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1 Acknowledgments

Investing in agricultural research for development has multidimensional impacts. It contributes to uplifting rural communities, strengthening the research system, making affordable, nutritious food available for locals, and boosting the country's economy. Funding for pulses research and development in Pakistan has been neglected for many years. ACIAR's investment in the pulses agriculture sector came at the right time when Pakistan's government considered these crops a priority to reverse their decline. The people of Pakistan acknowledge ACIAR for taking this step. Project working was not possible without management support from Charles Sturt University. Local partners Pakistan Agricultural Research Council (PARC), Pir Mehar Ali Shah Arid Agricultural University Rawalpindi (PMAS AAUR), Muhammad Nawaz Sharif University of Agriculture, Multan (MNSUAM), Sindh Agriculture University (SAU), Arid Zone Research Institute (AZRI), Quaid-e-Awan Agricultural Research Institute, Larkana (QAARI), Ahmad Wala Research Station, Khyber Pakhtunkhwa (ARS), National Rural Support Program (NRSP), Sindh Rural Support Program (SRSO), and Baluchistan Rural Support Program (BRSP) have provided excellent support in achieving the objectives of the project. Private companies Haji Sons, Shoaib Seed Corporation, RASCO Seeds, and KanzoAg also extended great support by taking the risk of investing in the pulses seed sector.

2 Executive summary

Pulses are important crops and a significant source of plant-based protein and minerals, especially for the less advantaged section of the population in Pakistan. However, the lack of investment in pulses research and development made pulses production unprofitable in Pakistan. Low yields and profits are mainly due to limited availability and access to seeds of improved pulse varieties and farmers' unawareness of the latest production technologies, resulting in poor crop management. Besides, limited mechanisation options for crop harvesting is the primary factor in reducing pulse production's profitability. The situation is further deteriorated by the support price policy of the government for significant crops like wheat, rice, sugarcane, and maize, as indicated in the outcomes of the ACIAR policy project ADP/2016/043, which reduced the area under pulse crops in Pakistan and consequently increased import dependence. In the past few years, Pakistan has faced an acute shortage of dollars, so the government banned international payments. These circumstances resulted in a short supply of pulses in the market, which led to a 100% hike in the prices of pulses in the local market. The demand for pulses is increasing with the increasing population, so there is a dire need to improve the local production of pulses to bridge the supply-demand gap.

The project aimed to increase the productivity and profitability of pulse crops (chickpea, lentil and groundnut) in the country through development-led inquiry (DLI) and a farmer-led participatory approach (FLPA). A situational analysis was conducted at all project sites to collect data, including socio-economic parameters, crop management practices, yields, production economics, post-harvest management, etc. to identify factors contributing to low yields and profitability. One-to-one interviews were conducted with male and female household members, including focus group discussions in all six sites. Major constraints identified included the non-availability of quality seed of improved varieties, poor weed and nutrient management, diseases and insects, and post-harvest losses. Based on the findings of the situational analysis, the team developed strategies to address the research questions. Six sites were selected for trials/experiments where Groups of Collaborative Research (GCRs) were established and engaged initially.

This project proved to be a catalyst for the government of Pakistan to commence mega-pulse projects, breaking new grounds and establishing successful models that have inspired further innovations. In this regard, the development of an improved quality seed system provided significant interest among farmers and seed companies to establish two village seed banks at Attock and Chakwal and four private seed companies, Haji Sons, KanzoAg, Shoaib Seed Corporation, and RASCO Seeds. A total of 783 tonnes of quality seed of improved varieties was produced during the project, comprising 609 tonnes of chickpeas, 45 tons of lentils, and 129 tonnes of groundnut. The Groups for Collaborative Research (GCRs) involving 90 participating farmers and researchers at six project sites undertook 42 improved production technology trials of chickpeas, 12 lentils, and 23 groundnuts. The learnings from these tested technologies were demonstrated to 935 pulse farming families, including 115 female growers, in collaboration with local NGOs, including the National Rural Support Program (NRSP), Sindh Rural Support Program (SRSO), and Baluchistan Rural Support Program (BRSP). Demonstrating an improved peanut harvester to 530 farmers in six farmer field days conducted at Attock, Chakwal, and Karak improved farmers' access to groundnut harvesting machines through service providers. The opportunity for crop value-addition activities to help farmers increase their profitability resulted in producing quality peanut butter, extra virgin peanut oil, and organic chickpeas. These products were showcased at forums such as Agri-Expos organised by the government of Punjab, the Chickpea Peanut Festival, and the Plant Centric Meal competition. More recently, the project's efforts for the organic certification of chickpeas by the Control Union in the Thal region involving two clusters of 10 farmers is a big step forward in developing this region as an organic chickpea hub.

