contents. Therefore, a strong message to deliver to farmers on seeding rates it to aim for approximately 200 plants m^{-2}.

  The results from cereal–legume mixtures indicated that barley monoculture and barley–grasspea mixtures provided greater yield than the other combinations in the rainfed production system. Hungarian vetch was specifically included in this trial because it has excellent cold tolerance and has an advantage over common vetch in cold areas; however, no such yield advantage was observed in this study. Therefore, further testing in higher altitude or colder regions may be useful. Under irrigated conditions, the forage pea–oat mixture was superior to other tested mixtures and monocultures in both Nangarhar and Baghlan. This is not surprising as the yield advantage of oats and forage pea over common vetch and triticale has been commonly reported. Overall, these experiments provided valuable information on optimum seeding rates and high-yielding mixtures and indicated that they have high potential to decrease the forage gap specifically in the dominant cereal-cropping systems of Afghanistan. Overall, the nutritive value of the forages presents moderate quality winter-feed for livestock. Although the DM yield of cereal–forage pea was superior to other cereal–legume mixtures, the cereal–grasspea or narbon vetch mixtures provided forages with greater CP contents.

A further forage mixture trial involving berseem clover and small-grain winter annual cereals was conducted. Sowing berseem clover with oat or triticale resulted in greater DM production compared to berseem clover alone. The highest yield increase occurred in the first harvest, mainly due to lower temperature requirements of annual cereals compared to berseem clover. This result is specifically important because the most farmers in Afghanistan grow berseem clover as a monoculture. The benefit of mixing this with cereals was also highlighted in on-farm demonstrations where farmers expressed their satisfaction with berseem clover–cereal mixtures. Further studies (e.g. mixture ratios and sowing rates) can be conducted to fine-tune and optimize the agronomic management of berseem clover–cereal mixtures.

- ***Fertility management studies:*** For security reasons, the most accessible fertilizer in the market in Afghanistan is DAP (diammonium phosphate). Therefore, most fertilizer application studies in this project used DAP in both on-station and on-farm studies. These studies indicated that application of DAP at 200 kg ha^{-1} provided greater yield than at 100 kg ha^{-1}. The results were consistent in the berseem clover–cereal mixture study and sainfoin–alfalfa comparison study, where various DAP and irrigation application regimes were tested. In these studies, 200 kg ha^{-1} DAP provided the greatest yield. Furthermore, the extra fertilizer may lead to less efficient nitrogen (N)-fixation by symbiotic bacteria.

- ***Perennial legumes and irrigation management studies:*** Sainfoin is a forage crop thought to have considerable potential in Afghanistan, given that it is successfully grown in similar agro-ecologies in the Central, West Asia, and North Africa region. Sainfoin is one of the most drought-tolerant perennial legumes that can thrive in drought prone, alkaline soils. It is extensively grown in highlands of West and Central Asia due to its tolerance to seasonally cold and hot climatic conditions. Its resistance to alfalfa weevil, combined with its bloat-free characteristics and secondary metabolite compounds that improve protein metabolism make it an extremely attractive forage crop particularly in low input or organic livestock production systems. However, the baseline survey indicated that sainfoin was unknown to farmers and the seeds were not available in the market. Therefore, we attempted to introduce sainfoin and demonstrate it as an excellent alternative to alfalfa in low-input production systems. We compared alfalfa and sainfoin with different levels of irrigation and fertilizer applications, and it provided excellent amounts of forage and appeared suitable to the agroecological conditions of Afghanistan. Sainfoin can be highly productive in areas where it is difficult to grow alfalfa due to extremely arid conditions. Therefore, further testing of sainfoin in different regions of Afghanistan is recommended.

  The effect of seeding rate on yield was also further tested in one of the mirror trials where we attempted to evaluate the effect of plant numbers on productivity of sainfoin in a rainfed system. In this trial, the effect of a nurse crop (Hungarian vetch and triticale) and seeding rate on the persistence and productivity of sainfoin was investigated. The common sainfoin seeding rate of 100 kg ha^{-1} provided over 250 established seedlings m^{-2} in monocultures. However, sainfoin yield was decreased only when numbers were reduced to less than 50 seedlings m^{-2}. Due to the paucity of information on the relationship between plant density and yield for sainfoin, this experiment provided some novel research results.

- ***Evaluation of shrub species for rehabilitation of degraded rangelands study:*** Based on the ACIAR recommendation made in Year 3 of the project to strengthen integration between ACIAR-funded projects in Afghanistan, joint research was initiated between the ACIAR-funded forage and watershed projects. The objective of the study was to evaluate different rehabilitation techniques (direct seeding and shrub seedling transplantation). Four promising species obtained from the established mother plants at ARIA research stations were evaluated. The trial was initiated in February 2017 at the watershed site in Mazar-i Sharif using semi-circular bunds. Given that this trial is still in the establishment phase (Year 2) we opted for non-destructive methods to assess the response of each species. Preliminary results indicate a significant effect of species. Among the four species the greatest height was for *A. halimus* followed by *A. nummularia*. Furthermore, findings showed that direct seeding is effective for revegetating rangelands.

- ***Evaluation of spineless cactus accessions as alternative feed sources in Nangarhar:*** Following the training course in Jordan, ARIA participants showed an interest in evaluating cactus as an alternative feed source to reduce the feed gap and enhance livelihoods of poor livestock holders in Afghanistan. Therefore, 20 promising spineless cactus accessions (*Opuntia ficus-indica*) were introduced to Afghanistan. The cactus cladodes were originally planted at the e-Hada farm in Nangarhar but then transferred to Nangarhar Research Station due to lack of protection at e-Hada. Preliminary findings indicate significant differences in the number of new cladodes produced among the different cactus accessions. More time is needed to continue monitoring and evaluation of these accessions in the field and at a later stage when feeding animals.

7.1 Introduced forage germplasm

A total of 97 genotypes (68 legume, 11 cereal, and 18 shrubs) were evaluated for adaptation and productivity and were compared to locally available cultivars (Table 1). From these germplasm, nine promising (based on preliminary data) genotypes were tested on-station and on-farm in order to generate data to support varietal registration/introduction. Forage shrubs are currently exempt from formal release and introduction protocols. Consequently, 18 forage shrub accessions/ecotypes (13 from ICARDA and five from Australia) were multiplied on-station for distribution to public agencies, international and national developmental agencies, as well as private farmers. Based on the interest from national research system counterparts, 20 spineless cactus accessions were planted on-station in Nangarhar for evaluation of adaptability and farmer interest (Table 2).

Table 1. List and origin of germplasm tested in Afghanistan

Forage legumes			
Common names	**Scientific names**	**Varieties**	**Origin**
Narbon vetch	*Vicia narbonensis*	Cyprus, #2606, and Velox	ICARDA
Grasspea	*Lathyrus sativus*	Alibar, #334, and #885	ICARDA
Common vetch	*Vicia sativa*	#2604, Baraka, and Rasina	ICARDA, Australia
Hungarian vetch	*Vicia pannonica*	Tarm beyazi	Turkey
Alfalfa	*Medicago sativa*	Aleppo, #597, #1981, Vendor, Sequel, and Legenel	ICARDA, Holland, Australia, USA

Sainfoin	*Onobrychis sativa*	Ozerbey and unknown	Turkey, Canada
Forage pea	*Pisum sativum*	#40-10	Canada
Shore medic	*Medicago littoralis*	Angil	Australia
Spiny medic	*M. sphaerocarpos*	Orion	Australia
Snail medic	*M. scutelata*	Silver	Australia
Sand medic	*M. tornata*	Tornafiled	Australia
Burr medic	*M. polymorpha*	Cavalier	Australia
Barrel medic	*M. truncatula*	Cyprus	Australia
Cut-leaved medic	*M. laciniata*	Lib 955.3	Australia
Crimson clover	*Trifolium incarnatum*	Caprera	Australia
Balansa clover	*T. michelianum*	Frontier	Australia
Mediterranean clover	*T. spumosum*	Bartolo	Australia
Gland clover	*T. glanduliferum*	Prima	Australia
Reversed clover	*T. resupinatum*	Prolific	Australia
Shield clover	*T. clypeatum*	Early sel	Australia
Arrowleaf clover	*T. vesiculosum*	Cefala	Australia
Purple clover	*T. purpureum*	#14953	Australia
Fenugreek	*Trigonella foenum graecum*	SA 5045	Australia
Serradella	*Ornithopus sativus*	Cadiz	Australia
Cicer milkvetch	*Astragalus cicer*	Ham 1.1	Australia
Caterpillar plant	*Scorpiurus muricatus*	GCN 119	Australia
Biserrula	*Biserrula pelecinus*	Casbah	Australia
Disk trefoil	*Hymenocarpos circinatus*	#13817	Australia
Clustered birdsfoot trefoil	*Lotus ornithopodioides*	Mid	Australia
Sulla	*Hedysarum coronarium*	Aokau	Australia
Winged bean	*Tetragonalobus purpureum*	SA 920	Australia
Small-grain winter annuals			
Triticale	*Triticosecale* wittmack	#7, #37, #5045, Alperbey, Melez, Mikham, and Tatlicak	Turkey
Oats	*Avena sativa*	Seydisehir, Faikbey, and Yeniceri	Turkey
Rye	*Secale cereale*	Aslim	Turkey
Forage shrubs			
Indian ricegrass	*Achnatherum hymenoides*		ICARDA
Astragalus	*Astragalus asterias*		
Forage Kochia	*Kochia prostrata*		
Fourwing saltbush	*Atriplex canescens*		
Shadscale saltbush	*Atriplex confertifolia*		
Valley saltbush	*Atriplex cuneate*		
Waxy saltbush	*Atriplex glauca*		
Big saltbush	*Atriplex lentiformis*		
Old man saltbush	*Atriplex nummularia*		
Cattle saltbush	*Atriplex polycarpa*		
Basin saltbush	*Atriplex tridentate*		
Wavy-leaved saltbush	*Atriplex undulata*		
Mediterranean saltbush	*Atriplex halimus*		
Small-leaf bluebush	*Maireana brevifolia* (R.Br)		Australia
Old man saltbush	*Atriplex nummularia* – #48, #10, #29, and #32		
Dual-purpose legumes (food–feed)			
19 mung bean, four cowpea, and three pigeon pea accessions			World Vegetable Center (AVRDC)

Table 2. List and origin of cactus accessions

Accessions	Utilization	Origin
V1_ Copena V1	Forage	Mexico
2_25_15	Forage	Mexico
2_26_21	Forage	Mexico
2_17_25	Forage	Mexico
N	Forage	Tunisia
31_ Burbank Azrou_69223	Fruit/forage	Algeria
34_ Caref 58_69219	Fruit/forage	Algeria
20_ Sbeitla_74071	Fruit/forage	Tunisia
46_ Mornag B_74076	Fruit/forage	Tunisia
47_ Mornag B_74076	Fruit/forage	Tunisia
6_ Ain Boudriess_96245	Fruit/forage	Tunisia
32_ Matmata_69242	Fruit/forage	Tunisia
Zelfeue	Fruit/forage	Tunisia
26_ Djebel Bargou_68247	Fruit/forage	Tunisia
13_ Bab Toza_74115	Fruit/forage	Morocco
22_ El Borouj_75018	Fruit/forage	Morocco
G	Fruit/forage	Tunisia
8_ Leavis_74010	Fruit/forage	Mexico
2_ Leavis SP5_74112	Fruit/forage	Mexico
10_ Ethiopie_73064	Fruit/forage	Ethiopia

7.2 On-station experiments

7.2.1 Variety comparison and evaluation trials

The variety comparison trials were established in a complete randomized block design with four replicates. Alfalfa plots were flood irrigated during the growing season, and winter annual legume and cereal varieties were managed under rainfed conditions. The soil in Nangarhar is sandy loam with alkaline characteristics (pH 8.4).

Alfalfa (*Medicago sativa****) varieties:*** Varieties were established at 20 ha kg^{-1} seeding rate in December 2014. The plots size was 1.8 m × 5 m. Plots were harvested four times in 2015 and five times in 2016 at a stubble height of 5 cm. The DM production of alfalfa varieties in 2014/15 growing season ranged from 10,000 kg DM ha^{-1} for the local cv Ghazni to 11,900 kg DM ha^{-1} for the introduced cv Sequel, but the difference was not significant (P = 0.56) (Fig. 2). The DM production of alfalfa varieties in 2015/16 ranged between 16,100 kg DM ha^{-1} (cv Ghazni) and 22,850 kg DM ha^{-1} (cv Aleppo). In 2016, cvs Sequel and Aleppo tended to have greater (P = 0.06) DM production than cv Ghazni by up to 6750 kg DM ha^{-1}.

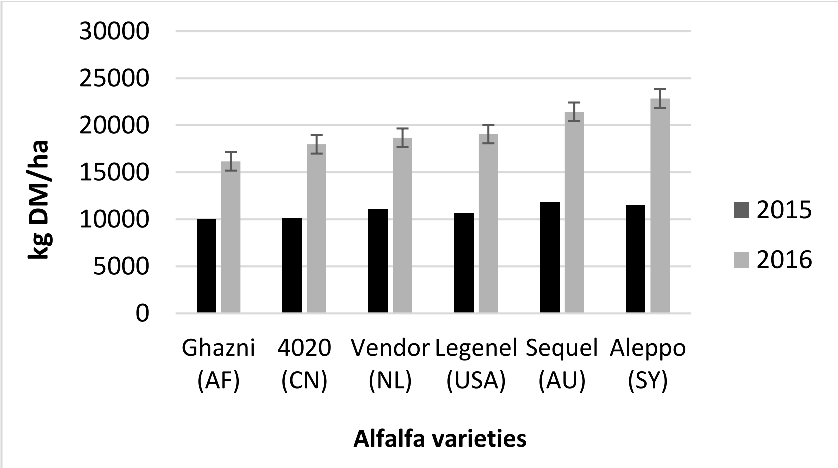

Fig. 2. Dry matter production (kg DM ha^{-1}) of local and imported alfalfa varieties in 2014/15 and 2015/16 growing seasons in Nangarhar. (Afghanistan: (AF), Canada (CA), Netherland (NL), United States of America (USA), Australia (AU), Syria (SY))

Common vetch (*Vicia sativa)* ***varieties***: The cvs Baraka, Capello, Morawa, Rasina, and Vs 2606 were compared to the local variety. In both years, varieties were harvested at pod-forming stage with hand sickles at 5 cm stubble height. Significant differences ($P < 0.01$) were detected for seed and forage yields (Table 3). In 2015, seed yields of cvs Baraka and Rasina exceeded 1500 kg ha^{-1} and were greater than the other cultivars including the local variety with only 542 kg ha^{-1}. In 2016, the DM yields were similar ($P = 0.43$) but there was a significant difference in seed yields of varieties. The results indicated that the local variety and cv Capello had the lowest seed yields, and cv Morawa had the highest. Although not statistically different from each other, cvs Morawa, Rasina, and Vs 2606 had greater DM yields than other cultivars. The results indicate that the local variety could be replaced by any of these three common vetch varieties based on their superior seed yields.

Table 3. Seed and forage production (kg DM ha^{-1}) of local and improved common vetch varieties in 2014/15 and 2015/16 growing seasons in Shesham Bagh, Nangarhar

Variety	Growth habit*	Seed yield (kg ha^{-1})	DM yield (kg ha^{-1})*	Seed yield (kg ha^{-1})	DM yield (kg ha^{-1})
		2014/15		**2015/16**	
Baraka	SE	1791a	–	1004b	2625
Capello	P	527bc	–	283c	1938
Local	P	542bc	–	527c	2521
Morawa	E	851b	–	1415a	3375
Rasina	E	1595a	–	1285ab	3354
Vs 2606	E	1413ab	–	1300ab	3479
SE		225.2		133.4	432.6
P		0.01		0.01	0.12

*P, prostrate; E, erect; SE, semi-erect; –, not measured
Means in the same column followed by same letter do not significantly differ (P=0.05)

Grasspea (*Lathyrus sativus)* ***varieties:*** Two grasspea varieties (cvs Alibar and L 885) originating from ICARDA were tested against three local varieties for seed and forage production. The seed yields of Alibar and L 885 appeared to be greater ($P = 0.06$) than local varieties in 2015 but both seed yield and DM production were similar in 2016 (Table 4). There is still a need for further testing of grasspea germplasm with a larger number of varieties in different agro-ecologies of Afghanistan.

Table 4. Seed and forage production (kg DM ha^{-1}) of local and imported grasspea varieties in 2014/15 and 2015/16 growing seasons in Shesham Bagh, Nangarhar

Variety	Growth habit*	Seed yield (kg ha^{-1})	DM yield (kg ha^{-1})*	Seed yield (kg ha^{-1})	DM yield (kg ha^{-1})
		2014/15		**2015/16**	
Alibar	SE	518	–	608	2854
L 885	SE	626	–	427	2771
Local 1	E	269	–	950	3146
Local 2	SE	222	–	935	3313
Local 3	E	–	–	496	2813
SE		159.9		152.3	365.8
P-value		0.06		0.09	0.79

*E, erect; SE, semi-erect; –, not measured
Means in the same column followed by same letter do not significantly differ (P=0.05)

Triticale (*Triticosecale wittmack*) ***varieties:*** Seed yield of the local and imported varieties ranged within 1604–2960 kg ha^{-1} (Table 5). Seed yields of cvs Alperbey, T 7, and Local 1 were greater than the others in both years. The DM yield of cv Alperbey and local cv T 7 were the highest. There were significant differences among cultivars for plant height. The plant heights of local cultivars were similar or greater than the imported ones, and cv Mikham was the shortest. The date of heading and maturity dates of cultivars also varied. It is noteworthy that the later maturing cultivars (23–26 May) had the highest seed yields under irrigated conditions in Nangarhar. The results indicate that currently available cvs Alperbey and T 7 have potential to increase seed and forage yield of triticale stands.

Table 5. Seed yield and forage production (kg DM ha^{-1}) of local and improved triticale varieties in 2014/15 and 2015/16 growing seasons in Shesham Bagh, Nangarhar

Variety	Maturity date	Seed yield (kg ha^{-1})	DM yield (kg ha^{-1})*	Maturity date	Seed yield (kg ha^{-1})	DM yield (kg ha^{-1})
	2014/15			**2015/16**		
Alperbey	24 May	2960a	–	22 May	2442cd	6556cd
Melez	8 May	1604b	–	15 May	1169a	4778a
Mikham	8 May	2265ab	–	15 May	1561ab	4861ab
Tatlicak	11 May	1924b	–	16 May	1731b	5500abc
T 37	24 May	2374ab	–	22 May	2758d	6611d
T 7	26 May	2840a	–	22 May	2467cd	6556cd
Local 1	23 May	2860a	–	16 May	1931bc	5861bc
Local 2	11 May	1677b	–	19 May	1792b	5944cd
SE		613.9			204.7	371.3
P		0.01			0.01	0.01

* –, not measured
Means in the same column followed by same letter do not significantly differ (P=0.05)

Oat (*Avena sativa)* ***varieties:*** Among tested local and imported oat varieties, cv Yeniceri had the greatest seed yield of more than 1800 kg ha^{-1}, while cv Seydisehir had the lowest with 1083 kg ha^{-1} in 2015 (Table 6). It was of note that the local varieties, except for Local 1 were taller than the imported ones. The cv Yeniceri also provided the greatest forage DM yield in 2016, indicating its potential for increased forage and grain production.

Table 6. Agronomic characteristics and seed yield of local and imported oat varieties in 2014/15 and 2015/16 growing seasons in Shesham Bagh, Nangarhar

Variety	Maturity date	Seed yield (kg ha⁻¹)	DM yield (kg ha⁻¹)*	Maturity date	Seed yield (kg ha⁻¹)	DM yield (kg ha⁻¹)
	2014/15			**2015/16**		
Yeniceri	11 May	1825a	–	10 May	1661d	5694c
Seydisehir	18 May	1083d	–	18 May	492ab	1806a
Faikbey	17 May	1230cd	–	16 May	336a	1444a
Local 1	11 May	1383cd	–	15 May	1222cd	4306bc
Local 2	11 May	1544bc	–	19 May	633ab	2028a
Local 3	12 May	1434bcd	–	15 May	906bc	3250ab
Local 4	12 May	1379cd	–	15 May	731abc	2389a
SE		137.0			177.9	613.9
P		0.05			0.01	0.01

* –, not measured
Means in the same column followed by same letter do not significantly differ (P=0.05)

Self-regenerating annual medics and underutilized forage legumes: Self-regenerating annual medics and underutilized forage legumes originating from Australia were evaluated for their adaptation and vigor in nursery rows (4 × 0.6 m) in both Nangarhar and Baghlan in 2015/16. Most of these legumes were successfully established and produced seed at least in one location. In addition, they formed root nodules with local rhizobia, indicating their potential for N fixation. The only exception was *Medicago tornata* that failed to germinate (Table 7). This provides excellent baseline information for future rangeland and integrated crop–livestock studies in Afghanistan.