To improve the understanding of farmers about the pulses value chain, seven stakeholders' workshops and events were organised and attended by 421 farmers, academia, the public and industries like Volka foods, Nuts and Legumes, English Biscuit Manufacturers (EMB), and Biomasdar Pvt. (Ltd). Ninety-two farmer field days, training, seminars, conferences, meetings, visits, and showcasing events were conducted where project learnings were shared with 8796 farmers, researchers, academia, extension agents, input suppliers, service providers, and industry representatives. Three-hundred-and-seventy-one farmers were trained for seed production across all project sites. Short videos of success stories were made and telecasted to disseminate the project learnings. Thirteen articles for newsletters, ten brochures, three research papers and two theses were published during the project's life.

Varietal seed production and availability of the seed resulted in seed replacement on 7768 hectares under chickpea crop, 1148 hectares under lentil crop, and 806 hectares under groundnut crop. With the establishment of village seed banks, the availability of quality seed has improved locally at Attock and Chakwal. Linking seed-producing farmers with seed companies has enhanced the profitability of both farmers and seed companies. The four companies, two in Punjab and one in Baluchistan, actively engaged in pulse seed production, will ensure the sustainable supply of pulse seed at Bhakkar, Larkana, and Jafferabad in the future. Improved varietal seeds, combined with improved production technologies like seed inoculation, fungicide treatment, weed management, insect management, and mechanised harvesting, has resulted in an 18.5% increase in productivity of chickpea, lentil and groundnut production across all sites with an average economic gain of PKR 30,000 per hectare. Providing multi-crop seed cleaners and graders to village seed banks will help develop entrepreneurship, ensure the sustainability of seed supply after the project's life, and uplift the local community economically. The training in peanut oil extraction, filtration, packing and branding, and providing two small oil extraction units will also help local farming communities grow their business. The introduction of chemical weed management and mechanised harvesting has significantly reduced the workload of female households.

The introduction of hermetic storage technology to produce hermetic storage bags has improved the quality of lives of farm families, especially women, as they were using carcinogenic mercury in grain storage mud bins in the past. These hermetic grain storage bags, developed by the project, are ideal for long-term grain storage as they are impervious to outside moisture, and the exchange of oxygen and carbon dioxide gases inside creates a carbon dioxide-rich atmosphere not congenial for insects and microbial growth.

As 90% of the chickpea crop is grown on the sand dunes of Thal, the demonstration of compatible organic production technology and a low-cost, efficient irrigation system has provided an option for an environmentally sustainable production system for the farmers. The DLI approach not only built the capacity of researchers, farmers, and representatives from third-sector organisations but also bridged the gap between farmers and researchers. The project team collaborated closely with the ACIAR small ruminant project and the Pulses Value Chain under the Aik Saath umbrella. Project beneficiaries learned during the Creep Feeding trial for small ruminants about the nutritional requirements of animals, diseases, and their management from the ACIAR small ruminants project. This resulted in GCR farmers at Bhakkar starting animal fattening businesses. Chickpea and lentil farmers of Chakwal were linked to pulse value chains while working with the ACIAR pulse value chain project. The project team shared the learnings with beneficiaries of those projects in joint events like seminars and farmer gatherings. The periodic reporting of the project activities was also published on the Aik Saath website. Research institutes strengthened by procuring machinery like a multi-crop seeder/fertiliser drill, seed cleaner graders, threshers, and a laser land leveller. The project provided the first groundnut sowing drill in KPK for better crop establishment, enhancing their capacity for future research initiatives.

The project observed the need to develop high-input, responsive, site-specific, farmer and market-preferred pulse varieties to place them at competing levels in existing cropping systems. Value chains at some sites are developed for specific varieties; however, those varieties need improvement. Besides, when private companies were involved in the seed business, it was observed that research institutes developing the improved varieties could not produce basic seeds of those varieties according to the requirements of seed companies for certified seed production. Hence, there is a need to enhance the capacity of research institutes to produce enough basic seeds to meet the demand of seed companies. Involving third-sector organisations (TSO) like NRSP has contributed much to disseminating project learnings without extra cost. TSOs such as NRSP and SRSO have been pivotal in the project's efforts to develop women farmers' networks to leverage knowledge sharing using different means such as WhatsApp and Facebook. Societal barriers prevent the direct sharing of women farmers' knowledge and preferences, concurrently limiting their access to modern agricultural practices. It is, therefore, essential to link these women's associations to private and public agrarian networks to exchange agricultural insights, foster collaboration, and expand the reach of agricultural interventions. Recognising and supporting these existing networks can enhance the effectiveness of future projects.

Further strengthening of these relationships is needed to harvest maximum benefit for farmers. This relationship can lead to community farming and place farmers in a better position in pulses value chains by enhancing their buying and selling power. The private sector needs to be engaged differently for future projects. Opportunities explored in this project for future engagement of the private sector include R & D, manufacturing and service provision of pulses machinery, R & D in foliar fertilisers, herbicides, their availability and demonstration, mobile irrigation service providers in pulse growing regions, and the development of rental storages in pulse growing areas.

3 Background

Pulses in Pakistan are cultivated on 1.5 M ha, representing about 5% of the total cropping area. Chickpeas (Kabuli and Desi) and lentils are winter legumes (therefore, alternative crops to wheat), whereas groundnut is a summer legume (therefore a possible second crop after wheat). Together, they are considered the major legume crops in Pakistan. Chickpea occupies 73% of the total pulses area, and lentils occupy 5% of the total area devoted to pulses in the rabi season (winter). Conversely, groundnuts occupy 11.6% of the total area dedicated to pulses in the kharif season (summer).

Desi chickpea (small grain) is highly sought after for its particular taste and quality, and Pakistan is nearly self-sufficient for Desi. Kabuli (large grains) is nearly entirely imported. Pulses are traditionally grown in rainfed areas and on less fertile soils. Except for groundnuts, which are also grown under irrigation, most pulses are grown under rainfed conditions in the Punjab, KPK, and Sindh provinces. Increasing chickpea production in Baluchistan is a priority of the Pakistani government (Pakistan delegation visit to ACIAR).

During 1976–2010, chickpea and lentil crop prices increased by 9.87% and 11.09%, fluctuating yearly prices beyond the farmers' control. The growing area, yield, and production decreased during the same period, primarily due to the gradual discontinuation of intercropping of pulses with wheat, resulting in a cropping pattern shift towards high-value wheat crops (Rani et al., 2012). The area under production for lentils alone was reduced from 70,000 to 18,000 hectares, while the yields remained constant (Rani et al., 2012).

Increased prices have reduced the consumption of protein-rich pulses among people with low incomes (Rani et al., 2012; Rani et al., 2014). The consistent gap between the production and consumption of legumes, especially chickpeas (Kabuli type) and lentils (Chaudhry et al., 2002), has required Pakistan to import more pulses (Agriculture Statistics of Pakistan 2014). Overall, 630,000 tons of pulses were imported during 2010–2011, an increase of 41% over 2009–2010 (Khan, 2012). Because of the reliance on imports, the country is missing out on all the benefits that legumes bring to farming systems: nutrition security, crop diversification, soil health, disease control, and risk reduction.

Groundnuts are grown mainly in Punjab and KP on 81,700 hectares with an annual production of 81,300 tons and an average per hectare dry pod yield of 995 kg/ha. The annual production in 2012–2013 compared to the previous year showed an 8% increase in average yield per hectare, demonstrating the potential to increase production to cover the gap between demand and supply (Amjad, 2014). Despite its several uses, including its potential as an oil crop, the entire production is used for roasted nuts. It thus warrants further investigation for its value addition to the food chain. The lack of proper harvesting, post-harvest storage and processing technologies limits groundnut profitability.

The absence of effective policies is a factor behind the reduced pulse production area. The decline in the availability of pulses has eroded the production knowledge base (Rani, 2014). Although technological factors spanning from 1975 to 2011 have improved the yield and production of main crops, no concrete effort has been developed to establish sustainable legume cropping systems. The decline in the production area and lack of interest in reintroducing lentils and chickpeas have been attributed to multiple factors, such as poor marketing, reduced yields, price fluctuations, high labour costs, inefficient labour use, and a lack of adoption by farmers of modern-day technologies and cropping methods. Farmers have not had access to improved high-yielding, disease-resistant varieties developed and tested on research stations (Qasim et al., 2013; Kumar & Bourai, 2012). The government has recently considered greater price control to prevent price fluctuations, thereby providing incentives for increased production in marginal areas and different farming systems (Dawn, Business & Finance Weekly, November 2nd, 2015).