Table 7. Annual medics and legumes in nursery rows in Baghlan and Nangarhar in 2017

Forages	Flowering date	Vigor*	Seed yield (g m⁻²)	Root nodules#	Flowering date	Vigor*	Seed yield (g m⁻²)
	Baghlan				**Nangarhar**		
M. Littoralis	2 March	2	274	3	13 April	3	95
M. spherocarpus	13 March	2	339	2	5 April	3	110
M. scutelata	25 March	3	95	2	5 April	3	83
M. tornata	6 April	3	–	3	–	–	–
M. polymorpha	12 March	2	1384	4	8 April	2	33
T. incarnatum	23 March	1	342	3	8 April	3	165
S. muricatum	29 March	2	170	2	14 April	3	113
L ornithopodiodes	16 March	3	355	3	6 April	1	18
M. truncatula	20 April	3	153	3	5 April	3	50
M. laciniata	4 March	2	387	4	8 April	1	16
T. michelianum	18 March	2	131	3	3 April	2	30
T. spumosum	10 April	2	361	4	5 April	2	68
T. glandulferum	8 March	3	325	4	6 April	1	7
T. resupinatum	28 March	3	593	4	4 April	2	43
B. pelecinus	24 March	3	164	3	–	–	–
H. coronarium	18 March	1	–	3	–	–	–
T. clypeatum	–†	–	–	–	8 April	2	26
T. vesiculosum	29 March	1	1242	2	14 April	2	36
T. purpureum	10 April	3	588	2	18 April	1	15
T. balansae	20 March	2	247	4	2 April	3	325
O. sativus	22 March	3	118	4	–	–	–
A. namosa	24 March	3	478	3	7 April	3	287

H. circinatus	–	–	–	–	5 April	2	45
T. purpureum	25 March	3	423	2	7 April	1	0

* Score of vigor 1 (weak), 2 and 3 (strong)
# Score of nodulation 0 (no nodule) to 5 (full of healthy pink nodules)
† –, not measured

7.2.2 Agronomic evaluation of forage legumes and cereals

Agronomic evaluation experiments mainly aimed to investigate high-yielding winter annual legume and cereal combinations and optimum seeding rates for efficient forage production in both irrigated and rainfed conditions. In particular, sowing at high seeding rates or fertilizer application is quite common in the developing world, coupled with inefficient irrigation management, these result in poor resource use efficiency and increased cost for inputs. A forage mixture and seeding rate experiment was performed to test and demonstrate the most appropriate seeding rates and agronomic performance of forage mixtures and monocultures. Seed rates in the legume–cereal bi-crops experiments were calculated based on the 1000-seed weights of the plants to achieve the target populations. The experiments were harvested when the cereals were at the dough stage.

Effect of seeding rate on the yield of legume–cereal bi-crops in Mazar-i Sharif (rainfed): The soil in Mazar-i Sharif is silty loam with alkaline characteristics (pH 8.2). The experiment investigated the DM production of monocultures and binary mixtures of barley, triticale, grasspea, common vetch, and Hungarian vetch established at 100, 200, or 300 plants m^{-2} (Table 8).

Table 8. Dry matter production (kg ha^{-1}) of rainfed forage legume–cereal mixtures under three sowing rates (100, 200, and 300 plants m^{-2}) in 2015/16 and 2016/17 in Mazar-i Sharif. Rainfall during growing seasons was 193.1 and 245.7 mm, respectively.

	2016 Target density (plants m^{-2})			**2017** Target density (plants m^{-2})		
Forages	100	200	300	100	200	300
Hungarian vetch	1799	2352	2662	2330	2777	3296
Common vetch	3074	3283	3701	3201	3279	3924
Grasspea	3253	2973	3520	3904	3568	4224
Barley	3638	4340	4463	4648	5232	4858
Triticale	3027	3480	3747	3027	3480	3747
Common vetch + barley	3681	3482	4048	3733	3347	3747
Common vetch + triticale	3333	3467	3813	3440	3892	4074
Hungarian vetch + barley	3189	3640	3787	3827	4368	4544
Hungarian vetch + triticale	3117	3439	3867	3117	3439	3867
Grasspea + barley	3520	4085	4280	3626	4208	4408
Grasspea + triticale	3200	3840	4443	3200	3840	4443
SE	282.3					
*P** Crop (C)	0.01					
P Density (D)	0.01					
P Year (Y)	0.01					
P C × D	0.44					
P C ×Y	0.05					
P D × Y	0.97					
P C × D × Y	1.00					

* *P*, probability value

Biomass production of forage monocultures and mixtures was 3313, 3628, and 3975 kg DM ha^{-1} for sowing at 100, 200, and 300 plants m^{-2}, respectively. The DM production was comparable for sowing at 100 and 200 plants m^{-2}; and DM yields for 200 and 300 plants

m^{-2} were also not significantly different; however, sowing at 300 plants m^{-2} resulted in greater ($P < 0.01$) DM yield than sowing at 100 plants m^{-2} indicating that there is no need for seed rates to provide more than 200 plants m^{-2}. Averaged across the year and the sowing rates, barley had the highest ($P < 0.05$) DM production (4530 kg DM ha^{-1}). The DM production of its mixtures with grasspea also exceeded 4000 kg DM ha^{-1}. These were greater than yields obtained from triticale (3400 kg DM ha^{-1}) and its combination with the legumes. Grasspea (3574 kg DM ha^{-1}) and common vetch (3410 kg DM ha^{-1}) had greater DM yields than Hungarian vetch (2536 kg DM ha^{-1}). Overall, barley and its mixtures with forage legumes provided satisfactory DM yields but performance of triticale and Hungarian vetch was poorer under rainfed conditions of Mazar-i Sharif. Hungarian vetch has a higher cold tolerance compared to common vetch and so may be better suited to colder regions with higher altitudes.

Effect of seeding rate on yield of legume–cereal bi-crops in Nangarhar and Baghlan (irrigated):

This experiment investigated the DM production of monocultures and binary mixtures of oat, triticale, grasspea, forage pea, and narbon vetch at 100, 200, or 300 plants m^{-2} seeding rates (Table 9) under irrigated conditions in Nangarhar. Forage DM production was comparable for sowing rates at 200 and 300 plants m^{-2} but planting at 100 plants m^{-2} resulted in reduced biomass ($P < 0.05$, Table 9). Averaged across years, the lowest DM production was from narbon vetch + triticale mixture (5776 kg DM ha^{-1}), and forage pea + oats gave the highest of over 7900 kg DM ha^{-1}. Although grasspea had less DM production than forage pea, it produced approximately 2000 kg DM ha^{-1} more than narbon vetch. The results indicated that oats, triticale, forage pea, and to a lesser extent grasspea hold great promise to increase forage production in irrigated conditions in Nangarhar.

The soil in Baghlan is loamy with alkaline characteristics (pH 8.2). Averaged across sowing rates, DM yield of forages ranged from 7505 kg DM ha^{-1} for forage pea to 10,391 kg DM ha^{-1} for oats. In contrast to the results from Nangarhar, both grasspea and narbon vetch had similar yields to forage pea. Averaged across the locations and years, sowing at 200 or 300 plants m^{-2} resulted in similar DM production but 100 plants m^{-2} resulted in lower DM yield ($P < 0.01$). The results indicated that all the winter annual forage legumes and both cereals had high yield potential. A possible reason for a moderate DM production for forage pea in Baghlan compared to Nangarhar may be due to its lack of tolerance to the colder winter in Baghlan. The results also revealed no yield advantage for sowing at 300 compared to 200 plants m^{-2}.

Forage nutritive value:

The nutritive values of forages are presented in Table 10. The estimated metabolizable energy (ME) content of the forages ranged from 7.64 (oat) to 8.74 MJ kg^{-1} DM (forage pea–triticale) with significant differences ($P < 0.01$) among forage crops. The highest ME was obtained with the lowest sowing rate, and the sowing rate of 300 plants m^{-2} resulted in the lowest ME content. Similarly, the lowest seeding rate resulted in greatest CP ($P < 0.005$) and IVOMD ($P < 0.01$) contents of forages. The CP contents of legumes and legume–cereal mixtures were greater ($P < 0.01$) than for oat and triticale, which had similar CP contents. Forage pea–oat mixture had the greatest ($P < 0.001$) IVOMD, but oat alone had the lowest IVOMD content. Although NDF content of forages differed ($P < 0.01$) considerably, the effect of seeding rate was not significant ($P = 0.22$). There were interactions ($P < 0.01$) between crop mixtures and seeding rate for ADF and ADL content of forages. The ADF content of the forages was greater with sowing at 300 plants m^{-2} for legume monocultures except that forage pea had the lowest. Similarly, legume–cereal mixtures had lower ADF contents at the highest sowing rate. Overall, the effects of sowing at 100 and 200 plants m^{-2} were comparable. Overall, the nutritive value of forages were of moderate quality winter-feed for livestock. Although the DM yield of cereal–forage pea was superior to other cereal–legume mixtures, the cereal–grasspea or –narbon vetch mixtures provided forages with greater CP contents. The nutritive value results are consistent with the findings from the mirror trial site in Turkey and other studies reported in the literature.

Table 9. Dry matter production (kg ha^{-1}) of irrigated forage legume–cereal mixtures at three sowing rates (100, 200, and 300 plants m^{-2}) in 2015/16 in Nangarhar and Baghlan. Rainfall was 246 mm in 2015/16 and 106 mm in 2016/17 in Nangarhar.

	Baghlan						**Nangarhar**					
	2016			**2017**			**2016**			**2017**		
	Target density (plants m^{-2})			Target density (plants m^{-2})			Target density (plants m^{-2})			Target density (plants m^{-2})		
Forages	100	200	300	100	200	300	100	200	300	100	200	300
Grasspea	4994	5896	6431	8487	9300	9920	5147	8267	8227	7721	8724	9412
Oat	5200	6450	7743	7173	9200	9920	3400	3387	4027	3874	4792	4939
Triticale	6464	7759	8912	7773	9090	9573	5107	5893	6813	6204	6542	6700
Forage pea + oat	6200	8041	8177	12653	13013	14260	5368	7597	8279	8340	9060	9120
Narbon vetch + oat	6083	7080	8239	10293	11800	13813	5373	6680	7173	7029	8955	9510
Forage pea	5944	7689	7946	10220	11720	11200	6613	6613	8693	5572	7537	9465
Forage pea + triticale	5331	8070	8525	10733	12500	12773	4720	5400	5567	4844	7199	7453
Grasspea + oat	5284	7539	7979	10480	12500	12880	6787	8227	8200	5827	7752	8132
Grasspea + triticale	5511	6596	7029	10207	9627	9133	5413	6600	7160	7079	7793	8548
Narbon vetch + triticale	5467	7022	8562	9620	10527	11773	3867	4480	5740	5520	7344	7704
Narbon vetch	6565	6406	8353	9527	10133	10820	4120	5093	6387	6247	6931	7820
SE	702.5						753.2					
*P** Crop (C)	0.01						0.01					
P Density (D)	0.01						0.01					
P Year (Y)	0.01						0.01					
P C × D	0.57						0.96					
P C ×Y	0.01						0.07					
P D × Y	0.44						0.90					
P C × D × Y	0.99						0.95					

* *P*, probability value

Table 10. Nutritive value (ME, CP, IVOMD, NDF, ADF, and ADL) of the annual forage mixtures and monocultures grown at Nangahar in 2015/16

Crops	ME (MJ kg^{-1})			CP (%)			IVOMD (%)			NDF (%)			ADL (%)			ADF (%)		
	100	200	300	100	200	300	100	200	300	100	200	300	100	200	300	100	200	300
Grasspea	8.2	7.9	7.5	15.6	13.2	13.2	56.5	56.0	51.9	58.2	56.3	64.3	10.2	5.1	7.8	48.6	41.1	42.7
Narbon vetch	8.5	8.2	7.9	15.4	12.1	10.2	59.1	56.6	53.9	60.1	66.6	66.8	6.7	5.4	7.0	46.0	47.6	50.3
Forage pea	8.4	8.8	7.5	10.7	11.3	12.3	56.9	59.4	52.3	68.5	61.5	62.9	6.3	6.6	11.9	47.2	44.6	54.1
Forage pea + oat	8.5	8.8	8.8	13.5	10.2	8.6	58.1	59.2	59.1	64.4	64.4	64.6	5.3	5.9	6.0	42.5	44.8	45.4
Forage pea + triticale	8.6	8.2	8.2	10.4	11.2	11.0	57.7	56.0	56.2	64.3	66.9	67.9	6.4	5.1	6.0	46.5	48.3	49.4
Grasspea + oat	8.8	8.6	8.6	16.5	11.4	13.2	60.8	58.9	58.6	56.8	57.9	60.3	7.8	9.0	8.1	45.2	48.1	46.8
Grasspea + triticale	8.5	7.8	8.4	13.5	8.7	10.5	58.3	53.3	57.1	64.3	69.1	65.6	7.2	6.4	6.9	45.9	49.4	48.2
Narbon + oat	8.2	8.4	8.2	10.4	12.2	11.3	55.8	58.6	56.9	62.8	66.4	67.9	8.0	6.8	6.9	49.3	48.5	49.7
Narbon + triticale	8.7	8.1	8.2	15.8	10.1	10.2	60.3	55.6	56.2	60.0	67.0	67.8	7.6	6.4	6.3	45.6	49.9	47.5
Oats	8.0	7.5	7.4	7.5	6.9	6.8	53.8	51.7	52.2	66.7	69.0	66.0	8.1	6.9	5.8	51.8	49.2	43.7
Triticale	8.0	7.8	7.7	7.6	7.0	6.2	58.7	58.8	53.3	64.9	63.4	57.5	8.0	7.6	6.5	49.2	46.4	42.8
SE		0.25			1.54			1.55			2.67			0.84			1.95	
*P** Crop (C)		0.01			0.001			0.001			0.01			0.01			0.05	
P Sowing rate (SR)		0.005			0.01			0.001			0.22			0.05			0.94	
P C × SR		0.22			0.44			0.10			0.23			0.01			0.01	

* *P*, probability value

Effect of fertilizer rate on yield of berseem clover–cereal bi-crops in Nangarhar:

Berseem clover was planted with oat, triticale, or rye at 75%:25% ratio respectively in December 2015 and 2016. Plots were fertilized at 0, 100, or 200 kg ha^{-1}. Berseem clover plots were harvested multiple times during the season, and cereal monocultures were harvested only once at 5 cm stubble height. In 2016, forage production ranged from 2591 kg DM ha^{-1} (berseem clover) to 5733 kg DM ha^{-1} (triticale monoculture) (Fig. 3). Cultivating berseem clover with either oat or triticale resulted in greater DM production compared to berseem clover alone with the exception of berseem clover + rye which had a similar DM production to berseem clover alone. Application of DAP fertilizer at 100 kg ha^{-1} increased ($P < 0.01$) DM production from 2793 to 4595 kg DM ha^{-1}; fertilizer at 200 kg DM ha^{-1} resulted in a further increase ($P < 0.01$) in DM to 5501 kg DM ha^{-1}. There was no interaction between forages and fertilizer rates ($P = 0.60$). Similarly, forage production of berseem clover in 2017 was increased ($P < 0.01$) by intercropping with triticale or oat but intercropping with rye did not. Particularly, the first cut of berseem clover was lower than for the cereal monocultures and mixtures (Fig. 4). This indicates that forage production from berseem clover fields can be increased through intercropping with triticale and oats due to increased first cut yields.

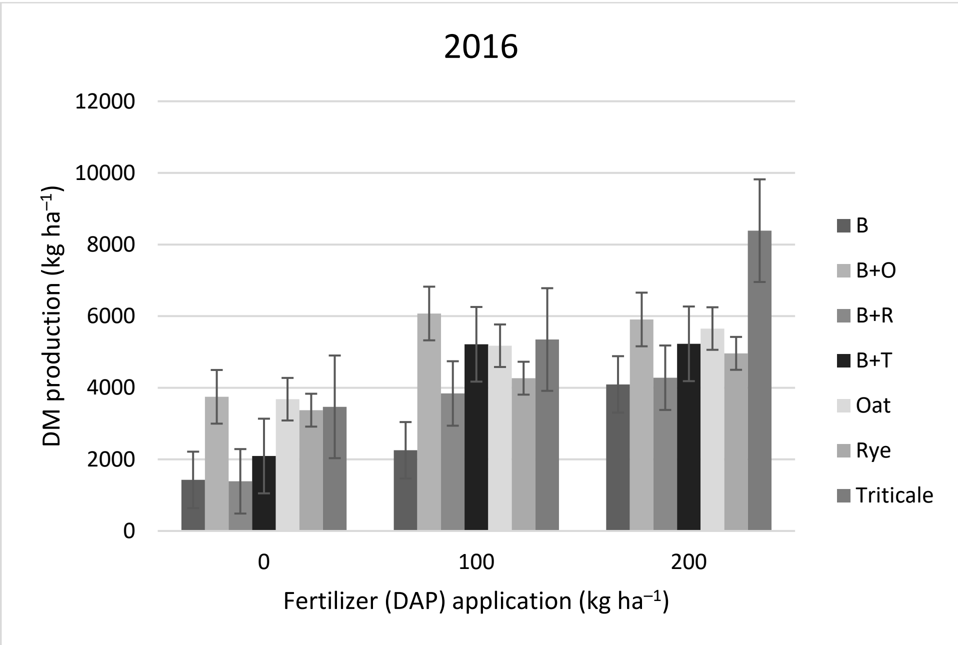

Fig. 3. Dry matter (DM) production of berseem clover–cereal mixtures and monocultures at three fertilizer rates (0, 100, and 200 kg DAP ha^{-1}) in Nangarhar in 2016.

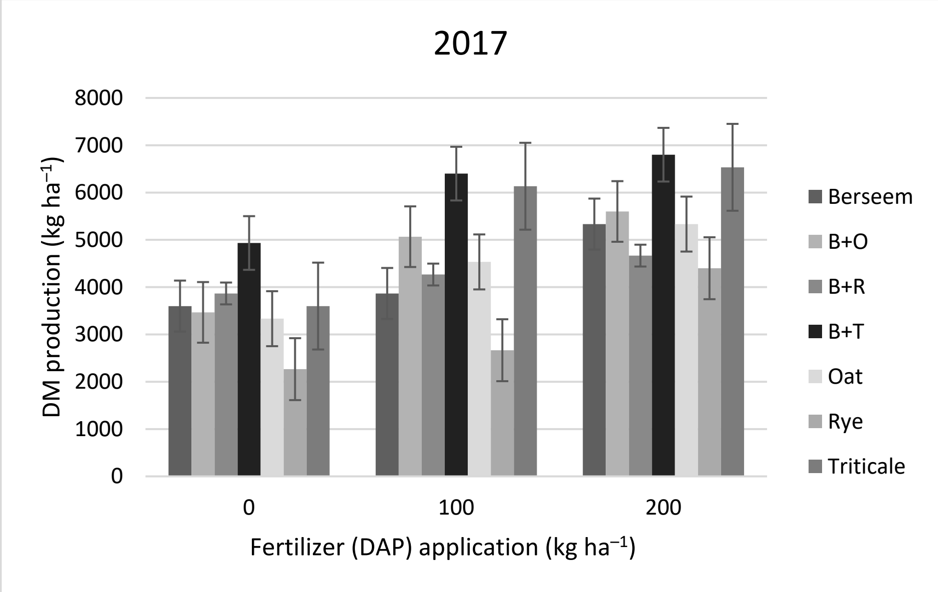

Fig. 4. Dry matter (DM) production of berseem clover–cereal mixtures and monocultures under three fertilizer rates (0, 100, and 200 kg DAP ha^{-1}) in Nangarhar in 2017.

Effect of fertilizer rate and irrigation on sainfoin and alfalfa in Baghlan:

The DM production of alfalfa and sainfoin were compared under three irrigations (irrigation only once, twice, or thrice) and three DAP fertilizer regimes (0, 100, and 200 kg ha^{-1}) in 2016–2018 in Baghlan. It was hypothesized that sainfoin can be more productive than alfalfa and express its comparative advantage at fewer numbers of irrigations because it is extremely drought tolerant. In contrast, alfalfa could produce more forage if irrigation is available as the season progresses. Harvest management was optimized for both crops. Alfalfa provided two and three cuts more than sainfoin in 2016 and 2017, respectively. In 2016, the total accumulated DM yield of alfalfa and sainfoin significantly ($P < 0.05$) differed with 8759 and 7059 kg DM ha^{-1}, respectively. However, response of forages to irrigation ($P = 0.18$) and fertilizer ($P = 0.33$) did not differ in the year of establishment (Fig. 5).