In Pakistan, wheat and rice are the most important staple food crops, occupying most of the country's cultivated areas and contributing 21.1% of added value to agriculture and 4.6% to the country's GDP. Over the last three decades, the increase in production has been attributed to the introduction of high-yielding dwarf cultivars and increased use of fertilisers. Pakistan now produces surplus wheat but is struggling to store the excess production, and low quality precludes export (Prikhodko & Zrilyi, 2013). Furthermore, price support for cereal farmers is becoming an unsustainable burden on the government budget. The government recently recommended replacing 1 M acres of wheat with pulse crops as a priority. Concurrently, the increased cereal production has depleted soil nitrogen to a point where regular fertiliser application is necessary, elevating the risks of financial losses for producers. Farmers' inability to invest in expensive fertilisers has significantly affected the wheat quality, rendering it unsuitable for export markets. Reintroducing economically viable alternative leguminous crops, such as chickpeas, lentils, and groundnuts, would provide a disease break and much-needed soil nitrogen and organic matter. This would give a platform to improve wheat grain yields and grain protein, as well as attributes such as grain hardness, grain colour, protein content, and the different dough properties desperately needed for domestic and international markets.

This project proposes to address important researchable issues and provide solutions for improving the production and profitability of the three crops in different cropping systems. While this will not be an exhaustive list, these researchable issues will cover the main priorities and represent an achievable set of tasks within the project's scope.

Labour shortages have been identified as a major constraint for crop establishment, weed control, crop harvesting, and storage. Therefore, the project will explore new agronomic practices and the use of small-scale machinery to try to relieve these constraints. The project will also undertake a large-scale transfer of Rhizobium inoculation technology to farmers to improve productivity. Scientists at NARC developed the technology currently produced and marketed by PATCO, PARC's commercialisation arm.

Diseases and pests have been identified as severe lentil and chickpea production constraints. The project will evaluate available varieties in selected agro-ecological zones to devise strategies to manage Ascochyta and pod borer damage. The lack of available processing technologies limits the profitability of groundnut and chickpea, and the project will explore ways to add value to these crops.

The difficulty farmers have in accessing high-yielding, disease-resistant varieties of lentils and chickpeas is constantly mentioned as a significant constraint to improving productivity. The project will, therefore, explore ways to implement the decentralised, village-based production of seeds.

Australia's success in becoming a significant pulses exporter within a short timeframe is attributed primarily to improved agronomic practices and germplasm enhancement programs. Furthermore, chickpeas and lentils are being included as rotational crops with reports of improvement in wheat grain protein levels of up to 5% and grain yield ranging from 8–131% through the provision of much-needed soil nitrogen (GRDC, 2009). The factors likely to affect pulse production include climate and season, price, varieties adapted to new areas, and management systems that lead to improved yield stability. An improved understanding of the impact of climate variability and climate change, including the role of pulses in rotation, will better estimate their impact on yields and the yields of following crops in a rotation system. Furthermore, the quality characteristics of Australian pulses, including cooking and processing properties, have increased the profitability of these crops. While consumers prefer visually appealing pulses that cook quickly and evenly, processers require pulses that perform in milling, splitting, and industrial cooking. These quality parameters are determined mainly by the genetics of the pulse varieties and the environment in which they are grown. The Australian experience and expertise can play a key role in improving legume production in Pakistan and help this developing country improve the health status of its citizens along with the knowledge base and income of small landholders.

The issues mentioned above raise the following primary research questions.

- What are the barriers to the adoption of the proposed innovations for pulses?
- Which agronomic practices, technologies, and available improved varieties can increase the productivity and profitability of chickpeas and lentils?
- How to mitigate the effect of farm labour shortage on pulse production?
- How to add value to chickpea and groundnut crops at the village level?
- How to ensure the availability of a quality seed supply for chickpea and lentil growers?

4 Objectives

This project, mainly through development-led inquiry (DLI), aims to enhance the production and profitability of pulses in Pakistan's existing cropping systems so that the decline in legume production can be reversed. The project will:

- Identify agronomic factors limiting lentils, chickpeas, and groundnut productivity and profitability and evaluate possible solutions.
- Increase opportunities for farmers to undertake post-harvest value addition to chickpea, lentil, and groundnut crops by adapting and demonstrating food processing technologies suitable for smallholders to add value to crops where appropriate.
- Develop and evaluate site-specific, village-based seed production and dissemination systems to increase farmer access to improved varieties.
- Disseminate the learning and practices from the project activities to other farmers and private sector participants, such as input suppliers and potential service providers.

In achieving its objectives, the project will address the following research questions:

1. What are the barriers to the adoption of the proposed innovations for pulses?
2. Which agronomic practices, technologies, and available improved varieties can increase the productivity and profitability of chickpeas and lentils?
3. How to mitigate the effect of farm labour shortage on pulse production?
4. How do you add value to village-level lentil, chickpea, and groundnut crops?
5. How to ensure the availability of a quality seed supply for chickpea and lentil growers?

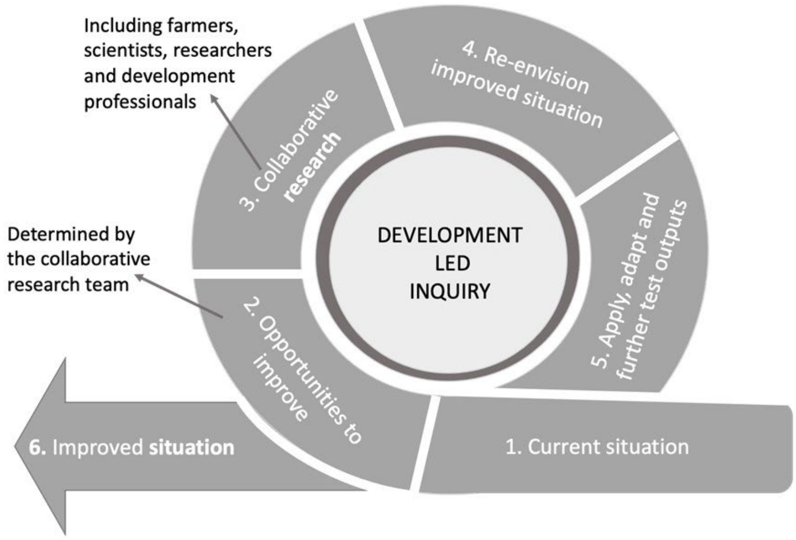
Under the leadership of Charles Sturt University, the project team comprises scientists from the Pakistan National Agricultural Research Centre (NARC), provincial research institutes, universities, and NGOs.

5 Methodology

The approach used for this project is development-led inquiry (DLI), which is designed to improve complex and dynamic situations and generate new knowledge (DeFrancesco et al, 2008; Pretty, 1995). The system provides a framework to respond to development needs, with continuous iterations to re-envision enhanced conditions. It is linked directly to users (farming communities, groups and individuals). NGOs are integral to the research system, facilitating the research agenda and building relationships between the farming communities and other stakeholders. In this way, DLI involves all stakeholders in the inquiry process rather than as recipients of new knowledge after the research.

Third-sector organisations operate in rural communities and are connected directly with communities. They can play an essential role in agricultural development. DLI is an approach that enables third-sector organisations, academics, government departments, and research institutions to work with farmers as partners to design and carry out research. The new knowledge generated from such research is iteratively applied to enhance decisions to improve situations. DLI incorporates development non-governmental organisations (NGOs), a subset of third-sector organisations.

DLI operates where the stakeholders decide to improve a specific situation. In this project, the government of Pakistan, agricultural research systems, and farming communities agreed to enhance the production of pulses (chickpeas, lentils, and groundnuts) in Pakistan. DLI provides an opportunity for continuous improvement in a cyclic fashion rather than a linear development mode. Below is the diagram representing the development steps in a DLI system.



This approach enables all actors and stakeholders with different backgrounds, interests, and organisational structures to operate in the system for development. The project started operations by bringing together stakeholders through inception and operational planning workshops in December 2016, run by researchers from Charles Sturt University (CSU), Wagga Wagga, NSW, Australia. The MSA was signed by all the heads of the participating organisations. The operational plan was developed in collaboration with pulses stakeholders in Pakistan. Refining the project objectives, finalising the project partners, and prioritising the project sites were done.