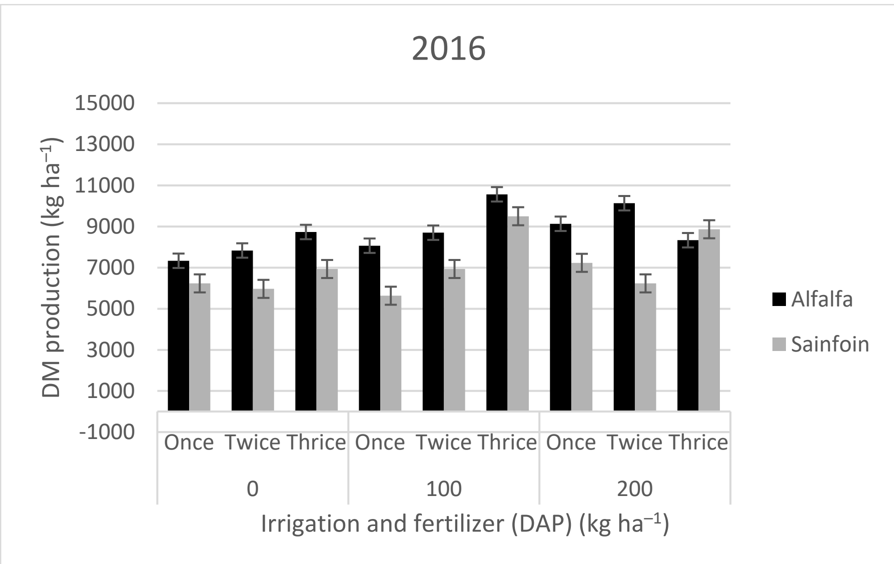

Fig. 5. Response of alfalfa and sainfoin to fertilizer rates (0, 100, and 200 DAP kg ha^{-1}) and irrigation (once, twice, or thrice) in 2015/16 in Baghlan.

In 2017, average DM yield of alfalfa was 16,356 kg DM ha^{-1}, and was 8722 kg DM ha^{-1} greater ($P < 0.01$) than that for sainfoin (Fig. 6). Irrigating the forages three times resulted in greater ($P < 0.05$) yield compared to irrigating once. However, irrigation application twice and thrice resulted in similar DM yields, indicating a higher water use efficiency when irrigating only twice during the growing season. Application of DAP compared to no fertilizer application resulted in similar DM yields. This was probably the due to the N-fixing ability of both legumes but application of N at 200 kg ha^{-1} increased the DM yield by over 30%. The DM yields of both legumes were impressive and comparable to yields reported in the literature. The yield advantage of alfalfa over sainfoin is well-known. However, under rainfed conditions or on hillsides, sainfoin can be a highly persistent and productive forage.

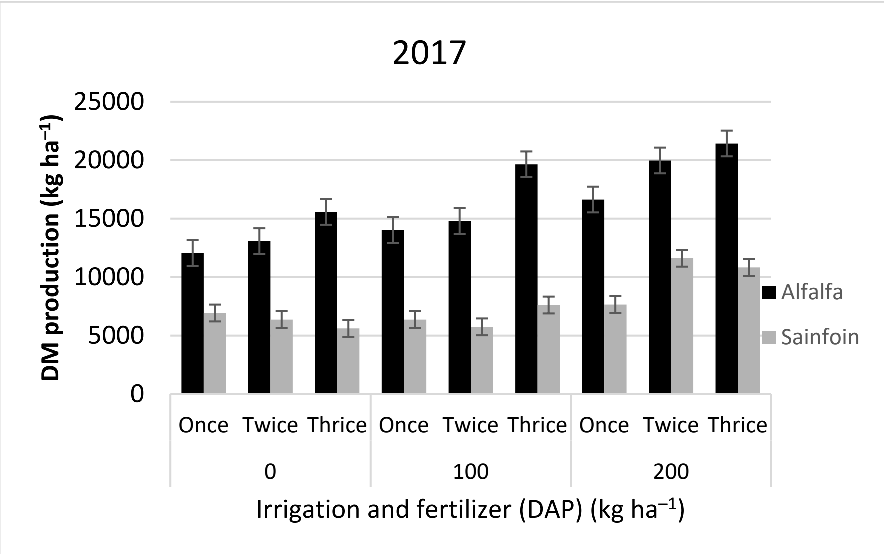

Fig. 6. Response of alfalfa and sainfoin to fertilizer rates (0, 100, and 200 DAP kg ha^{-1}) and irrigation (once, twice, or thrice) in 2016/17 in Baghlan.

Assessment of different propagation techniques and shrub species for rehabilitation of degraded rangelands at watershed scale in Mazar-i Sharif:

As stated earlier, this study was added late in the project (2017) to enhance ties between forage and watershed projects. The main objective was to evaluate which propagation technique (direct seeding or seedling transplantation) would lead to satisfactory rehabilitation. Four promising species obtained from established mother plants at ARIA research stations were evaluated: *Maireana brevifolia*, *Atriplex halimus*, *A. lentiformis*, and *A. nummularia* (as a control). The trial was implemented at watershed scale in Mazar-i Sharif (rainfed conditions) using semi-circular bunds.

Preliminary results indicated significant effects of species and treatments on plant height, width, length, and cover. Among the four species, *A. halimus* had the greatest height followed by *A. nummularia* (Fig. 7); *A. nummularia* had the greatest width (120 cm) and *A. lentiformis* the least (74 cm) (Fig. 7); *A. nummularia* had the highest plant cover (36%) and *A. lentiformis* the lowest (33%) (Fig. 7).

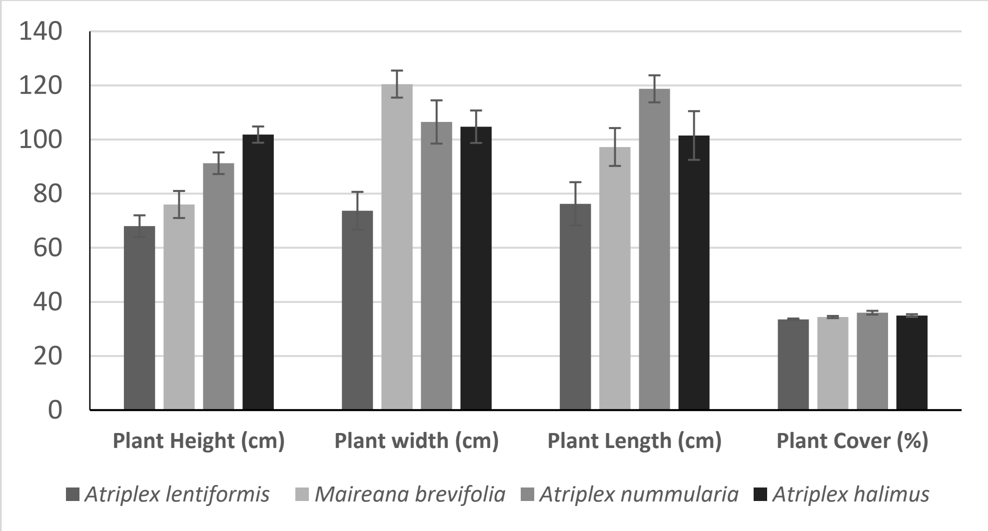

Fig. 7. Height (cm), width (cm), and plant cover (%) for one-year-old shrubs (*Maireana brevifolia*, *Atriplex halimus*, *A. lentiformis*, and *A. nummularia*) planted under two establishment treatments (seedlings and direct seeding) in Mazar-i Sharif.

Furthermore, the seedlings showed better performance in plant growth/vigor compared to plants from direct seeding. This is expected because the age of seedlings when transplanted was 4–6 months. The height, width, length, and cover of plants from the seedling treatment were significantly higher than those directly seeded (Table 10).

Table 10. Plant growth attributes of four different rangelands species (*Atriplex halimus, A. nummularia, A. lentiformis*, and *Maireana brevifolia*) as affected by two establishment treatments

Seeding technique	Height (cm)	Width (cm)	Length (cm)	Plant cover (%)
Seedlings	90	112	112	35
Direct seeding	78	91	85	34
P value	0.001	0.01	0.0001	0.02

Evaluation of spineless cactus accessions as alternative feed sources in Nangarhar:

The main purpose of this study was to evaluate the potential of cactus pear as an alternative feed source to reduce the feed gap in Afghanistan. To achieve this goal, 20 promising cactus (*Opuntia ficus-indica*) accessions were introduced to Afghanistan. The cactus cladodes were originally planted at the farm e-Hada in Nangarhar on 27 April 2017. Approximately six healthy cladodes from each accession were planted in the field.

The first observations were recorded one month after transplantation, when more than 50% of the cladodes had started sprouting, indicating good establishment. Unfortunately, 40% of the cactus cladodes were later damaged mostly by direct livestock grazing due to absence of protection (fence) or by low temperature (frost). However, at least three cladodes from each accession were still sufficiently healthy to be transplanted and these were transferred to Nangarhar Research Station. During the 2018 winter, the cactus cladodes were set back due to unexpectedly low temperatures. It looked as if this trial would have to be abandoned as most plants were seriously damaged by cold; however, when the weather began to warm up, new buds emerged.

The preliminary results of the evaluation in April 2018 showed significant differences among the accessions regarding overall performance. We used a scale of range 0–5 to assess cactus (0 = dead, 1 = bad condition, 2 = medium, 3 = good, 4 = very good, 5 = excellent). The accession labeled "N" from Tunisia and 13_ Bab Toza_74115_Morocco showed the best performance and produced the highest number of new cladodes, whereas 32_ Matmata_69242_Tunisia, 2-17-25 Mexico, and 26_ Djebel Bargou_68247_Tunisia had the lowest number of cladodes and performance (Fig. 8).

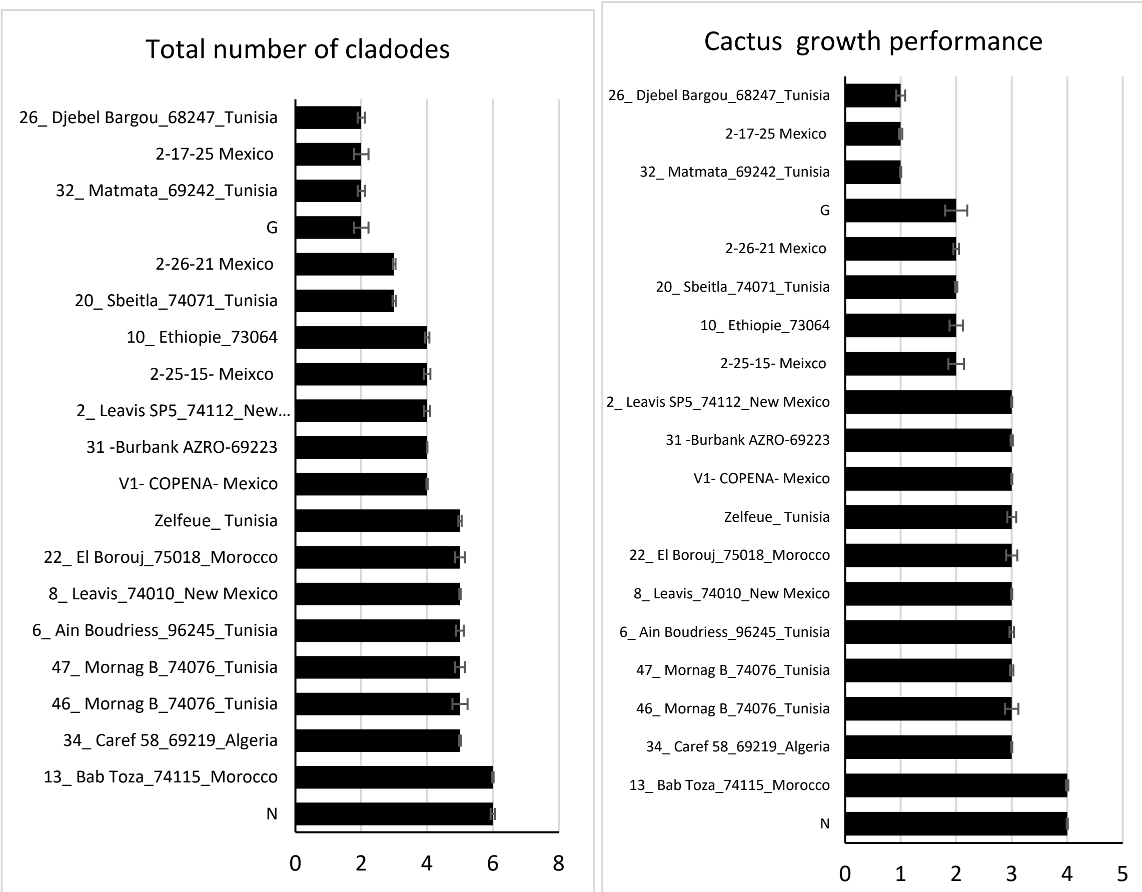

Fig. 8. The average number of new cladodes per plant and growth performance (based on a score of 0–5) of cactus accessions transplanted in Nangarhar.

7.3 On-farm demonstrations

With the intent of introducing promising forage species and proper agronomic management practices to farmers, four on-farm demonstrations were conducted in both Baghlan and Nangarhar Provinces. Forage pea, narbon vetch, triticale, oat, berseem clover, grasspea, alfalfa, and sainfoin were planted in farmers' fields and various simple intercropping and fertility management practices were demonstrated. A total of 32 farmers collaborated in these demonstration activities in Nangarhar. Similarly, four demonstration activities were carried out in Baghlan with participation of 32 farmers in 2016 and 2017. However, in some cases data could not be collected due to security reasons. When possible, farmers' feedback and perceptions on the demonstration activities and introduced forages were documented.

7.3.1 Nangarhar Province

Annual legumes and triticale bi-crops: The objective of the demonstration was to quantify biomass production potential of promising forage legumes (forage pea and narbon vetch) and triticale in mixtures and monocultures. Forage pea and narbon vetch were intercropped with triticale at 75%:25% seeding ratio and the fields were harvested at 5 cm stubble height when triticale reached the dough stage of maturity. The average DM production across the triticale–forage legume mixtures ranged from 7050 kg DM ha^{-1} (narbon vetch–triticale) to 12,900 kg DM ha^{-1} (forage pea–triticale) (Fig. 9) in 2016.

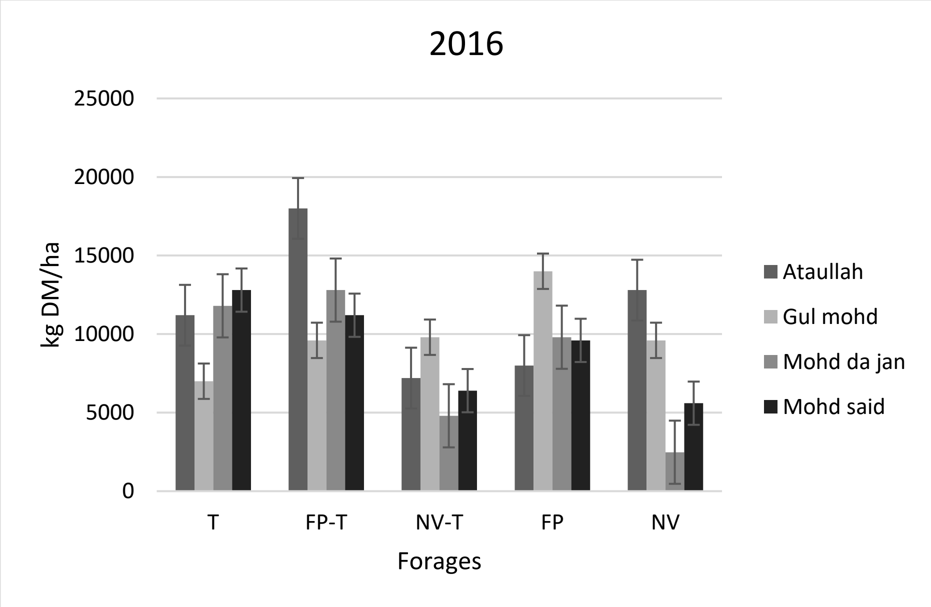

Fig. 9. On-farm dry matter production of triticale (T) and forage legume mixtures and monocultures in 2016. NV, narbon vetch; FP, forage pea.

Large variations were detected for DM yields of the forages among different farms, indicating different management and agroecological conditions. Overall, the on-farm study confirmed the results obtained from on-station trials and indicated the high production potential of forage legumes, in particular forage pea, both in monocultures and in mixtures with triticale.

Farmers' perceptions and comments (2016):

1. Ataullah stated that germination and establishment of the crop were good. He found that the biomass production was higher than the local varieties that he had planted before. He thought that the forage looked highly nutritive for livestock.
2. M. Sayeed stated that he had high biomass and seed production. He kept the seed for planting again next year in mixtures, which he liked better than monocultures. He also thinks that the feeding value seemed higher than the locally available varieties.
3. Gul Mohammad stated that he planted legume–cereal mixtures. He liked the leafy forage with high biomass and seed production. He kept some seeds for planting again.
4. M. Jan stated that he received forage pea and cereal seed and planted them in a mixture. The production was good but gave only one cut. He is interested in high-yielding multi-cut forage crops.

Berseem clover and cereal–forage mixtures:
The objective was to quantify and demonstrate biomass production potential of berseem clover in monocultures and mixtures with forage cereals. Results are only available for the first cut yield of berseem clover. The average DM production of berseem clover monoculture was 2340 kg ha^{-1} (Fig. 10). When cultivated with oat and triticale, the DM production of berseem clover–cereal mixtures exceeded 9000 kg DM ha^{-1}. Oat monoculture had the highest DM production of 11,530 kg ha^{-1}, which was significanlty higher than for triticale with 8280 kg ha^{-1}. The mixing of berseem clover with forage cereals greatly increased forage production of berseem clover.

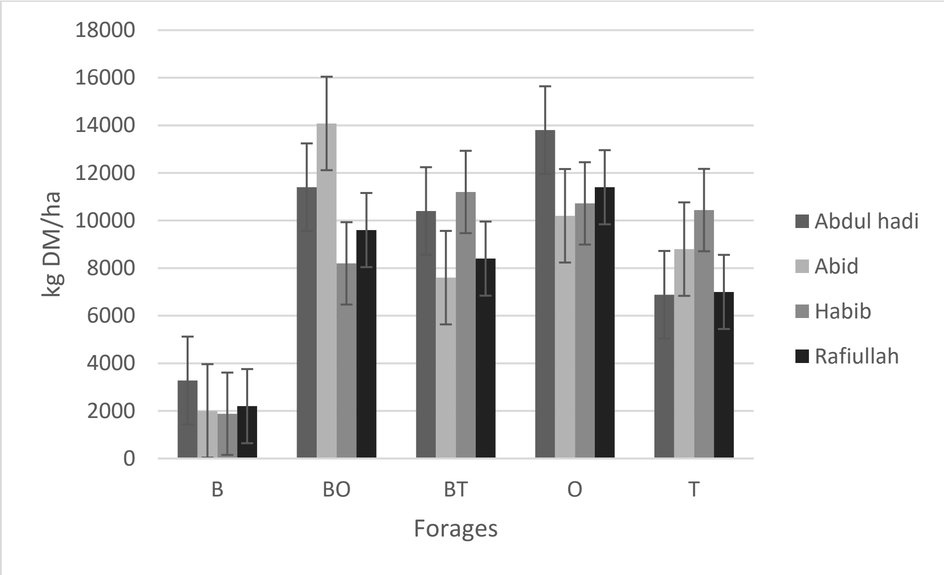

Fig. 10. On-farm dry matter production of berseem clover (B), triticale (T), and oat (O) mixtures and monocultures in 2016.

In 2017, the DM production of berseem clover and its combination with triticale and oats ranged within 4200–14,200 kg DM ha^{-1} (Fig. 11). Overall, mixtures out-yielded monocultures but the main advantage of binary mixtures of berseem clover was the increased first cut yield compared to berseem monoculture.

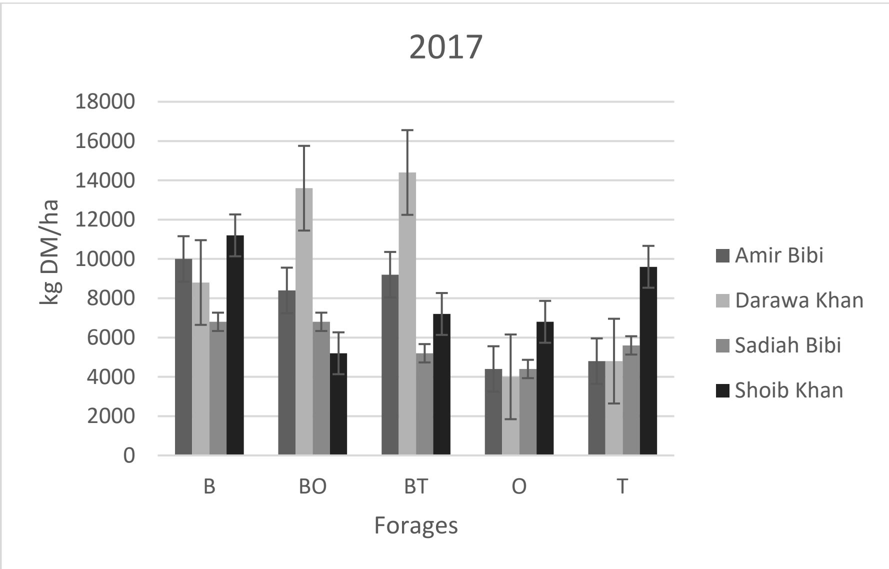

Fig. 11. On-farm dry matter production of berseem clover (B), triticale (T), and oat (O) mixtures and monocultures in 2017.

Farmers' perceptions and comments (2016):

1. Rafiuallah stated that he had high fresh biomass production in multiple cuts. His forage production increased this year and he is grateful to ICARDA for that. He is keen on planting the same mixture in 2017 with the seeds he produced.
2. Abid stated that he had the first cut only 45 days after planting the mixture. His livestock liked consuming the forage and showed no health problems. He also observed less weeds compared to berseem monoculture.
3. Habib stated that he had no experience with berseem clover–cereal mixtures, but he appreciated the green forage during the shortage in winter. He thinks that the animals liked eating this mixture and had higher production.
4. Abdul Hadiy stated that he traditionally cultivated berseem clover and maize for his livestock, but he thinks that he has new forage varieties which are very useful for his livestock. He planted the berseem clover–cereal mixture according to the guidance of the technical staff of ICARDA. Crop growth was very good with high forage production. He also observed an increase in milk and meat production of his animals. He wants to produce the seeds for himself and his fellow farmers.

Forage legumes and fertility management:
The objective was to quantify the biomass and seed production potential of forage pea, grasspea, and narbon vetch under various fertilizer application managements. In both years, the highest DM production exceeding 8000 kg DM ha^{-1} was for forage pea, and grasspea had the lowest (Figs. 12 and 13), with that of narbon vetch intermediate. Application of DAP fertilizer at 100 kg ha^{-1} resulted in similar DM production of forage legumes with manure application at a rate of 3 t ha^{-1}. However, DM production of forages fertilized at 200 kg ha^{-1} DAP was greater than both manure and DAP application at 100 kg ha^{-1}.

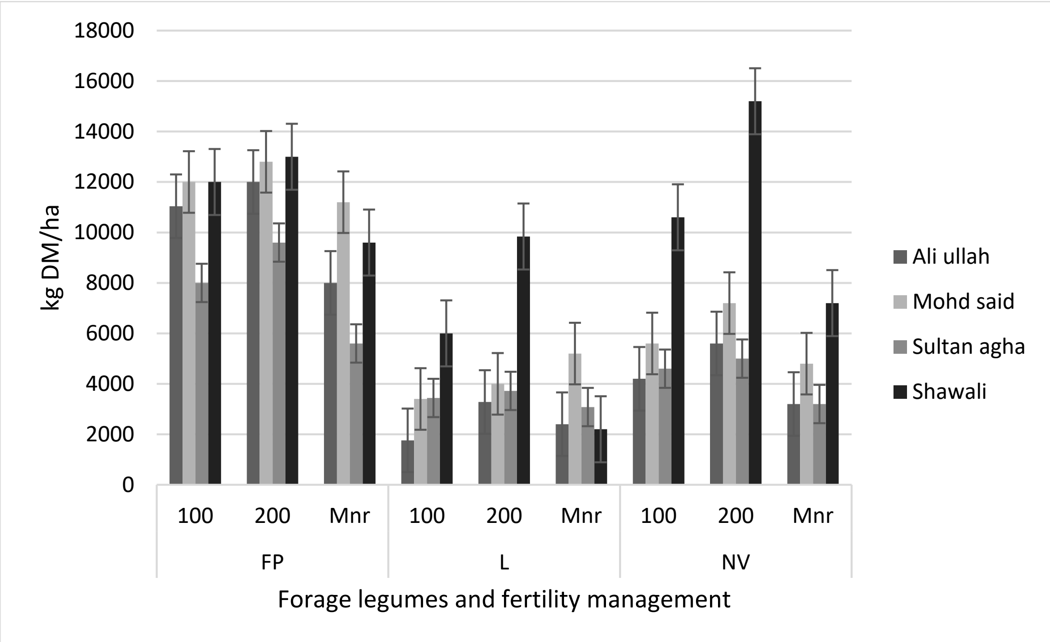

Fig. 12. On-farm DM production of forage pea (FP), grasspea (L), and narbon vetch (NV) either with manure (Mnr) or fertilizer application (DAP) at rates of 100 or 200 kg ha^{-1} in 2016

In 2017, forage pea had the greatest DM yield of close to 20 t ha^{-1}, whereas narbon vetch (8100 kg ha^{-1}) and lathyrus (7100 kg ha^{-1}) had similar but lower DM yields. Fertilizer application at 100 and 200 kg ha^{-1} resulted in similar DM yields but manure application provided approximately 1200 kg ha^{-1} less forage production.

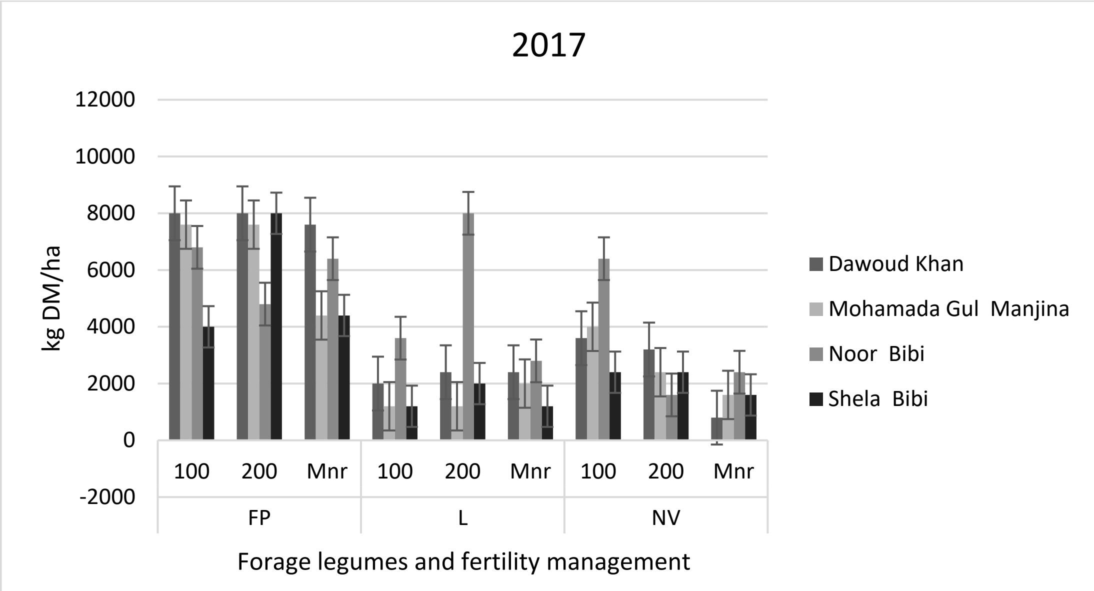

Fig. 13. On-farm DM production of forage pea (FP), grasspea (L), and narbon vetch (NV) either with manure (Mnr) or fertilizer application (DAP) at rates of 100 or 200 kg ha^{-1} in 2017

Farmers' perceptions and comments (2016):

1. Sha Wali stated that germination and establishment were good. He compared the effect of fertilizer application in his mixtures and the fertilizer resulted in higher yield. He said the forages and the concept of mixing them together were new to him, but he produced good forage for his animals. He will keep the seed to plant again.
2. Sultan Agha stated that the mixture provided valuable forage for his animals. He wants to produce seed for himself and his relatives.
3. Ali Wala stated that his animals liked consuming the forage mixture that he grew, and their production increased. He thinks he was lucky that he tried this new forage crop which he wants to plant again to produce seed for himself and other farmers.
4. M. Sayed stated that he did not know the application time of DAP fertilizer. This demonstration was good training for him in agronomic management of the forages. He wants to plant again and produce seed as he thinks that the adaptation in his region would be good.

Forage legumes and fertilizer application rates:
The objective was to quantify and demonstrate the biomass and seed production potential of berseem clover, alfalfa, and sainfoin under various fertilizer application managements. The average DM production ranged within 3030–3850 kg DM ha^{-1} and was similar for each forage (Figs 14 and 15). Forage production at the fertilizer application rates of 0, 100, and 200 kg ha^{-1} was 3400, 3170, and 4150 kg DM ha^{-1}, respectively.

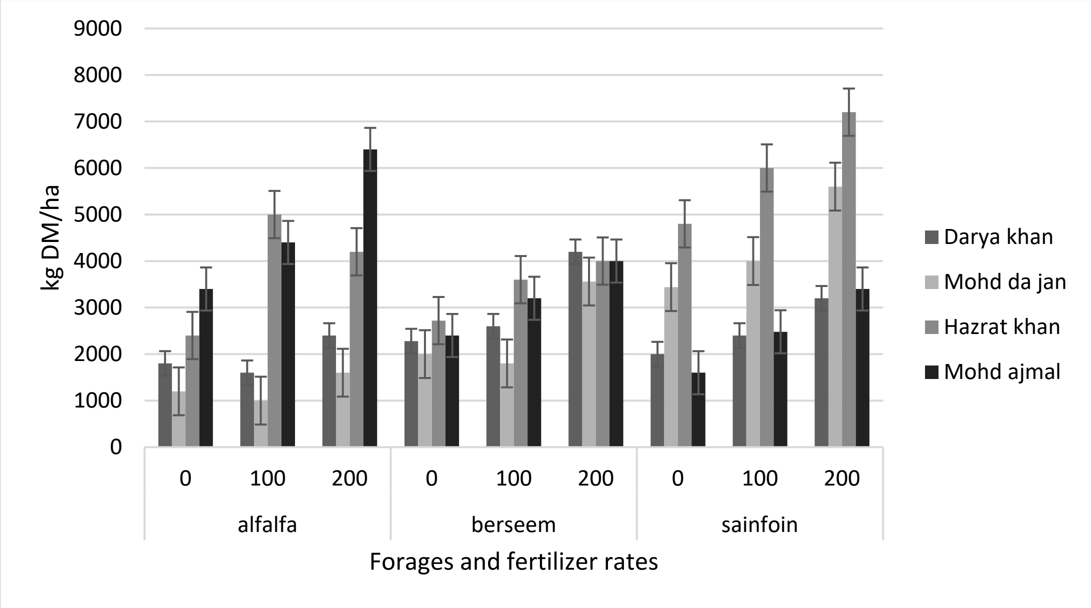

Fig. 14. On-farm dry matter production of berseem clover, alfalfa, and sainfoin at 0, 100, and 200 kg ha^{-1} DAP rates in 2016.

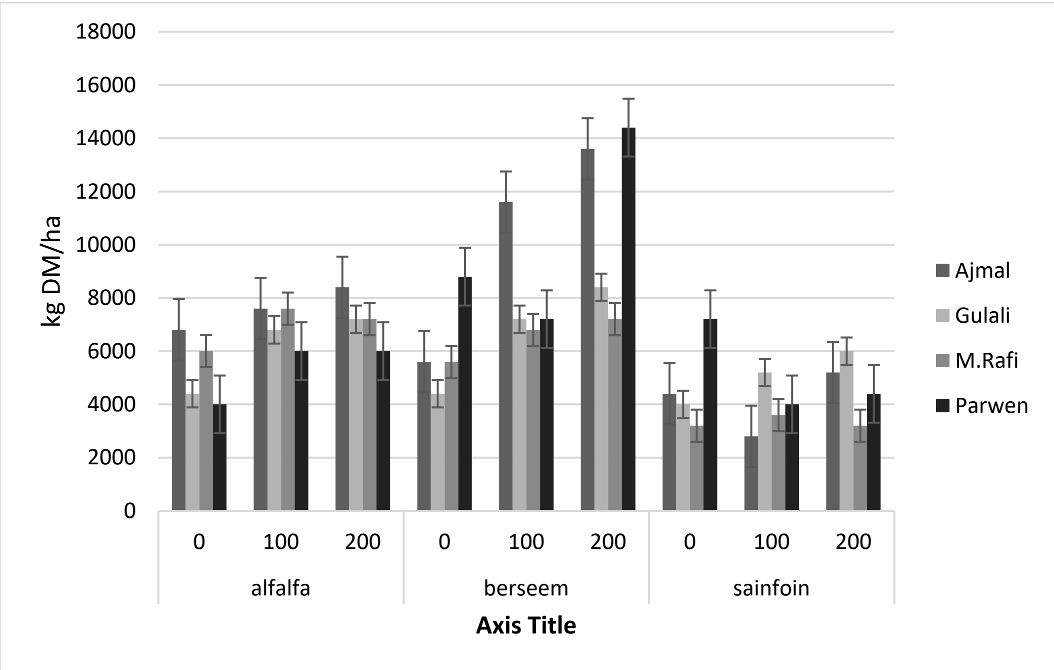

Fig. 15. On-farm dry matter production of berseem clover, alfalfa, and sainfoin at 0, 100, and 200 kg ha^{-1} DAP rates in 2017.

Farmers' perceptions and comments (2016):

1. Darya Khan stated that he did not know much about the forage crops except alfalfa. This demonstration in his field provided him an opportunity to learn more. He got 3–4 cuts for forages from alfalfa, sainfoin, and berseem clover but did not record seed production. He liked sainfoin because it was perennial and grew very well in his field.
2. Hazrat Khan stated that yield was increased with fertilizer application. He is now more aware of the advantages of legumes for soil fertility.
3. M. Jan stated that he is now more familiar with different forage crops. He was satisfied with the production and the animals liked eating them.

4. M. Ajmal stated that he planted the forages based on guidance from ICARDA technical staff. He liked the forage crops he tried. Some other farmers visited his field and requested seeds.

7.3.2 Baghlan Province

Annual forage legume and triticale mixtures:
The objective was to quantify biomass production potential of promising forage legumes (forage pea and Hungarian vetch) and triticale in mixtures and monocultures. Fresh biomass production of the triticale–forage legume mixtures ranged from 20,300 kg DM ha^{-1} for forage pea–triticale mixture to 24,600 kg DM ha^{-1} for Hungarian vetch monoculture (Fig. 16). The DM data are not presented due to abnormally high variation among DM content of the forages.

Note: The demonstration was aimed to be established at six farms but due to security reasons, only three farms were included in the study. However, data were collected from only two farms due to security problems.

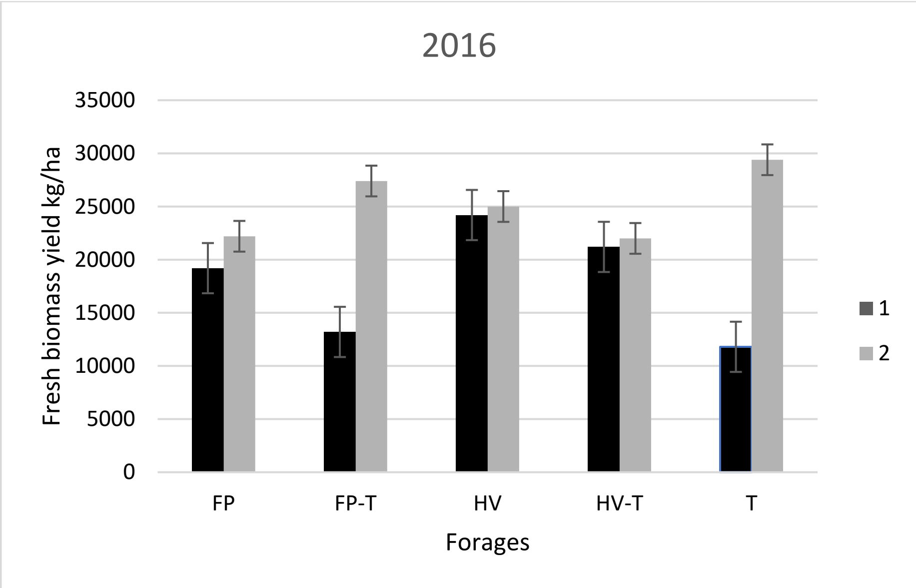

Fig. 16. On-farm fresh biomass production of triticale (T), forage pea (FP), and Hungarian vetch (HV) mixtures and monocultures in 2016.

Forage pea and its mixtures had similar DM yields, which were greater than for monoculture Hungarian vetch. It was of note that Hungarian vetch–triticale mixture resulted in higher yield compared to Hungarian vetch monoculture. Possibly due to higher yield potential of forage pea, intercropping with triticale did not result in the same outcome (Fig. 17).

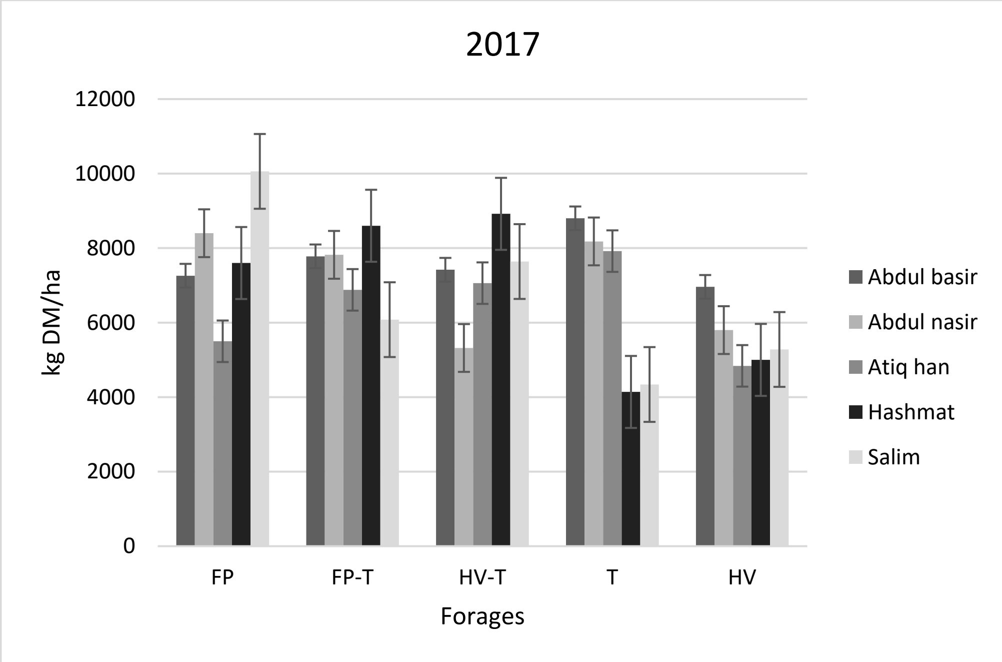

Fig. 17. On-farm DM yield of triticale (T), forage pea (FP), and Hungarian vetch (HV) mixtures and monocultures in 2017.

Farmers' perceptions and comments (2016):

1. Abdul Basir stated that he particularly liked triticale. His animals consumed triticale well. He requested more seed.
2. Abdul Ahmad stated that all of the forage varieties were good but he thinks forage pea was the best. In addition, his animals liked forage pea a lot and he wanted to have more forage pea seeds.

Berseem clover and cereal–forage mixtures:
The objective was to quantify and demonstrate the biomass production potential of berseem clover in monocultures and in mixtures with forage cereals. The average DM production of berseem clover monoculture was 6433 kg ha^{-1} (Fig. 18). When berseem clover was cultivated with oat or triticale, the DM production was 7967 and 7200 kg DM ha^{-1}, respectively. There were similar trends in 2017 except that berseem monoculture provided less DM (4390 kg ha^{-1}), but mixtures with oat (9188 kg ha^{-1}) and triticale (8020 kg ha^{-1}) had greater yields. Overall, these yields indicated the value of mixing berseem clover with small-grain winter annuals to increase forage yields (Fig. 19).