Based on the contribution to the national production of pulses in Pakistan, the project identified six sites to operate:

Site 1: Attock

Site 2: Chakwal

Site 3: Bhakkar

Site 4: Karak

Site 5: Larkana

Site 6: Jafferabad

Based on the project sites, local partner agricultural research institutes were identified as:

Sites 1 and 2: Peer Mehr Ali Shah Arid Agriculture University, Rawalpindi (PMASAAUR)

Site 3: MNS University of Agriculture, Multan & Arid Zone Research Institute (AZRI), Bhakkar

Site 4: Agricultural Research Station, Ahmedwala, Karak

Site 5: Sindh Agricultural University (SAU), Tandojam & Quaid e Awam Agricultural Research Center (QAARC), Larkana

Site 6: Baluchistan Agricultural Research and Development Center (BARDC), Quetta and Agricultural Research Institute (ARI), Jafferabad

Coordination unit: National Agricultural Research Center (NARC), PARC.

Current situation

5.1 Objective 1: Agronomy

Identify agronomic factors limiting the productivity and profitability of lentils, chickpeas and groundnut, and evaluate possible solutions.

Situational analysis:

To identify the site-specific agronomic limiting factors, a two-step situational analysis was conducted.

Step one situational analysis:

A facilitation running sheet was developed in a workshop with relevant stakeholders, including researchers, farmers, input suppliers, and extension workers. The first step situational analysis objectives were to engage families farming pulses, introduce the project and team to the communities, and get an overview of agronomic factors limiting the productivity and profitability of chickpeas, lentils, and groundnuts. In the first step, the facilitation running sheet was discussed separately with larger groups of men, women, and youth at all project sites. A three-member team comprising a facilitator and two notetakers conducted the situational analysis. Based on the information collected, a detailed situational analysis tool in collaboration with Social Sciences Research Institute (SSRI) at NARC was developed.

Second step situational analysis:

Groups for Collaborative Research (GCRs) were established, including 15 pulse farming families on each side, local partner research institutes, academia from partner universities, a coordination unit at NARC, project officers, and project partners in Australia. So, 90 pulse farming families on all sites were engaged in collaborative research. The second step, situational analysis as a baseline for the project, was conducted with farming families in GCRs at each location. The results were collated in a pulses situational analysis report attached.

The limiting factors/constraints in pulse production identified in the report (Appendix 1-Table 8) are:

1. Resource constraints: Labour and water
2. Abiotic constraints: Climate change (rain and heat waves at time of harvest)
3. Biotic constraints: Insect, disease, weeds, storage loss
4. Seed constraint: Quality and availability
5. Economic constraints: Input cost, low yields, non-availability of machines for harvesting, low selling price

Opportunities for Improvement

A workshop was conducted where all stakeholders participated, and issues identified during the situational analysis were discussed. The stakeholders brought All possible options to the table, and the workshop drew boundaries where farmers could work with agricultural research systems to improve the situation. The sectors selected to improve the situation in the DLI system by the research team were:

1. Knowledge about the latest available production technology
2. Profitability through value addition
3. Accessibility of quality seeds of improved varieties
4. Communication within and outside the DLI system for sharing the learnings

Collaborative research

Improve knowledge about the latest available production technology

Groups for collaborative research (GCRs) planned and conducted farmer-led technology trials to test in the farmers' fields the improved varieties, rhizobium inoculation, seed treatment with a fungicide to manage seed/soil-borne diseases, weed management, foliar disease management, nutrition management, insect management, and mechanised harvesting. These technologies were tested with farmers for two consecutive years for inclusive learning. Researchers from local partner research institutes visited the trials with GCR farmers during the cropping period to observe and learn with farmers about their priorities and point of view about the ongoing trial.

Re-envisioning the improved situation:

The trial results were analysed and shared with farmers for input and confirmation. New issues, bottlenecks, and researchable questions raised by the GCR farmers were converted into trials with a **learn and adapt** approach. These included lifesaving irrigation and foliar fertiliser trials in the Thal area, green leaves harvesting in a rice-based cropping system, zero tillage, a seed inoculating agent, seed primer trials for chickpea and a raised bed comparison with flatbed sowing, a land levelling trial, seed rate trials, and a harvesting machine comparison trial on a groundnut crop. The results were also shared with collaborators and research institutes to incorporate their research objectives and steer future farmer-participatory research.

5.2 Objective 2: Post-harvest

Increase opportunities for farmers to undertake post-harvest value addition to chickpea, lentil, and groundnut crops.