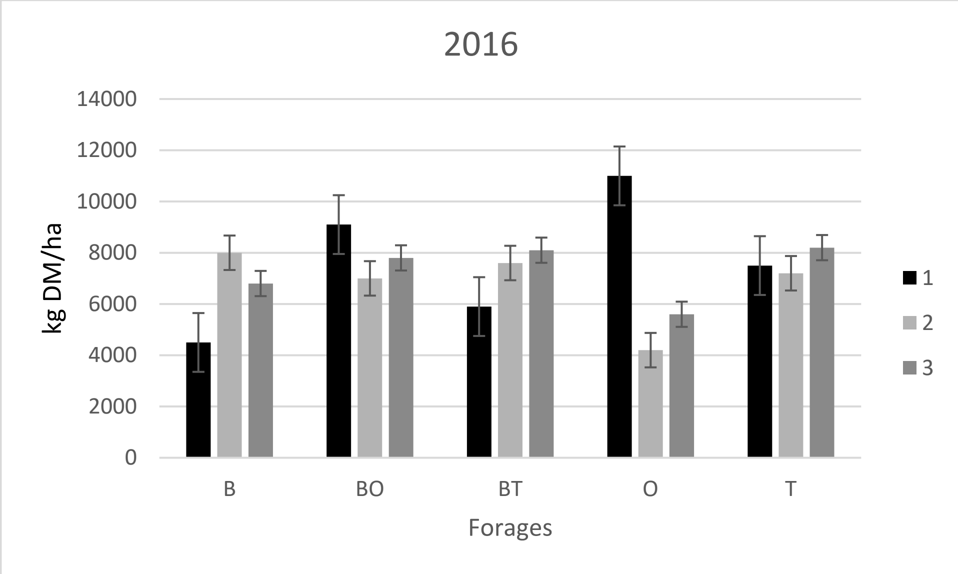

Fig. 18. On-farm dry matter production of berseem clover (B), triticale (T), and oat (O) mixtures and monocultures in 2016.

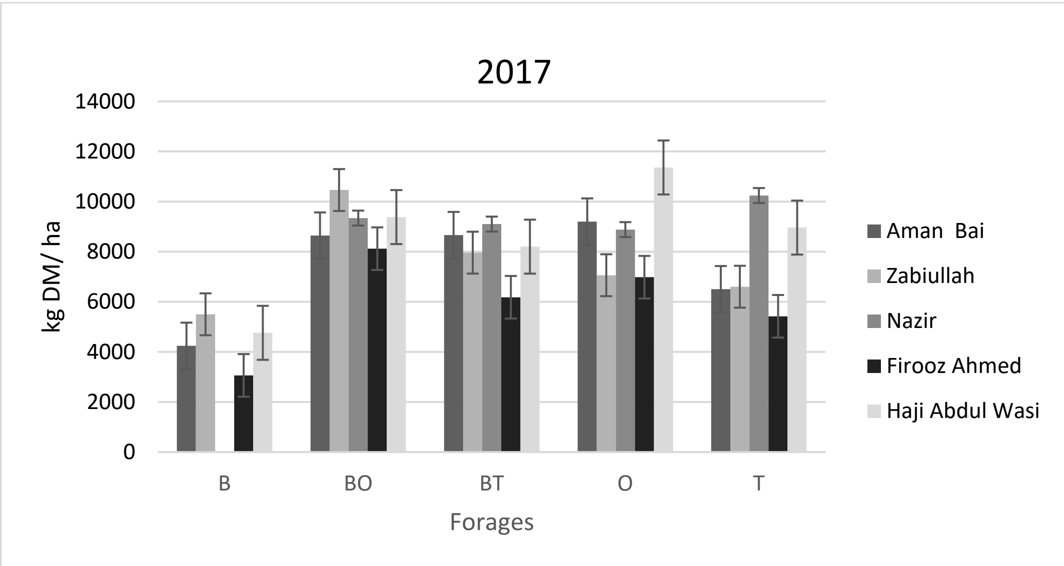

Fig. 19. On-farm dry matter production of berseem clover (B), triticale (T), and oat (O) mixtures and monocultures in 2017

Farmers' perceptions and comments (2016):

1. Gul Rahman stated that he satisfied with the production of ICARDA forage crops. Animals liked consuming the forages. He requested more seeds and fertilizer for his demonstration plots.
2. Abdul Nasir did not respond to the interview request about the demonstration plots.
3. Gul Rahman stated that the he was happy with the forages that he grew in his demonstration plots and he was willing to continue this activity.

Forage legumes and fertilizer application rates:
The objective was to quantify the biomass and seed production potential of forage pea, Hungarian vetch, and Grasspea under various fertilizer application managements. The average DM production of forage pea, Hungarian vetch, and Grasspea was 6017, 6350, and 5100 kg DM ha^{-1}, respectively, and similar for each forage legume (P = 0.68; Fig. 20).

Application of fertilizer at 100 and 200 kg ha^{-1} resulted in differences in forage DM yield. However, unfertilized forage had significantly lower (*P* < 0.05) DM production. There was no interaction between forages and fertilizer rates (*P* > 0.05).

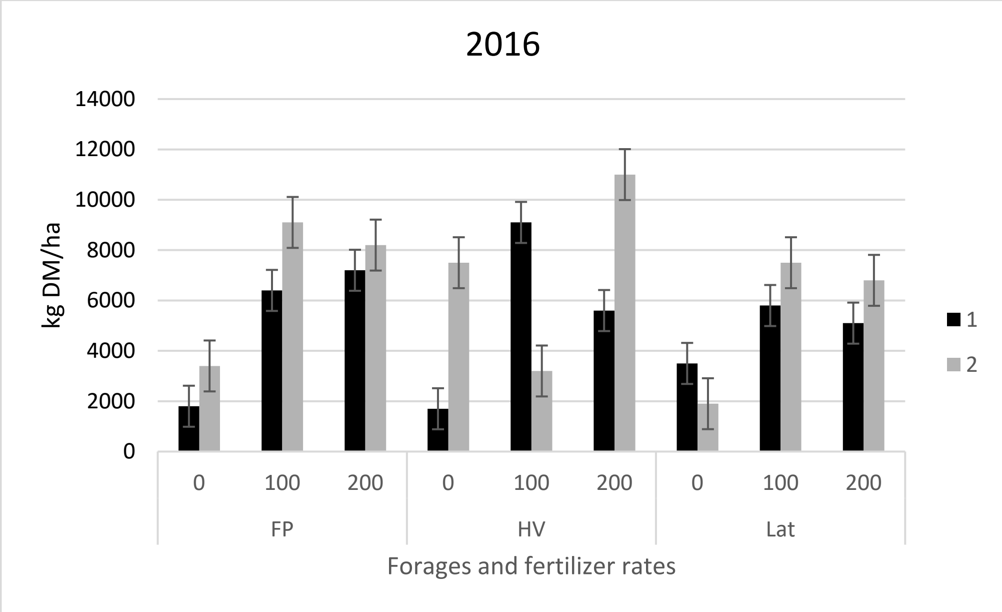

Fig. 20. On-farm DM production of forage pea (FP), Hungarian vetch (HV), and Grasspea (Lat) fertilized at 0, 100, or 200 kg ha^{-1} DAP in 2016.

In 2017, forage pea provided the highest (*P* < 0.05) DM yield that exceeded 8300 kg DM ha^{-1}, Hungarian vetch had the lowest (6714 kg DM ha^{-1}) and Grasspea was intermediate (Fig. 21). Surprisingly, fertilizer rates resulted in no differences, possibly due to poor agronomic management or improper application of fertilizer.

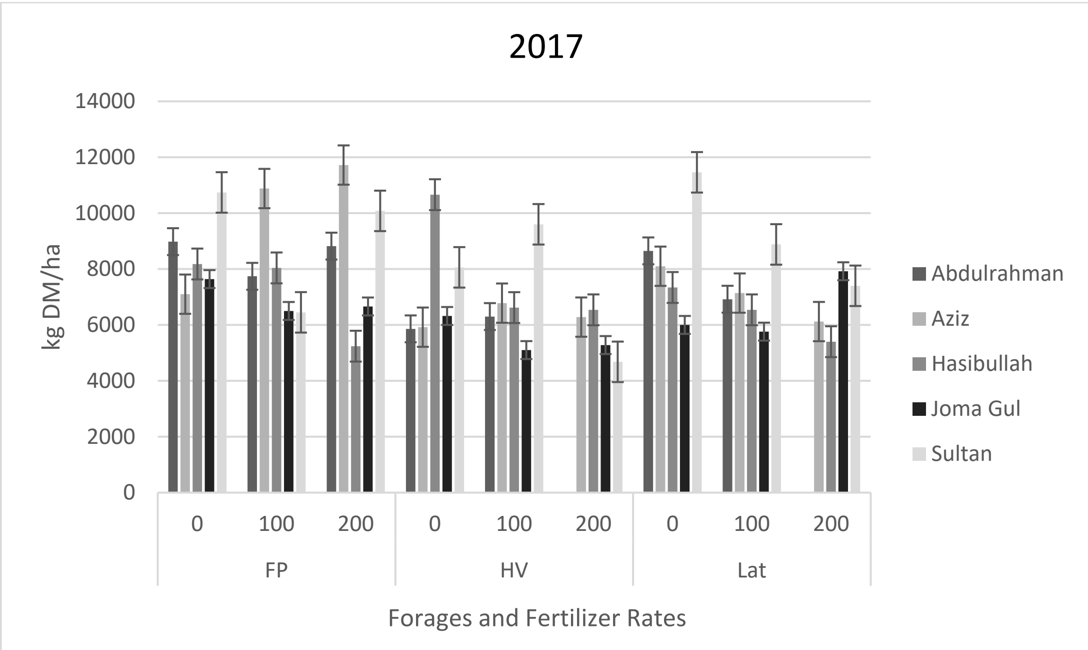

Fig. 21. On-farm DM production of forage pea (FP), Hungarian vetch (HV), and Grasspea (Lat) fertilized at 0, 100, or 200 kg ha^{-1} DAP in 2017.

Farmers' perceptions and comments (2016):

1. Jumadin stated that he liked the forage crops that ICARDA introduced. He thought forage pea in particular was the best because of good yield and palatability to animals. He did not produce any seed but would like to get more from ICARDA to try again.
2. Abdullah moved somewhere else, so the interview was not possible.

A second set of on-farm trials quantified the biomass and seed production potential of berseem clover, alfalfa, and sainfoin under various fertilizer application managements. An interaction was detected between forages and fertilizer application levels and type ($P < 0.05$) (Fig. 22). Application of DAP at 100 kg ha^{-1} resulted in similar DM production to application of manure for sainfoin and berseem clover. However, the response of alfalfa to manure application was similar to DAP at 200 kg ha^{-1}, which was significantly greater than the DM production at DAP 100 kg ha^{-1}. In 2017, DAP application at 100 and 200 kg ha^{-1} rates resulted in similar DM yields, which were greater than forage yields for manure application. The DM yields of forages were similar (Figs 22 and 23).

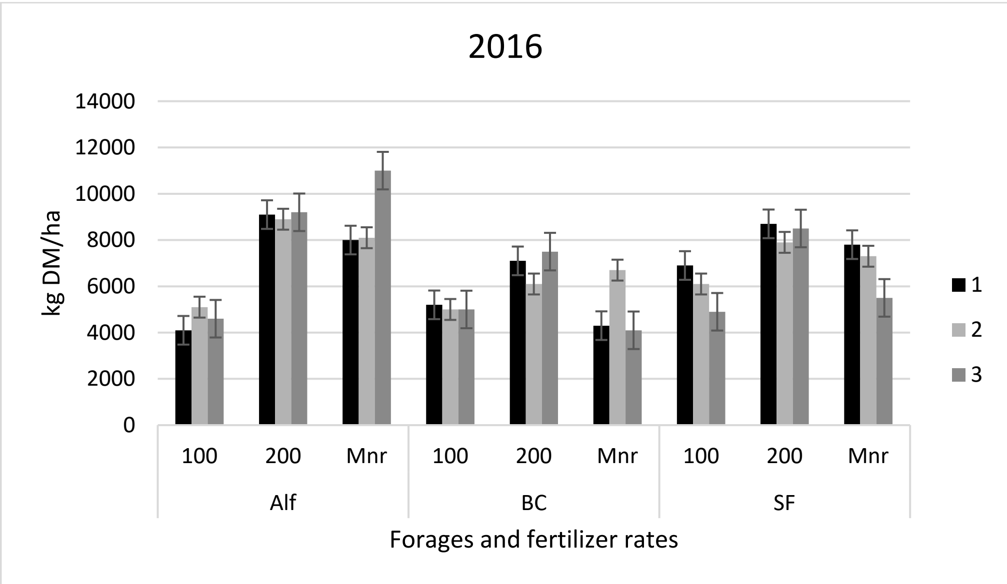

Fig. 22. On-farm DM production of alfalfa (Alf), berseem clover (BC), and sainfoin (SF) fertilized with 100 or 200 DAP kg ha^{-1} or cattle manure in 2016.

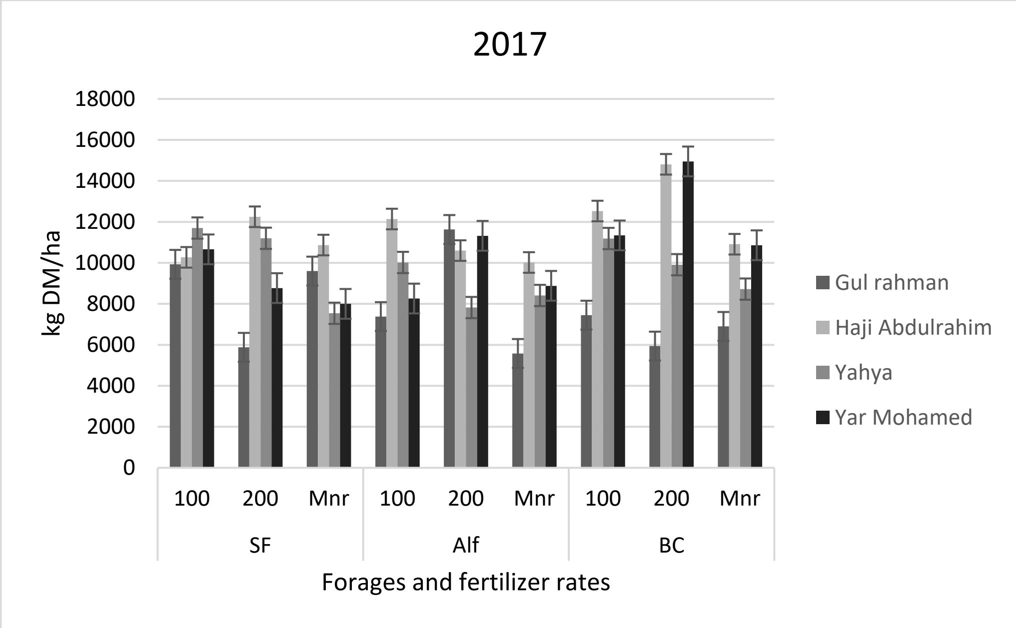

Fig. 23. On-farm DM production of alfalfa (Alf), berseem clover (BC), and sainfoin (SF) fertilized with 100 or 200 DAP kg ha^{-1} or cattle manure in 2017.

Farmers' perceptions and comments (2016):

1. L. Mohammad stated that he liked all the forage varieties but sainfoin was the best. He collected some seed from the demonstration plots, but he needed more seed for this year from ICARDA.
2. Mohammad Zaman stated that all the varieties were good and performed better than locally available forage crops. He requested more sainfoin seeds.
3. M. Gul said that all of the introduced forage varieties were new to him. His animals liked eating the forage crops, but he thought sainfoin was the best.

7.4 Mirror trials in Turkey and Australia

Mirror trial sites in this project successfully served as training sites where capacity building and more controlled research on the introduced forages were carried out. In particular, more in-depth agronomic and animal feeding studies were realized in the mirror trial sites. The experiments also served as training activities for the ICARDA and NARS from Afghanistan. The results indicated the role and potential of the forages in integrated crop–livestock systems in a dry highland environment. The results were published in high impact-factor journals.

7.4.1 Mirror trial site in Konya, Turkey

Experiment 1: Determination of the fattening performance, meat quality, water footprint, and feeding system efficiency of weaned Anatolian merino and Akkaraman lambs under different feeding systems (*abstract orally presented at the 2018 ASAS-CSAS Annual Meeting & Trade Show in Vancouver, Canada in July 2018*)

This study aimed to compare the performance and meat quality of fattening lambs of Akkaraman (AKK, fat tailed) and Central Anatolian Merino sheep (CAM, lean tailed) breeds, under different feeding systems based on low-input, annual forage, medium input, perennial forage (pasture), and high-input, concentrated feeding systems. A total of nine lambs of both genotypes were fattened with diets based on either triticale–Hungarian vetch, sown pasture, or concentrated feed. The feeding was commenced simultaneously for each diet type and continued for 63 days in three periods of 21 days. Upon completion of the fattening period, all lambs were slaughtered to determine their carcass characteristics and meat quality traits. Lambs fed on concentrate had greater ($P < 0.05$)

feed intake than those on forage-based diets. In addition, the in vivo digestibility of triticale–Hungarian vetch and pasture decreased as the season progressed. In relation to the feed intake and digestibility of diets, the liveweight gains of lambs that consumed triticale–Hungarian vetch and pasture were lower ($P < 0.05$) than those fed on concentrate. As a result, lambs consuming forage-based diets had lower final liveweights at slaughter than lambs fed on concentrate. Parallel to final liveweights, weight-related carcass traits were greater ($P < 0.05$) for lambs that consumed concentrate than those fed forage-based diets. The results indicated that under concentrate feeding system, AKK had lower tallow contents than CAM. In addition, the n6/n3 ratio of fatty acids decreased ($P < 0.05$) with forage-based compared to concentrate-based feeding. However, C18:2, cis-9 trans-11, C12:2 trans-10 cis-12, and α-linolenic acid (C18:3n3) composition of the fatty acids increased with forage-based feeding ($P < 0.05$). There was no profound difference between AKK and CAM lambs in performance and meat quality.

Experiment 2: Effect of nurse crop and seeding rate on the productivity and persistence of sainfoin (*abstract presented at ASA, CSSA & SSSA International Annual Meetings in Baltimore, 4–7 November 2018*)

Sainfoin is one of the most drought-tolerant legumes and has excellent feeding value because of its bloat-free characteristics and secondary metabolite compounds improving protein metabolism. However, low DM production in the year of establishment and poor persistency are its main limitations. A three-year study in the Central Anatolian Region of Turkey compared the persistence and productivity of sainfoin planted either with triticale or Hungarian vetch as nurse crop at three seeding rates (30, 60, and 90 kg ha^{-1}) during 2014–2017. Planting sainfoin with a nurse crop at high seeding rates (90 kg ha^{-1}) reduced the number of established sainfoin seedlings compared to control, but the effect of lower seeding rates (30 and 60 kg ha^{-1}) was non-significant. Sainfoin–Hungarian vetch mixtures had 1228 kg ha^{-1} greater ($P < 0.01$) DM yield than sainfoin monocultures during the year of establishment (2014). Planting sainfoin with triticale resulted in much greater yield, exceeding 10 t ha^{-1}. The subsequent sainfoin DM production in 2016, ranging within 1764–2009 kg ha^{-1}, did not differ among treatments. However, DM yield in 2017 tended to be lower ($P = 0.07$) in sainfoin–triticale plots compared to sainfoin monoculture and sainfoin–Hungarian vetch. The seeding rate of nurse crops had no effect on DM yield in the year of establishment or in following years. The findings indicated that planting sainfoin with a nurse crop could substantially increase DM yield in the year of establishment with no yield penalties in subsequent years despite fewer established plants compared to monoculture.

Experiment 3: Bio-economic analysis of dual-purpose management of winter cereals in high and low-input production systems (*published in Field Crop Research-Special Issue*)

Dual-purpose management of cereals holds promise to reduce the feed gap and better integrate crop and livestock systems, especially in drylands where forage deficit is severe. However, there is limited information on which cereal species and type of management would be optimal for both forage and grain production in dry highland environments. A two-year field study (2013–2015) in the Central Anatolian plateau of Turkey investigated the effect of spring defoliation of barley, triticale, and wheat varieties at tillering and stem elongation stages and a no-cut (grain-based) system under low- and high-input management on yield and quality of forage, straw, and grain. Overall, barley had greater ($P < 0.01$) forage DM accumulation within the winter–spring season, relative to wheat and triticale, with the exception of the low-input system in 2014 when all cereal species and varieties had similar DM yield for both defoliation stages. Differences in straw yields favored barley over triticale and wheat for the low-input system in 2014 ($P < 0.09$), but not 2015, and for the high-input system in 2014 ($P < 0.05$) and 2015 ($P < 0.07$). Most frequently, cutting at stem elongation had the lowest total DM production. Similarly, grain yield was lower when cut at this stage for both years and input management systems. Total CP was greater in systems with cut forages compared to no-cut. Bio-economic modeling indicated that growing cereals only for grain led to higher profits when precipitation was below average, but dual-purpose management based on defoliation at tillering led to higher profits during an average year. Also, cultivation of barley led to higher profits in all periods. The findings provide a convincing case for dual-purpose management of cereal forages both under low- and high-input systems for improved efficiency and profitability in crop–livestock farming.

Experiment 4: Feeding value of rye, triticale, and wheat straw produced under a dual-purpose management system (*published in Journal of Animal Science*)

Dual-purpose management of winter cereals for grazing and grain production provides highly nutritive forage for ruminants in spring and may positively affect straw feeding value. A two-year study investigated the effect of spring defoliation of triticale, wheat, and rye crops at tillering and stem elongation stages on total biomass and grain yields. Furthermore, straw samples from un-defoliated (control) and spring-defoliated wheat, triticale, and rye crops at tillering and stem elongation were evaluated for nutritional value and voluntary feed intake in young sheep as a means of also assessing the efficiency of dual-purpose management systems for winter feeding. Nine total mixed rations, each containing 35% straw, were fed to 54 one-year-old Anatolian Merino ewes that were kept in individual pens for a period of 28 days. Mechanical defoliation of the crops at tillering did not affect annual biomass production or grain yields. However, biomass and grain yields were reduced ($P < 0.01$) by 55% and 52%, respectively, in crops defoliated at stem elongation. Straw of spring-defoliated cereal crops had significantly lower cell wall content ($P < 0.01$) but higher CP ($P < 0.001$), non-fiber carbohydrates ($P < 0.001$), and energy values ($P < 0.001$) compared to straw from un-defoliated crops. Intake of DM and organic matter for spring-defoliated straw exceeded 50 g head^{-1} d^{-1} compared to control ($P < 0.01$). However, weight gain did not differ among treatments ($P > 0.05$). It is possible that increases in feeding value of defoliated straw could improve liveweight gains in regimens differing in supplement type and duration.

Experiment 5: Spring grazing management of winter annuals

The fieldwork of this experiment was finalized in May 2018. The samples will be analyzed for their nutritive value in summer 2018 and the results published in 2019.

7.4.2 Mirror trial site in Western Australia

Experiment 1: Yield and forage quality of mixtures of vetch and cereal mixtures.

This experiment was designed to complement activities in Afghanistan and Turkey and provided an opportunity for training the Afghan researchers who visited Australia in October 2016. Three species of vetch, common (*Vicia sativa*), purple (*V. bengalensis*), and woolly pod (*V. villosa*) were sown alone or in 1:1 mixtures with forage oats or barley. Each treatment was sown as four replicated plots (1.5 m × 20 m) and randomly distributed in four experimental blocks. The site at Kellerberrin, Western Australia, was a sandy loam, with pH 5.2 ($CaCl_2$). Total seeding rate was 40 kg ha^{-1}, either the species alone or in mixtures. At sowing, 100 kg of DAP fertilizer was applied. The site received 401 mm of annual rainfall in 2016 although only 190 mm fell during the growing season (May–Nov.). Low seasonal rainfall, particularly in spring, means that the results are unlikely to be representative of a typical season in this area. The vetches were inoculated with Australian commercial vetch inoculant prior to sowing. Part of the plots were harvested by mowing to 4 cm at 116 days after sowing, which was prior to the vetch flowering and at mid-booting stage of the cereals. This was to simulate grazing or a hay cut.

The DM yields at the first cutting time ranged from 1900 kg ha^{-1} for common vetch to 5400 kg ha^{-1} for barley (Fig. 24a). On a pairwise comparison the pure oat and barley treatments yielded significantly more DM than legume monoculture treatments but not the mixture treatments. The vetch species generally comprised around 40% of the DM yield in the mixture treatments. Purple vetch was the most productive legume monoculture. The second harvest was conducted 140 days after sowing when both the cereals and vetches were flowering and therefore at peak biomass. The DM yields ranged between 9500 kg ha^{-1} for oats alone and 3400 kg ha^{-1} for woolly pod vetch alone (Fig. 25b). The oats appeared more competitive against vetches, which on average comprised 38% of the DM in the mixture, compared to barley where vetch represented 58% of the DM produced. The 30 days of regrowth was poor after mowing and combined the yield prior to mowing produced similar to considerably less total DM yield than the unharvested plots. An unusually dry spring means that this result may be atypical. The proportion of vetch in the biomass remained the same with or without mowing. After mowing, oats remained more competitive against vetch than barley, with vetch representing 26% and 71% of the biomass, respectively.

Fig. 25 presents the dry matter digestibility (DMD) and CP content of samples at each time period. The majority of samples from the first cutting in September had sufficient energy and protein to allow for modest ruminant growth (Fig. 25a). The exception was for the tetraploid ryegrass that was very poor and the barley and oat monocultures that were protein deficient (CP of 5.8–7.8%). Adding legumes to cereals tended to decrease digestibility of the diet but increase the CP content. Fig. 26 presents DMD data combined with biomass production to give estimated ME (MJ ha^{-1}). The barley and oat treatments yielded 40,000 MJ ME ha^{-1} and the next most productive treatment was woolly pod vetch mixed with barley at 35,000 MJ ME ha^{-1}.

Leaving plots uncut until November led to a large decline in CP across most plots but not a large decline in DMD (Fig. 26b). The treatments that would allow a 50-kg wether to maintain liveweight include the three vetches, the three barley–vetch mixes, and the mixed common vetch–oat treatment. In terms of ME yield, oats was superior with 96,000 MJ ME ha^{-1}, followed by woolly pod–oat mixture (80,000 MJ ME ha^{-1}) and purple vetch–oat (75,000 MJ ME ha^{-1}; Fig. 26b). The poorest treatment was the woolly pod vetch monoculture with 28,000 MJ ME ha^{-1}.

Regrowth from plots that were cut in September had higher nutritional value than uncut plots with all treatments having DMD and CP values above the minimum maintenance requirement for a 50-kg wether (with the exception of tetraploid ryegrass; Fig. 3c). The estimated ME was low, ranging from 7000 for barley to >13,000 MJ ME ha^{-1} for purple vetch and tetraploid ryegrass (Fig. 26c). The data indicated that tetraploid ryegrass was unlikely to have had a large increase in digestibility over time. These differences in feed quality would lead to different production outcomes, depending on the production system (maintenance vs fattening vs reproducing or lactating). If feed conservation is not an option, the value of the feed resource is also a function of feed demand within the livestock system. These data will be subject to feed base modeling with data from 2017 in Australia and data from the sites in Afghanistan and Turkey.

Despite a poor season with less than half the average growing season rainfall, the results were not dissimilar to expectations. The cereals provided the most feed, especially early in the season, while they maintained digestibility, CP became deficient as they matured. Mixing cereals with vetches led to a decline in biomass production compared to cereal monocultures but higher CP levels. In Australian systems, where producers are heavily reliant on herbicides, these mixtures are problematic to manage so unlikely to be adopted based on these figures. Of the mixtures, woolly pod vetch and oats seemed the most promising. Cutting to simulate grazing led to biomass with superior nutritional value compared to uncut plots. Unfortunately, the poor season limited regrowth after cutting so there was very little biomass. This experiment needs to be repeated. In June 2017, another experiment was established with varying proportions of vetch and cereal and also three rates of N to evaluate the influence on cereal protein content and also how it may change composition when mixed with legumes.

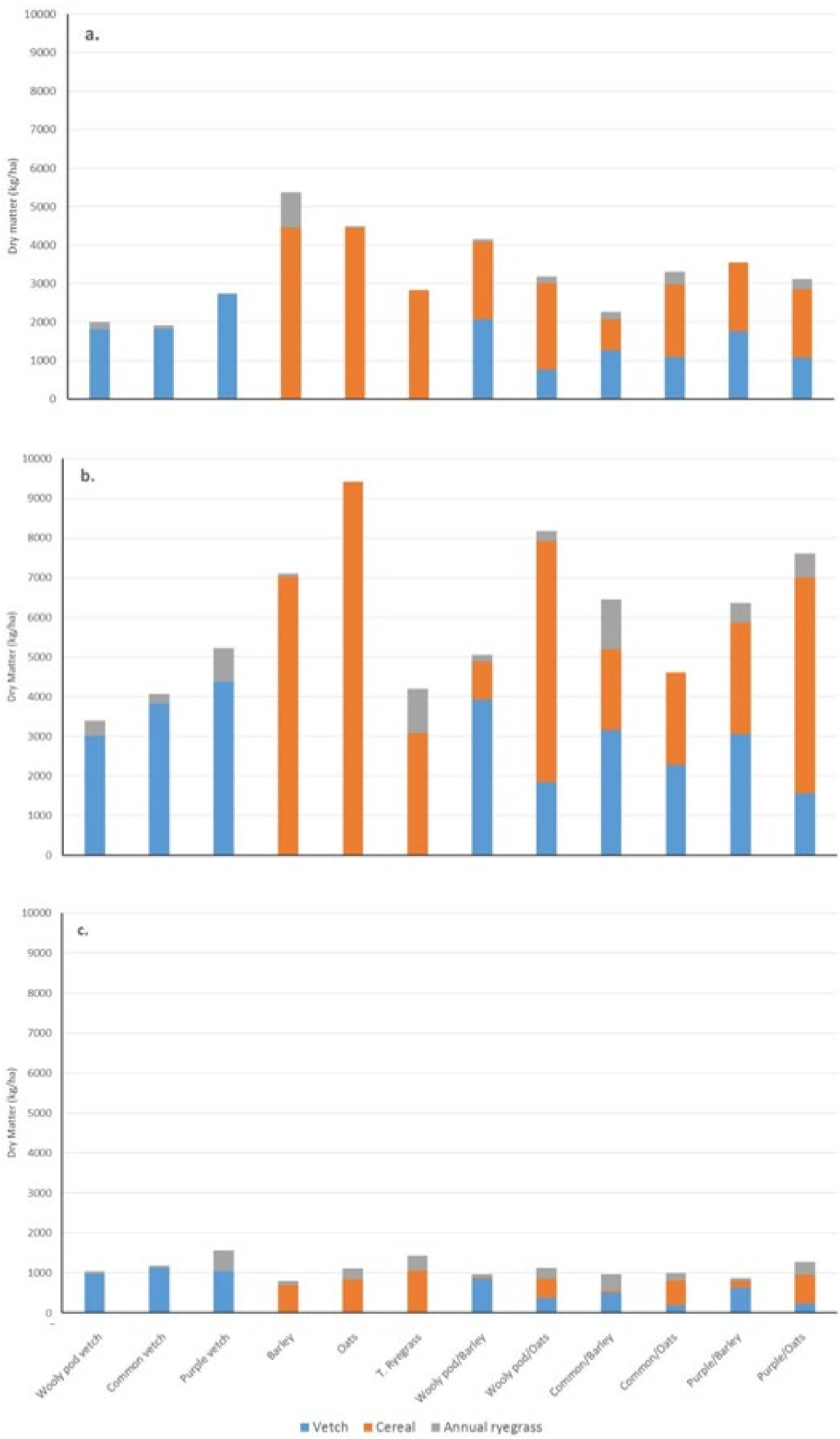

Fig. 24. Dry matter yield (kg ha^{-1}) of vetch–cereal mixtures sown at Kellerberrin, Western Australia. Mean biomass of plots sampled on (a) 16 September 2016 and (b) 11 October 2016 and (c) regrowth of plots cut on 16 September 2016 and sampled on 11 October 2016. The annual ryegrass component was self-sown (weed).

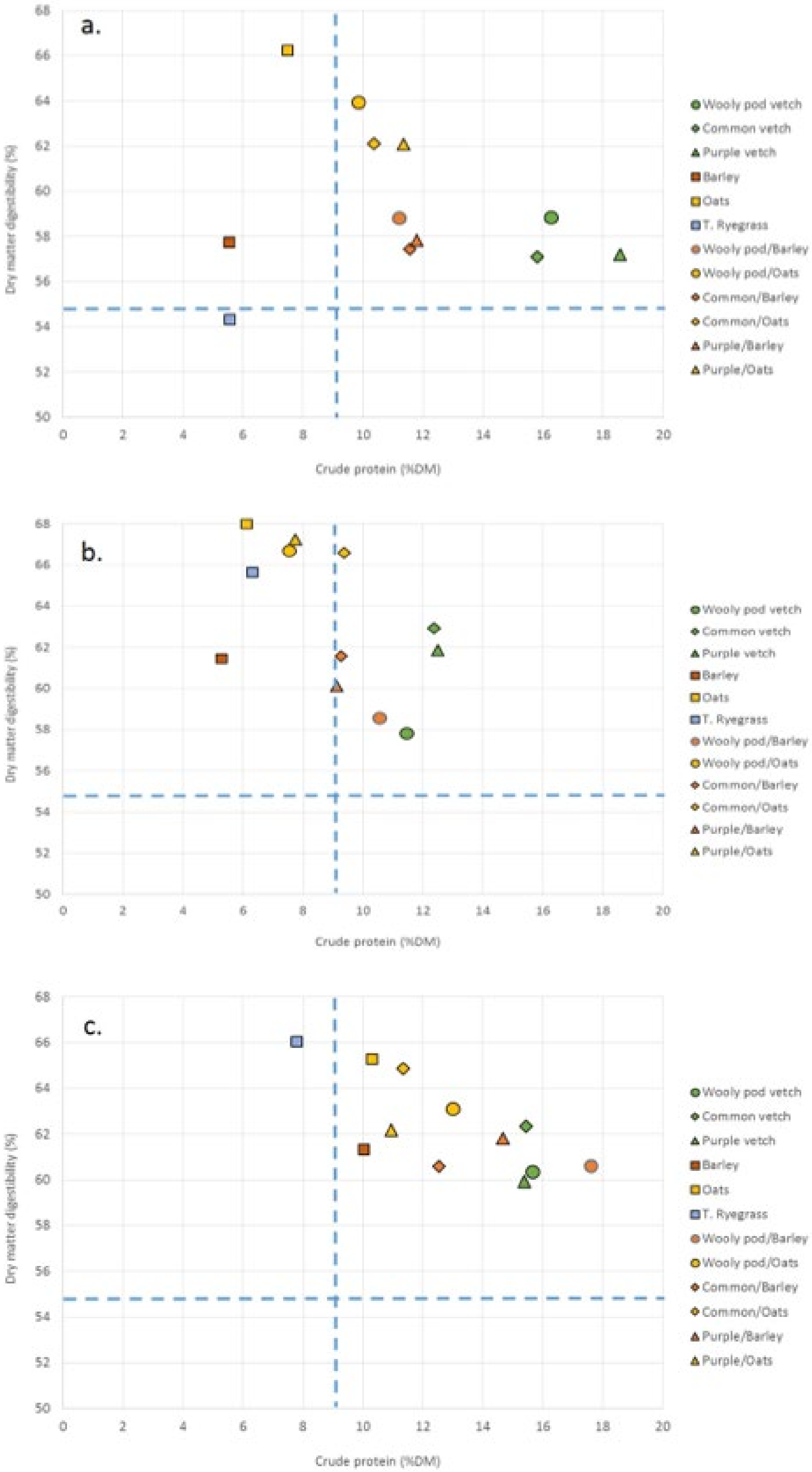

Fig. 25 Dry matter digestibility and crude protein content of the biomass samples from the three harvests. Mean biomass of plots sampled on (a) 16 September 2016 and (b) 11 October 2016 and (c) regrowth of plots cut on 16 September 2016 and sampled on 11 October 2016. The blue dashed lines represent the energy and protein content where the diet is deemed to be deficient and a dry 50-kg wether (A castrated male sheep) is unlikely to maintain live weight.

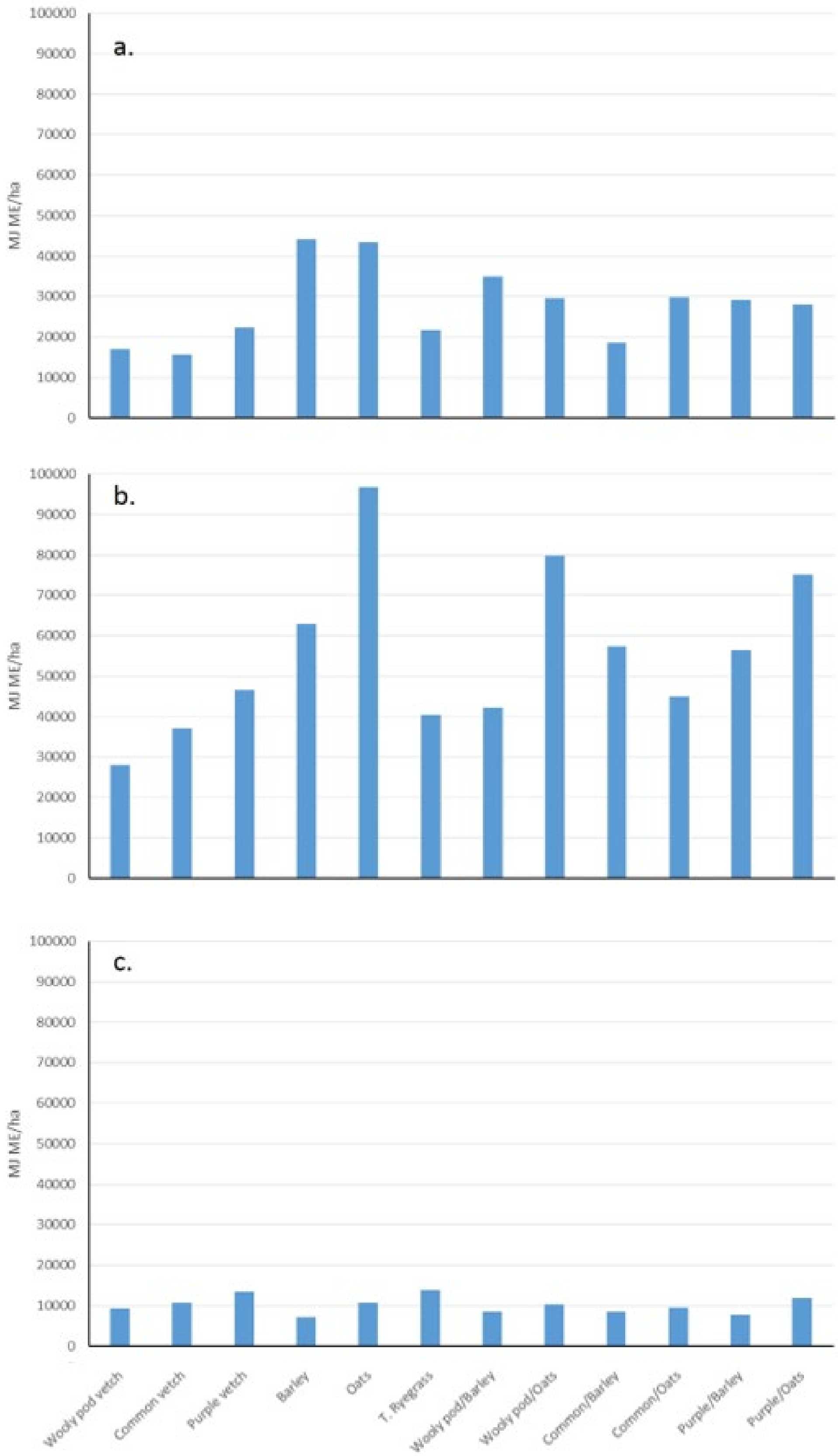

Fig. 26 Metabolizable energy yield (MJ ME ha^{-1}, calculated at the maintenance level of feeding) of vetch–cereal mixtures sown at Kellerberrin, Western Australia. Plots sampled on (a) 16 September 2016 and (b) 11 October 2016 and (c) regrowth of plots cut on 16 September 2016 and sampled on 11 October 2016.

7.5 Capacity development and gender

Research trials, within which the effects of seeding rates and planting of forage legumes and cereals in mixtures relative to forage monocultures were tested, improved both practical and theoretical knowledge and understanding of national research staff. Through engagement with ICARDA, CSIRO, and Murdoch University scientists, national researchers sharpened their practical skills in relation to (i) evaluation of seedling survival rates – germination, field establishment, and limiting factors (seed dormancy and temperature) in annual and perennial forages; and (ii) avenues for addressing issues related to effective on-farm forage and fodder crop and seed production. There were 18 capacity development events undertaken during the project (Appendix 1). In total, 445 participants benefited from these courses, including 53 females (12%). The themes were carefully selected in consultation with MAIL and ACIAR to enhance capacity of ARIA in aspects related to forage production. Not only theoretical, but in most cases practical, sessions were conducted with hands-on experience to ensure each participant was able to undertake similar trials or data analysis on his/her own. Inclusion of participants from international development organizations also ensured that processes and technologies developed were relevant to anticipated end users, with avenues assessed for efficacy in scaling-out of processes and systems developed; as well as for broad uptake of varieties tested and ultimately introduced.