Situational analysis for the current status of farm-level value addition of pulses (Appendix 2)

To start work on this objective, a situational analysis was conducted to learn with GCRs about the prevalent trends of on-farm pulse value addition, barriers, and opportunities. No value addition was done for commercial purposes at any site. Limited crude value addition with chickpea and lentil splits, chickpea flour, roasted peanuts, and peanut oil was reported for domestic consumption.

In the next step, farmers were exposed to different value addition options during various events at MNSUAM and PMAS AAUR, where they were encouraged to go for commercial value addition. Farmers were reluctant as it required the storage of produce, learning new skills, and investment in required machinery, and there was a lack of market linkages. In this instance, the project decided to facilitate them in product development, packaging, labelling, and showcasing to establish market linkages. In this regard, showcase events like the Pulses-Mango Festival, Chickpea Peanut Fest, and plant-centric meals were organised at Islamabad and Multan, where farmers displayed organically produced chickpeas, chickpea flour, and peanut oil.

Re-envisioning the improved situation:

Despite all the facilitations, the project learned that farmers are not encouraged enough in crop value addition. So, to improve their understanding and potential profitability, the project decided to link them with higher strata of the pulses value chain. Chickpeas and lentil farmers were linked to the ACIAR Pulses Value Chain project, where they performed the walk the pulses chain activity and learned about the industry standards. Engaging groundnut farmers with English Biscuit Manufacturers (EBM), the leading biscuit manufacturers in Pakistan, was a paramount step in understanding the industry requirement for quality peanuts. However, linking farmers with the peanut processing industry, such as Nut and Legume, proved crucial in understanding the intermediate processing steps before shipping peanuts to food manufacturers. Stakeholder workshops were also organised to strengthen the linkage between farmers, EBM, and the Nut and Legume company. Since it is difficult for the industry to interact with individual farmers, and farmers were also reluctant to store their produce due to paying off the loans and limited on-farm grain storage capacity, local small to medium enterprises (SMEs) are considered very important. SMEs' presence in the workshops was a great encouragement for both farmers and the industry.

The project successfully initiated the organic chickpeas value chain for the first time in Pakistan, where selected GCR farmers were facilitated in organic chickpea production, including certified organic fertiliser, organic certifications, specific storage conditions and subsequent linking to the buyers.

Farmer field days were conducted on post-harvest crop management, where farmers learned on-farm drying, cleaning, grading, and grain storage for domestic use. Hermetic bags storage technology was introduced for safe storage of pulses with the help of Haji Sons company. Farmers were convinced by hermetic technology but complained that bags were expensive. The company said these are imported bags, so the rupee depreciation against the dollar had made them expensive. So, the project worked for the local production of these bags to make them available at the cost farmers were willing to pay.

5.3 Objective 3: Village-based seed production

Develop and evaluate, in partnership with farmers, site-specific village-based seed production and dissemination systems to facilitate access to improved varieties.

Situational analysis revealed that farmers were unaware of the latest pulse varieties. Smallholder farmers lack access to quality seeds of improved varieties without a formal seed supply system. The project started working on this objective with farmers' exposure to the latest improved pulse varieties by conducting varietal trials with GCR farmers at all project sites. The farmers were able to learn about the traits of improved varieties.

Farmers and researchers visited to observe the varietal trials continually over the period, recording and analysing the data. Farmers scored the varieties at the flowering and maturity stages. The analysed data was shared with the farmers for reflective feedback. These varietal trials were conducted for two years.

The following year, willing farmers with irrigation facilities were identified at each site for seed production. The project provided certified seeds of improved varieties. GCRs organised seed production training during cropping to develop a sustainable seed supply system. Opportunities for seed production were also identified concurrently for each project site.

At Attock and Chakwal, no private seed company was ready to enter the pulse seed business; however, farmers were willing to establish village seed banks on these sites. In this regard, the project team visited a village wheat seed bank to learn about its operation. This bank was established under CIMMYT in collaboration with the National Rural Support Program (NRSP). The project facilitated the next phase of exposure visits of willing farmers from Attock and Chakwal, where researchers mediated farmer-to-farmer learning. Consequently, village seed banks were established with GCRs and NRSP farmers at Attock and Chakwal. The project provided multi-crop seed cleaner graders to each bank to strengthen the seed banks. To ensure the sustainability of the seed banks, NRSP, as an essential stakeholder, and PMAS AAUR, as a collaborating organisation, will look after the operations of the seed banks. A legal contract was signed between the managing seed bank farmers and PMAS AAUR.