Although genotypes were evaluated, and source seed produced, large-scale seed multiplication and commercialization by VBSEs and PSEs continues to be constrained by limited national capacity to operate the complex variety evaluation and release processes stipulated within the national seed laws and regulations. Project scientists from ICARDA and Australia tried their best to work closely with national counterparts on navigating through the inherent complexities. Unfortunately, the working environment in Afghanistan prevented visits by key project personnel from ICARDA and Australia. Given stringent regulations and caution exercised by national systems in releasing forage varieties, the best that this project initiative can hope for in the short term is for the tested varieties to be introduced for large-scale verification. There is good reason to believe that this will occur in due course, and particularly so given that the project has delivered data and scientific evidence to support adaptability as well as demonstrated evidence in terms of demand from farm households in a number of provinces. One clear constraint within this operating environment, however, is lack of seed availability to put more land under demonstration and further research trials. This is due to (i) time lag required to generate seed, (ii) delays on the part of the national varietal release committee, and (iii) delays in securing larger areas of land within research stations to support trials and multiplication. These challenges, as well as avenues for resolution, are in the hands of the national system. The project initiative has provided knowledge, methodologies, and processes for the national system to act. Contacts have also been established such that future need for importing seed, within national seed system regulations, can be facilitated with relative ease.

In addition to the support provided to national systems for informing varietal introduction and release, research trials generated significant interest from the development community, thereby allowing for pressure from outside of the national system to support varietal introduction. Through ICARDA facilitation, the Aga Khan Foundation – a reputable international development organization – is collaboratively involved in overseeing demonstration trials within provinces outside of the targeted project area and providing relevant benefits and outcomes to farmers within its catchment area. Although seed produced through these demonstration trials is legally owned by ARIA, given that systems for introduction are still not in place for tested varieties, farmers involved in demonstration benefit from the retention of forage generated, thereby reducing the feed gap within their localities. Women remain key beneficiaries in this regard, given social and cultural norms related to the feeding and upkeep of small ruminants – a duty that falls to females within farm households.

Gender-related research, within the targeted provinces of Baghlan and Nangarhar has revealed a better understanding of challenges and opportunities for innovation systems to foster equity in the benefits derived from more effective forage production and marketing systems; as well as equality in opportunity to access services and resources therein. One key lesson learned is that social and cultural norms related to female access to knowledge and learning opportunities are often flexible and not as rigid as often portrayed. Equally important is the realization that constituent groups within Afghan society have differing opinions and visions in relation to constraints that plague the further development of forage production and marketing systems. Break-out sessions from a workshop held in Dubai (3–5 July 2017) exemplify these differences:

Constraints	Underlying cause
Group 1 (women)	
Lack of improved seed varieties in local market	Not enough extension; need for female extension
	Lack of effective communication between governmental agencies and farmers
	Less attention devoted by ARIA and international research sector to the release of new forage varieties
Culture and the interest of farmers to produce food crops of selected forage seeds	Extension agents do not actively promote the planting of forage
	Competition between the production of food and fodder crops
	Farmers follow what their parents planted and not necessarily what is in demand
	Farmers view food crops as sources of cash
	Farmers lack markets for forage crops and do not ascribe value to productivity gains of livestock through greater (volume and nutrition) feed and fodder availability
Limited land for forage production	Issues of access to credit to support land rental or purchase
	Lack of profitable markets for forage crops
	Small land areas, particularly in Baghlan, that lead to competition between food and forage crops; the latter having less priority from a food security perspective
Group 2 (Development practitioners, NGOs)	
Weak land cadastral system	Small land holdings (poverty)
	No clear land ownership rights policy/system
	Land grabbing (illegal)
Land degradation/over-exploitation of rangeland and pastures	No proper grazing plans/system in place or not being implemented
	No one cares about issues related to communal land
	Shortage of animal feed/fodder and fuel wood (energy for domestic consumption)
Poor awareness about the importance of rangeland and tenure rights	High rates of illiteracy within communities
	Rangeland/pastures are a neglected sector for both the public sector and civil society
	Vague land tenure arrangements
Group 3 (MAIL)	
Lack of clear strategies and implementation plans for natural resource management	Impact of protracted conflict
	Lack of functional government in place
	Weak institutional arrangements and integration
	Limited government capacity

Lack of coordination and proper prioritization of interventions and investments	Deviation of development partners from government priorities
	Focus on short-term benefits
Poor community mobilization and empowerment	Local community resistance to change
	Poor level of education and public awareness
	Community leadership issues (inclusiveness)
Group 4 (private sector)	
Lack of real data and information from market and farmers	Lack of coordination and communication between public and private actors
Lack of government support for introduction and production of forage seed varieties	Limited capacity
	Lack of coordination and communication with stakeholders
	Lack of improved seed of forage varieties

This study further confirmed that that gender roles, norms, and relations in different but related ways, affect women's and men's opportunities to access and benefit from innovation processes in the forage systems in Baghlan and Nangarhar. As such, the study illustrated the importance of embedding different aspects of gender in agriculture innovation system (AIS) perspectives to better understand the nature of relationships between actors in innovation systems, and how these gendered relations shape women's and men's experiences as innovators. Three important insights are evident from the study for research and development practice. First, the gender norms of seclusion and the appropriateness of female–male interactions, as well as perceptions about women's bodily strength or intellectual capacity, greatly affect gender relations in the forage innovation system in Baghlan and Nangarhar. These gender relations in turn shape the ability of different groups of women to learn about and adopt new farm practices that can help them to reduce their forage feed gap. Second, an overly strong analytic focus on male–female dichotomies can wrongly portray women as a homogenous group in which all women face the same challenges and opportunities in a given innovation system. Indeed, the study found that the social markers of marital status and household status shape the experiences of different women and men farmers in the forage innovation system. Finally, the study argued that there exist several innovation spaces in the forage innovation system in Baghlan and Nangarhar. Researchers and development practitioners should strive to understand how innovation spaces value and promote certain kinds of innovative activity and 'innovators', while devaluing and even actively discouraging others through the production and reinforcement of particular gender roles, norms, and relations.

8 Impacts

Objective Verifiable Indicators	Achievement (Annual and Cumulative)
Number, type, and productivity benefits of new forage and fodder options promoted. • At least three new forage cereal/legume and two shrub species promoted • Expected increase in forage production of 25% through the promotion of high-yielding forage species with an extended season of forage availability • 1000 new households growing promoted forage species will decrease the lamb mortality rate by 15–20%, increase weaning weight by 3 kg per lamb, and increase ewe prolificacy by 15% in the short term • Feed costs reduced by 10–15% • Overall benefits from increases in forage and animal production result in 10% higher incomes	A total of 102 improved annual and perennial forage legumes and cereal genotypes of various origins, together with 18 shrub species were evaluated for their DM and nutritive value content in Baghlan and Nangarhar Provinces (irrigated environments) and Mazar-i Sharif (rainfed environment). Based on agronomic performance, farmers' perceptions, and perspectives on ease of seed production, 9 annual and perennial forage crops (Oat Yeniceri , Triticale Tatlicak , Vicia sativa Rasina , Vicia sativa Baraka, Narbon vetch cv Velox, Forage pea cv #40-10, Sainfoin cv Ozerbey and Alfalfa cv Sequel)were identified to have potential (economic and environmental) value within regional contemporary crop–livestock production systems; and more generally within the republic as a whole. Seeds of these were multiplied and are being demonstrated on-farm to promote familiarity and interest prior to official introduction/release. The objectively verifiable indicators listed to the left, and as defined in the initial project document, are now questionable in light of a better understanding of regulatory systems. It appears that there was an early presumption that forage crops would not enter into the formal system for seed production and commercialization – there is still ambiguity in this regard. Farmers engaged with on-farm demonstrations have the right to retain forage produced with the varieties tested and demonstrated for use as forage, but not the right to sell or use the seed in subsequent cropping seasons for forage crop production without prior approval. Thus, given that the varieties under trial have not officially passed through the seed committee for widespread release, farmer-to-farmer dissemination, as well as introduction into local and national seed value chains has not taken place. By late 2017, farmers will have limited access to the promising genotypes through the large-scale verification and demonstration trials that the project hopes will be jointly undertaken by the Aga Khan Foundation (possibly Action Aid in addition) and ARIA. At best, the on-farm demonstrations are raising awareness on the potential of new varieties and possibly (hopefully) demand for seeds in anticipation of release for broad uptake.
Number and percentage of farmers (men and women) incorporating new forage and fodder options on their landholdings: • Total of 1000 farmers (80% male, 20% female) to be engaged in the new forage production options	As an initial step, 24 farmers in Baghlan and 24 farmers in Nangarhar were engaged in the maintenance of on-farm observation plots in order to provide farmers on adjacent lands with visual proof of higher productivity and economic value. Through field days, on-farm demonstrations, and linkages with other ongoing projects this initiative was further attempting to reach out to crop–livestock farmers, and farmer unions in Nangarhar Province. The "Dairy Union", representing approximately 1500 farmers is one specific example of expressed (consolidated) need for improved forage seeds and tested agronomic packages as expressed by farmer members. As forage production in the country is much lower than demand, there is a presumption that any variety/technology introduced by the ACIAR-Forage Project will be quickly adopted by farmers, either individually, or through institutions such as the Dairy Union who are 'customers in waiting' for the outputs. Similarly, the recently completed MAIL-IFAD-ICARDA dairy goat project established

Objective Verifiable Indicators	Achievement (Annual and Cumulative)
	a network of 1200 woman eager to continue their engagement with research for development initiatives through the adoption of effective contemporary production practices (soft knowledge) and technologies (embodied knowledge) generated through this initiative. Although there is expressed interest from both of these farmer networks, effective engagement and linkages are limited by the extent of seed availability, which is expected to be available for greater distribution in early 2018. More importantly, however, are regulatory requirements that restrict widespread dissemination of seed prior to formal release/introduction.
Area planted and productivity benefits achieved by farmers incorporating new forage and fodder options: • Area planted with new forages at research and demonstration sites is expected to total 10 ha in each province. At the provincial level, 200 ha of land to be dedicated to new forage production options	Twelve hectares of land in Nangarhar are currently utilized as on-farm demonstration plots, but in Baghlan the size is much smaller (0.1 ha) due to security concerns. In terms of forage trials on research stations, 0.25 ha in Baghlan and 0.80 ha in Nangarhar are under project oversight. Attainment of desired land under demonstration and research trials continues to be limited due to lack of seed availability. The lack of availability in seed is due to (i) time required to generate seed, (ii) delays on the part of the national varietal release committee, and (iii) delays in securing greater amounts of land within research stations for research trials and multiplication given what appears to be political sensitivity in this area and (protocol and institutional) delays in the engaging of formal discussions with the Ministry of Agriculture.
Accessibility of new forage and fodder options for farmers: • Seeds and planting material available through two VBSEs and four community-managed plantations	Quality seed and seedlings of the 10 tested, well-adapted and smallholder livestock-preferred forage and pasture species and cultivars selected through the project have been planted in Dare-e-Noor and Farm-e-Jadeed Districts of Nangarhar, and also in Baghlan, to produce, process, and make available for further multiplication and dissemination. There has unfortunately not been any movement on seed commercialization due to stringent regulations related to formal variety release that are complex, lengthy, and fraught with difficulties in an environment with both limited national capacity and budgetary resources.
Number of village and informal seed programs incorporating new forage and fodder options, and quantity available: • Two of 17 well-established VBSEs will be used for forage seed processing and delivery. In addition, four community-based forage shrub plantations will be established, to provide shrub seed and seedlings to farmers	Specialized threshing and aspiration machines for forage crops were purchased from Kimseed in order to upgrade the quality of seed produced from adapted and small livestock holders' preferred forages and pastures for further multiplication and use. Two training courses on forage seed production and post-harvest seed operations were completed in the fall of 2016 and early 2018. Although genotypes have been evaluated, and source seed produced, large-scale seed multiplication and commercialization by VBSEs and PSEs is constrained by limited national capacity to operate the complex variety evaluation and release processes stipulated within the national seed laws and regulations. Project scientists from ICARDA and Australia continue to work with national counterparts on navigating through the complexities as well as in the imparting of experiences internationally; with a desire that regulations related to forage varieties within national regulations for release will be relaxed over time.

Objective Verifiable Indicators	Achievement (Annual and Cumulative)
Improved capacity and policy commitment of Afghan agencies in the ownership and operation of testing programs for new forage and fodder varieties: • Provision of technical backstopping and in-service training to enhance the capacity within Afghan research institutions and agricultural service providers	A total of 20 in and out of country training events were undertaken on forage and forage seed production, concepts related to gender, intra-household survey design and implementation, as well as the design and management of basic agronomy trials since the inception of the project. In April 2015 and 2016, two training courses were realized in Turkey for Afghan NARS. Another training course for NARS partners was undertaken in Amman and Cairo on 27 April to 3 May 2017. Workshop on forage value-chain innovation and gender roles involving different stakeholders was organized in Dubai 2017. Extended training in Australia for two young field staff on forage agronomy and animal nutrition was also realized in the fall of 2016. Training of Afghan females (six) in shrub propagation techniques, nursery management, and enterprise development was conducted in the first quarter of 2018 in Amman, Jordan. Two technical training sessions in the set up and operation of the Kimseed seed cleaning equipment were provided in late 2016 and March 2018 for staff from MAIL, as part of the training workshop held in Nangarhar. Moreover, two technical visits of national project and MAIL staff to ICARDA seed facilities in Lebanon as well as collaborating institutions in Perth (Murdoch University, CSIRO). A specialized training course on data management and analysis was organized in Kabul for ARIA staff in 2018. Three field days demonstrating forage trials targeting farmers, extension officers, and agriculture students were organized in 2015 and 2016. Two transition workshops were conducted to increase the readiness of engagement and self-monitoring of the activities beyond the project lifetime of NARS. A list of participants in the training is provided within the latest version of the technical report, a link for which is provided within List of publications produced by project.

8.1 Scientific impacts – now and in 5 years

The project has studied the dynamics of forage production within the practices of crop–livestock production in the target regions of Afghanistan. The baseline survey provided basic insight into the current state of feed resources for livestock. The assessment and testing of adaptability for improved forage varieties with varied physiological and functional attributes validated production potential and suitability for crop–livestock farming systems of Afghanistan. Research trials on sainfoin, alfalfa, berseem clover, and winter annual cereals and legumes are providing knowledge on options for how to better utilize scarce inputs such as water and fertilizer effectively in forage production – an area that has not received due research attention in Afghanistan – neither historically nor contemporarily.

Ultimately, increased productivity within forage-based crop–livestock farming systems is expected to increase incomes as well as security and asset wealth in healthy livestock holdings. To what extent this is achievable in the long-term remains unclear given ongoing conflict and an inability to administer research trials within Afghanistan under desired research conditions. To this end, the mirror trials in Western Australia and Turkey provided insight into agronomic and animal production potential of forages being introduced into Afghanistan, under ‘more ideal’ production and management practices, and within stable security environments. Mirror trials provided benchmark indicators which are helpful in uncovering avenues and approaches for bridging the gap between experiential outputs (in field and on-station in Afghanistan) and those obtained under ideal conditions. Without further support of external funding, this avenue for sustained research in relatively more optimal conditions will be closed. However, testimonial from a MAIL partner (online link provided in Appendix 1) provides insight into a number of areas where national partners exposed to international research sites see value in ongoing research (new and improved) being undertaken in Afghanistan. The agronomic and animal feeding experiments within Afghanistan and mirror trial sites provided large amount of highly valuable and novel information for farmers and scientists. Some of the results were published in highly respected journals (Journal of Animal Science and Field Crop Research) indicating the potential importance and impact of the information published.

Through greater interaction within the project working committee, and within the process of handing over data and project information to the national system of research, ARIA has taken on a more prominent role in the assignment of field staff for maintenance of on-station trials. Although issues remain concerning budgets to support basic maintenance, there is clear indication of growing ownership of research trial sites. This is a positive development in view of maintenance of on-station trials and demonstration sites after the end of the project. Equally important is the engagement of a reputable international development organization – the Aga Khan Foundation – in a partnership with ARIA, wherein demonstration of tested varieties is being introduced into provinces outside the project catchment area, thereby providing further data and evidence to support varietal introduction and, in the medium to long term, varietal release.

8.2 Capacity impacts – now and in 5 years

In-service training activities for both national system and national ICARDA research staff have provided improved knowledge and understanding on dryland forage and forage seed production systems and how to better design and manage basic forage experiments with greater efficacy. They have also helped in a better understanding of the scientific process and created opportunities for establishing collaborative multidisciplinary work between national research systems and civil society collaborators. Whether national budgets will continue to support the research undertaken within the current life of this project, as well as after its completion, remains an open question.

In realizing that a significant number of international organizations are active in Afghanistan, within the area of agricultural development, attention to training staff of NGOs is now well appreciated. In 2016, 13 staff of Action Aid in Mazar (two female and 11 male) and 15 staff in Bamyan (two female and 13 male) were trained, together with one research staff member based at ICARDA offices in Mazar, on aspects related to *Atriplex* plantation and effective seed production practices.

Two young ICARDA staff trained by CSIRO and Murdoch University collaborators are now applying their new skills learned in Afghanistan. One recently completed a nodulation survey for forage legumes under trial within this project, with technical backstopping from Murdoch University (Brad Nutt). The other is applying his new skills within the ACIAR-funded watershed initiative.

There were 18 capacity development events undertaken during the project (Appendix 1). In total, 445 participants benefited from this initiative, including 53 females (12%). The themes were carefully selected in consultation with MAIL and ACIAR to enhance capacity of ARIA in aspects related to forage production. Not only theoretical, but in most cases practical sessions, were conducted with hands-on experience to ensure each participant was able to undertake similar trials or data analysis on his/her own. Equally important was the inclusion of participants employed with international development organizations for out-scaling of processes and demonstration of technologies tested and developed.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

In light of regulatory restrictions for release/introduction, it is too early to gauge economic impacts that can be directly or indirectly attributed to the project's interventions. The project was premised on the notion that a reduction in winter-feeding gaps will lead to improved livestock productivity as well as preservation of capital assets (live animals) and stored wealth that can be liquidated at a time of need. Based on the outcomes of the project, this premise still holds and is relevant. In particular, variety comparisons and agronomic research findings are highly relevant to the existing forage production systems of Afghanistan and, when the agronomic packages are applied, they present potential to increase biomass production and farmers' incomes. For instance, the results indicated that (i) alfalfa production can be increased by more than 5 t DM ha^{-1}; (ii) although the differences in biomass production of annual legumes were marginal, with the introduction of improved varieties, seed yield can at least be increased by 60%. Similarly, small-grain winter cereals can be intercropped with berseem clover to increase potential biomass production by up to 60%; (iii) winter annual cereal–legume mixtures can help reduce the winter feed shortage both in rainfed and irrigated areas; and (iv) the dual-purpose management of the introduced cereals holds promise to reduce the feed gap without penalizing food production and to better integrate crop and livestock systems especially in drylands where forage deficit is severe. An extra 1–2 t DM ha^{-1} of high-quality forage can be grazed by livestock in early spring when the feed deficit is greatest. The economic benefit of these potential increases can be immediate. The key lies in the ability for national systems to move forward on the process of varietal introduction and large-scale verification to realize the anticipated economic potential. Data and evidence has been generated to support this move through facilitation provided by this project initiative. Whether or not national systems move forward with this knowledge is a matter of national political economy.

8.3.2 Social impacts

Gender-focused research attempted to answer three overarching questions that will be of immense importance for developmental outcomes once the project initiative formally hands over facilitation of processes and systems developed, data, and knowledge gathered:

1. What are the systemic constraints to closing the winter livestock feed deficit within existing value chains, and what opportunities (entry points) exist to mitigate these constraints?
2. For different typologies of households (female-headed and conventional) how do the four dimensions of (i) decision making; (ii) norms and values; (iii) access, control, and use of resources; and (iv) division of 'labor and responsibilities' affect issues of equity and inclusivity within forage production systems?
3. What are the perceptions and realities related to the sharing and development of knowledge for women within agricultural production systems in Afghanistan, and more specifically within forage production and marketing systems?

The research shows that men and women are differently embedded in the forage innovation system. Data from the research illustrates that the space to innovate for farmers highly depends on their relations with other actors, the norms that are driving the system, and the resources individuals can mobilize to improve their practices. These norms, roles, and relations are highly gendered.

The intentions of women farmers to innovate often differ from those of men as a result of gendered roles and responsibilities within the household and community. For example, women are responsible for animal welfare, food security, kitchen gardens, and poultry, which affect their interests and preferences for trying out and adopting new seed varieties and related innovations (such as new storage methods).

The space to innovate in a forage system is also influenced by the ability to establish and maintain relations with other actors. The study shows that women have limited access to formal sources of information and knowledge, such as MAIL, NGOs, or ICARDA. Women largely depend on their social network, including family, neighbors, and other farmers to access information that men readily access through the sources mentioned above. Male farmers included in the study have access to more formal sources of information, including government extension (MAIL), NGOs, and projects such as the ICARDA led project. These actors play an important role in bringing about innovation. Further, due to strict gender norms around women's mobility, women are often effectively prevented from interacting with male actors that are considered not to belong to the family. Data show that women farmers work most of the time inside the household, or on land in close proximity to where they live. However, it should be stressed that widowed women and women heads of households do break these gender norms as they are forced to take on traditional 'male roles' in agriculture. As such, female heads of households in Baghlan and Nangarhar are often under immense labor pressure as they are solely responsible for both cultivating the land as well as conducting reproductive roles within their households. It should also be stressed that a woman's age and education also impact her ability to access information and challenge traditional gender norms surrounding the division of labor, mobility, and autonomy.

The research also finds that gender norms and gender myths are consciously or unconsciously reproduced by different actors within the forage system, effectively reinforcing existing gender inequalities and hampering women's space to innovate. For example, women's access to grazing grounds is limited by the idea that it is not safe for women to leave their compounds. Hence, they are forced to start feeding the animals fodder in autumn. As a result, women experience a forage gap relatively early and have different strategies to deal with the gap compared to male farmers. Another norm, i.e. that woman should not interact with men from outside their family, highly influences women's opportunities to access formal sources of knowledge. As a result, data show that women are rarely given the opportunity to test new innovations (for forage production and storage) before the innovations have been tested by men. An interesting exception is that women are 'allowed' to be the 'innovators' in spaces considered to be under women's control, such as kitchen gardens and poultry farms. In conclusion, the study identifies both challenges and opportunities for women to create space to innovate, exert agency to mobilize support from their informal networks, both as part of a male-headed household and as female heads of households. These challenges and opportunities are mediated by gender norms, roles, and relations produced and reinforced by the forage system. It is imperative that these norms, roles, and relations are considered when attempting to introduce new forage varieties into the forage system in Baghlan and Nangarhar as they might effectively prevent women from both adopting and benefiting from the new varieties.

Co-opting national agricultural research systems (NARS) partners and private sector participants into the development and implementation of this research has uncovered a wealth of information on bias related to the roles of women in agricultural production and marketing. Through greater interaction and joint research, one expected outcome is a better understanding of the need for sensitivity in recognizing these prejudices and in addressing the core underpinnings of bias to meaningfully affect change.

8.3.3 Environmental impacts

Notwithstanding the nature of this initiative, largely aimed at fostering the development of national systems to support efficacy in forage production and marketing systems, the relatively short timeframe under which project activities were undertaken does not lend itself to an assessment of environmental impacts. Over time, however, and if processes and systems are institutional, there is anticipation of improved soil fertility and enhanced water productivity within both rainfed and irrigated production environments. In particular, the successful nodulation of the introduced forage legumes indicates the potential for improve the fertility and physical conditions of soil, thereby reducing erosion and associated nutrient losses. Similarly, adoption and potential incorporation of dual-purpose management cereals can relieve grazing pressure on marginal rangelands in early spring.

8.4 Communication and dissemination activities

The main purpose of forming a project working committee was to enhance effective communication between project partners and foster ownership of the national system for the many processes, systems, and products developed. This would also serve as a transition mechanism to formally hand over the forage project to MAIL.

A number of publications were produced, inclusive of ISI papers, conference proceedings, technical reports, and blogs that aided efficacy in the communication of project findings to national and international audiences. The following papers are planned for publication:

- Effect of seeding rate on the yield of legume–cereal bi-crops in irrigated and rainfed production systems of Afghanistan
- The effects of a forage-based and concentrate feeding system on the performance and meat quality of crossbred and fat-tailed, indigenous lambs
- Effect of nurse crop and seeding rate on the persistence, productivity, and nutritive value of sainfoin in a cereal-based production system.

During the last year of the project and based on recommendations from ACIAR and ARIA, three transition workshops were held in Kabul attended by ARIA staff, ICARDA, and an ACIAR monitoring and evaluation advisor. These workshops presented opportunities for all concerned parties to exchange ideas and assess progress toward achievements of project outcomes.

All project deliverables and outcomes are being posted at ICARDA's repository site Monitoring, Evaluation and Learning (MEL) for better management of information and data (refer to Section 10 References).

Seeds of proven forage varieties were distributed to various partners (e.g. ARIA, AKF, and Action Aid) for further testing and demonstration (refer to Section 6 Achievements).

9 Conclusions and recommendations

9.1 Conclusions

Despite inherent complexities in the operating environment within the war-torn republic, the project achieved a number of important outcomes:

- The project identified higher yielding alfalfa varieties for irrigated, and common vetch and oat varieties for rainfed, forage production systems. The imported alfalfa varieties can potentially increase biomass production by at least 5 t DM ha^{-1}. Three common vetch varieties were identified as superior varieties mainly from the seed production standpoint. Oat cv Yeniceri had a greater forage (up to 3.5 t DM ha^{-1}) and seed yield than local varieties. Oat also provided greater biomass yield when intercropped with forage pea. It is expected that the higher forage production will help livestock holders reduce the winter feed gap substantially and ultimately reduce feed costs by at least 20%.
- Credible field performance and superior nutritive value data from the germplasm adaptation trials and demonstrations support varietal introduction and release. Specifically, the following forage species/varieties can be promoted based on their greater forage and seed yields: Oat Yeniceri, Triticale Tatlicak , Vicia sativa Rasina , Vicia sativa Baraka, Narbon vetch cv Velox, Forage pea cv #40-10, Sainfoin cv Ozerbey and Alfalfa cv Sequel.
- A sizable seed stock from the promising lines was produced for further popularization, multiplication, and dissemination upon release. By replacing the local with introduced varieties, seed production can be increased by at least 60% in rainfed farming; however, further testing may be needed with a wider selection of varieties in different agro-ecologies of Afghanistan.
- Public awareness was created for effective forage seed demand upon variety release to facilitate scaling-out of processes and systems developed as well as broad uptake of technologies and varieties introduced. The potential adoption of the project outcomes may lead to higher household income.
- Capacity building was at the heart of this project. Afghan nationals benefited from international exposure to the best forage practices. Skills acquired would be valuable as long-lasting productive benefits.
- Scientific outputs (publications and data) to inform both policy and the research community were generated both within and outside Afghanistan. The mirror trial sites successfully served as training locations and more in-depth study sites for the target forage crops. Comparing benchmark indicators with those obtained within Afghanistan (on-farm and on-station) was helpful for understanding the gap between experiential outputs – obtained within a research environment plagued by continued concerns over security for both project staff and participating farm households – and those obtained under ideal conditions.
- Greater appreciation of the role of gender in research undertakings, specifically within the area of forage production and marketing systems, and within an environment where women continue to be marginalized in access to opportunity for gaining knowledge and equity in access to resources.

The forage project introduced crops for adaptation trials and possible introduction into the cropping and grazing lands. The species included legumes such as alfalfa, common vetch, grasspea, triticale, oat, narbon vetch, forage pea, and sainfoin; cereal crops triticale and oat; and shrubs such as *Atriplex* and cactus. The adaptation trials generated good performance results for the species tested. However, the introduced species have not been incorporated into a purposefully designed variety evaluation trial aiming at formal registration and release. The main reason for this is that no established variety evaluation and release system for introduced forage crops has been developed in Afghanistan. A systematic variety evaluation and release for oat, triticale, alfalfa, and *Trifolium* spp. does not exist within the republic. Consequently, adapted cultivars from the tested crop species can only be put into large-scale seed production and commercialization by public and private seed companies if, and only if, they pass successfully through a process of variety evaluation trials, with formal permission from the owner of the varieties. The latter is of little complication given ownership of a number is vested in ICARDA, and no objections have been obtained from private owners in Australia.

The republic is contemplating promulgation of a seed regulation policy, currently in draft form. Some of the cultivars tested may benefit from clause 11.2 stating that “All varieties of crops that are currently being multiplied under the certification scheme shall be considered as being officially released and shall be included in the first edition of the National List of Varieties. Traditional or local varieties of proven value may also be included in a separate section of the National List to enable the certification of such materials. The arrangements for varieties of perennial crops listed under Schedule 1C are described in Article 14.1 of the regulations.”

9.2 Recommendations

- Continue with discussions on how to leverage and move forward on systems and processes developed within the lifetime of this project. Specific action items recommended for ARIA include:
    - Validate the plant variety protection status of introduced cultivars and secure the necessary approvals and Value for Cultivation and Use and Distinctness, Uniformity, and Stability testing data required for introducing them into Afghanistan (supported by CSIRO and Murdoch University where Australian cultivars are concerned)
    - Extract performance data from the multi-location and seasonal adaptation trials to complement data from the country of origin (ICARDA has shared all data available with ARIA in so far as trials undertaken within the lifetime of this project initiative are concerned)
    - Formulation and submission of an application for registration and release of the cultivars for which all prerequisite conditions are met.

- It is essential that ARIA continues the seed multiplication activities. This can be done either through the traditional system of on-station multiplication or through alternative options such as in partnership with private and civil society organizations (e.g. VBSEs and international development organizations).
- Assessment of the seed systems and markets in Baghlan and Nangarhar Provinces from the baseline survey data collected under the forage project indicated the following:
    - Farmers’ knowledge of seed production standards is very poor and the necessity for strong extension efforts to raise farmers’ awareness is evident. Mass communication tools and hands-on training on seed standards are some of the ways to achieve this
    - Farmer-to-farmer (community) exchange is the common source for seed and information on many crops in Afghanistan and therefore crop-wise strategies for enhanced quality seed access need to be developed.
- Within the scope of this project, it was not possible to assess implications of using these proven forage varieties on animal health and performance. Therefore, an

integrated approach for assessing the impact of effective forage–animal relationships should ideally be undertaken by ARIA.

- The Community Livestock and Agriculture Project (CLAP), currently implemented by ICARDA, would do well in incorporating outcomes/learning from the forage project and pushing these forward in terms of scaling-out as well as scaling-up at the level of policy.
- Following on the gender-focused training in Jordan it was clear that Afghan women have significant potential to undertake and implement a women-led enterprise for producing seedlings. This can be supported through partnerships with international organizations and NGOs in collaboration with MAIL.

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10.2 List of publications produced by project

Papers (ISI papers and proceedings papers)

Ates, S., H. Cicek, G. Ozcan and M. Tezel (submitted). Effect of nurse crop and seeding rate on the productivity and persistence of sainfoin in Central Anatolia. 2018. Abstract accepted: Enhancing Productivity in a Changing Climate, ASA and CSSA Meeting, 4–7 November, Baltimore, Maryland, USA.

Ates, S., G. Keles, U. Demirci, S. Dogan and H. Ben Salem. 2017. Biomass yield and feeding value of rye, triticale, and wheat straw produced under a dual-purpose management system. *Journal of Animal Science* 95: 4893–4903. http://dx.doi.org/10.2527/jas2017.1888 http://hdl.handle.net/20.500.11766/8317

Ates, S., G. Keles, Y.A. Yigezu, U. Demirci, S. Dogan, S. Isik and M. Sahin. 2017. Bio-economic efficiency of creep supplementation of forage legumes or concentrate in pasture-based lamb production system. *Grass and Forage Science* 72(4): 818–832. http://hdl.handle.net/20.500.11766/6476 http://onlinelibrary.wiley.com/doi/10.1111/gfs.12291 http://dx.doi.org/10.1111/gfs.12291

Ates, S., M. Louhaichi and D. Feindel. 2016. Constraints to forage production and rangeland management in Afghanistan. 10th International Rangeland Congress. Saskatoon, Canada. http://hdl.handle.net/20.500.11766/5938

Ates, S., H. C. Norman, H. Ben Salem, B. Nutt and H. Cicek. 2015. Promising forage options to enhance livestock production in Mediterranean climate agricultural systems. Keynote Lectures. The 23rd International Grassland Congress. New Delhi, India, 20–24 November 2015 http://repo.mel.cgiar.org/20.500.11766/8300

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Tavva, S., R. Tellaria, Z. Bishaw, N. Abdul Aziz, S. Ates, Y.S. Saharawat and H. Esmati. 2015. Forage seed system, Indigenous knowledge and constraints of forage production in Afghanistan. The 23rd International Grassland Congress. New Delhi, India, 20–24 November 2015 http://hdl.handle.net/20.500.11766/4910

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Reports

Ates, S., Hassan, S., Biradar, C., Soofizada, Q., Esmati, H., Louhaichi, M. 2018. Characteristics of Baghlan and Nangarhar Provinces. Understanding forage production systems in Baghlan Province - forage options for smallholder livestock keepers in water-scarce environments of Afghanistan Project (AH/2012/021) funded by ACIAR. ICARDA. http://repo.mel.cgiar.org/20.500.11766/8314

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Kassem, S. and R. Mur. 2017. Understanding forage production systems in Baghlan Province. http://hdl.handle.net/20.500.11766/8306
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Nejatian A., M. Louhaichi and S. Hassan. 2018. Data collection, experimental design & data analysis in forage trials training course report.(ICARDA puplication) http://hdl.handle.net/20.500.11766/8279
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Tavva, S., R. Telleria and S. Kassam. 2015. Integrated baseline survey report (Baghlan, Nangarhar). http://hdl.handle.net/20.500.11766/8304

Communications (blogs and video):
Forage options for smallholder livestock in water-scarce environments of Afghanistan
https://livestock.cgiar.org/2017/07/05/forage-options-afghanistan/
http://hdl.handle.net/20.500.11766/8297

Improving forage value chains in Afghanistan blog
http://ttps://www.icarda.org/update/improving-forage-value-chains-afghanistan
http://hdl.handle.net/20.500.11766/8303

Ulufa* – "From Seed to Feed"
https://www.kit.nl/sed/news/ulufa-seed-feed/
http://hdl.handle.net/20.500.11766/8312

Reflections on Afghanistan forage initiative event blog
https://www.icarda.org/update/reflections-afghanistan-forage-initiative-event
http://hdl.handle.net/20.500.11766/8313

Fodder seeds: empowering women and closing gaps in Afghanistan
http://hdl.handle.net/20.500.11766/8316

Project impact video
https://www.youtube.com/watch?v=kDID9t3soKc&feature=youtu.be

Project reports:
2014 Annual Report: Forage options for smallholder livestock in water–scarce environments of Afghanistan
http://hdl.handle.net/20.500.11766/8310

2014–2015 Annual Report: Forage options for smallholder livestock in water–scarce environments of Afghanistan
http://hdl.handle.net/20.500.11766/8309

2015–2016 Annual Report: Forage options for smallholder livestock in water–scarce environments of Afghanistan
http://hdl.handle.net/20.500.11766/8308

Annual Technical Report July 2016 to June 2017
http://hdl.handle.net/20.500.11766/8318

Survey questionnaire
http://hdl.handle.net/20.500.11766/8305

Project agreements
Amendment to the MoA between ICARDA and MAIL in relation to the composition of the project working committee:
https://www.dropbox.com/s/iieiabkvoiow33h/MOA%20amendment.pdf?dl=0

1. Agreement with the Royal Tropical Institute (KIT) for collaborative gender focused research:
https://www.dropbox.com/s/02hwg70u5e4d5cd/ACIAR%20%20Forage%20Options%20Afghanistan%20-%20MOA%20KIT%20%28signed%29.pdf?dl=0

2. Tri-partite agreement between ICARDA, ARIA and Aga Khan Foundation (awaiting execution from AKF, but agreed to in principle by all parties):
https://www.dropbox.com/s/9bkvmajqztnxvkl/ICARDA-ARIA-AKF-Extension%20LoC.pdf?dl=0

11 Appendix 1: Training and workshops

Project activity	Training course	Date	Male	Female	Target trainees
Capacity building in measurement, monitoring, and assessment of forage production and nodulation surveys	A one-week theoretical and practical training course on forage production and forage experiments was undertaken on 18–22 May in the mirror trial site in Turkey	18–22 May 2015 Konya, Turkey	9	1	A total of 10 male ICARDA staff were trained
Capacity building in measurement, monitoring, and assessment of forage production and nodulation surveys	Course on forage production and forage experiments was given to the Animal Health Program team (13 members) of MADERA (NGO based in Afghanistan) and seven members of MAIL	13–15 January 2015 Kabul	17	4	Animal Health Program team (13 members) of MADERA, a Kabul-based NGO, with which ICARDA has developed collaborative work on the common forage production related activities
Capacity building in measurement, monitoring, and assessment of forage production and nodulation surveys	*Atriplex* plantation and effective seed production practices	2016 ICARDA offices in Mazar	4	24	Staff of Action Aid in Mazar and Bamyan
Capacity building in monitoring and assessment of forage production and nodulation surveys	A 5-day theoretical and practical training course on forage production and forage experiments was delivered on 30 May to 3 June at the mirror trial site in Turkey	30 May to 3 June 2016 Konya, Turkey	13	0	ICARDA and ARIA staff
Capacity building in monitoring and assessment of forage production and nodulation surveys	A 5-day practical and theoretical training course on forage biomass and seed production, alley cropping and water harvesting techniques, and the design and management of basic forage experiments was undertaken for NARS staff	28 April to 3 May 2017 Amman, Jordan, and Cairo, Egypt	16	6	Farmers and staff of ICARDA, NGO (AKF), and ARIA

Project activity	Training course	Date	Male	Female	Target trainees
Capacity building in seed production and seed business management	One staff member attended a 2-week course on Variety Maintenance and Small-Scale Seed Enterprise Development and Management	4–15 May 2015 Rabat, Morocco	1	0	
Capacity building in seed production and seed business management	Six Afghan female farmers/extension workers attended a group training course on seed propagation, nursery management, and enterprise development	7–12 April 2018 Amman, Jordan	0	6	AKF, farmers, and MAIL
Capacity building in socioeconomic survey techniques and survey data analysis	A 2-day training course on the baseline survey and survey data analysis	20–21 October 2014 Kabul	10	0	ICARDA and ARIA staff
Capacity building in socioeconomic survey techniques and survey data analysis	Workshop on assessing the systemic and gendered opportunities and constraints for innovation in forage value chains in Afghanistan, with a focus on Baghlan Province	3 July 2017 Dubai	16	4	Stakeholders, including Afghan government officials, researchers, development practitioners, cooperative members, private seed and input suppliers, as well as farmers
Capacity building for two national researchers on scientific methodology, seed production, rhizobiology, plant evaluation, and basic nutritive assessment	Training on scientific methodology, seed production, rhizobiology, plant evaluation, and basic nutritive assessment	August 2016 Australia	2	0	Abdul Haq Farhang and Himat Sahil
Capacity building for next users (development partners and farmers) in forage options	One field day was organized with the participation of 80 farmers, extension officers, agriculture students, and ICARDA staff in the ongoing trial sites in Baghlan	3 May 2015 Baghlan region	80	0	Farmers, extension officers, agriculture students, and ICARDA staff

Project activity	Training course	Date	Male	Female	Target trainees
Capacity building for next users (development partners and farmers) in forage options	One field day was organized with the participation of 65 farmers, extension officers, agriculture students, and ICARDA staff in the ongoing trial sites in Nangarhar	5 May 2015 Nangarhar region	65	0	Farmers, extension officers, agriculture students, and ICARDA staff
Capacity enhancement for next users (development partners and farmers)	One field day was organized for 79 farmers, extension officers, agriculture students, and ICARDA staff within the ongoing trial sites in Nangarhar	27 May 2016 Nangarhar region	79	0	Farmers, extension officers, agriculture students, and ICARDA staff
Capacity building for next users (development partners and farmers) in forage options	The Second Transition Workshop was held on 20 November 2017 – Kabul Serena Hotel Conference Room	20 November 2017 Kabul	18	0	ARIA staff
Capacity building for next users (development partners and farmers) in forage options	Organized a post POG meeting of the forage project in New Delhi to discuss plan of work for 2018, the way forward, and enhance communication between all stakeholders	28 November 2017 New Delhi	18	0	ARIA staff
Capacity building for next users (development partners and farmers) in forage options	The Second Transition Workshop was conducted on 14 February 2018 at ARIA headquarters	14 February 2018 Kabul	13	0	ARIA staff
Capacity building for next users (development partners and farmers) in forage options	A specialized group training course on seed processing was conducted for ARIA staff on using the equipment to be transferred to ARIA	13 March 2018 Kabul	15	0	ARIA staff
Capacity building for next users (development partners and farmers) in forage options	A group training course on “Data Collection, Experimental Design & Data Analysis in Forage Trials”	16–18 April 2018 Kabul	15	1	ARIA staff

1. Agenda for 2017 activity planning meeting (Beirut):

   https://www.dropbox.com/s/7gaxue6tp2hjau5/Forage%20planning%20meeting%20%282017%29%20FINAL.docx?dl=0

2. Jordan and Egypt traveling workshop agenda:

   https://www.dropbox.com/s/a79krfpgqo974p0/Final%20Agenda%20%28Jordan%20and%20Cairo%29_Apr%2027.docx?dl=0

3. Jordan and Egypt traveling workshop participant list:

   https://www.dropbox.com/s/9qwnssp8m8rag2f/Final%20participant%20list%20and%20logistics.xlsx?dl=0

4. Data Collection, Experimental Design & Data Analysis in Forage Trials Training course. Agenda:

   http://hdl.handle.net/20.500.11766/8279