Two seed companies, Haji Sons and KanzoAg, were engaged for the pulses seed business at site 3. Seed-producing farmers at this site was linked with these companies. At site 5, the Shoaib Seed Corporation and at site 6, the RASCO seed company were engaged for the certified seed production of pulses. Without NGOs and private seed companies, the Agricultural Research Station, Karak, as a public sector organisation, remained the only source of certified seeds of improved pulse varieties for the Karak region in KP.

5.4 Objective 4: Dissemination and scaling out

Disseminate the learning and practices from the project activities to other farmers and private sector participants, such as input suppliers and potential service providers.

The project's learnings were made possible after forming Groups for Collaborative Research (GCRs) involving farm families and researchers at each site. GCRs developed the package of tested technologies in the project's developmental phase using development-led inquiry and farmer-led participatory approaches as tools.

Apply, adapt and further test outputs:

For the expansion phase, third-sector organisations (NGOs) were engaged. NRSP was engaged to expand project activities at Attock, Chakwal, and Bhakkar. The Sindh Rural Support Program (SRSO) was engaged in activities at Larkana, and the Baluchistan Rural Support Program was engaged in activities in Jafferabad. The dissemination of project learning started with planting technology package demonstration plots with NRSP, SRSO, and BRSP farmers. Farmer-to-farmer learning was facilitated by conducting farmer field days and seminars where GCR farmers demonstrated tested production technologies like seed inoculation, fungicide treatment, pre-emergence herbicide application, insect management, and nutrient management. Improved planting and harvesting machines were demonstrated with the help of service providers at farmer field days.

Specific workshops were organised where women farmers interacted with women to learn about the opportunities to access the latest information and learnings in a culturally safe environment that could alleviate their labour-intensive outdoor farm activities, concurrently exposing them to value-addition and market access.

Project partners also published brochures about improved production technologies and distributed them among farmers during field days, seminars, conferences, and showcasing events. Short videos of success stories were also made and telecasted on cable networks to reach the maximum number of farmers. Radio programs were recorded and telecasted. Articles on project activities were also published in an online newsletter, *The Pulse*.

Learnings of the project about machinery requirements and suitable pulse varieties for different pulse growing areas were also shared with the Pulses Mega Project under the Public Sector Development Program (PSDP) through joint partners.

Improve communication within and outside the DLI system to share the learnings:

Communication within the project was mainly through emails and weekly site meetings on Zoom. Communication with sites and farmers was established through a Whatsapp group for each site, periodic visits, and a situational analysis of different project stages. Regular annual review and planning meetings were organized during the project, where Australian scientists also participated. Facebook pages were established to spread learning and advertise seed availability with village seed banks.

6 Achievements against activities and outputs/milestones

Objective 1: ***To identify agronomic factors limiting the productivity and profitability of lentils, chickpeas, and groundnuts and evaluate possible solutions, mostly through farmer-led research and demonstrations of suitable innovations.***

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1 PC	Conduct farmer-led, researcher managed variety, yield and quality trials where appropriate (likely to be all selected project areas).	Yield/quality field trials conducted. Data collected, analysed, reported and discussed with farm families for future application.	Oct 2017 to April 2019	**Site 1 (Attock)** The average yield data of a chickpea varietal trial conducted at site 1 for two years, viz. 2017–18 and 2018–19, revealed that Noor 2013 outclassed other varieties with a 1467 kg/ha yield. Chattan was in second position with an average yield of 1424 kg/ha, whereas Fakhr e Thal and Bittle 2016 were on par with an average yield of 1356 kg/ha and 1352 kg/ha, respectively. Lentil variety Markaz 2009 performed best with an average yield of 1167 kg/ha. Punjab Masoor also performed well with a yield of 1048 kg/ha. Groundnut variety BARI 2011 was the best-performing variety at site 1 with an average yield of 1821 kg/ha, followed by BARI 2016 with an average yield of 1521 kg/ha. **Site 2 (Chakwal)** Chickpea variety Noor 2013 performed best with an average yield of 823 kg/ha, whereas Thal 2006 and Bhakkar 2011 were on par with an average yield of 762 kg/ha and 761 kg/ha during 2018–19. Fakhr e Thal was also among the top-performing varieties, with a yield of 735 kg/ha. The farmer abandoned the trial in 2017–18. NIAB Masoor was the best-performing lentil variety, with an average yield of 467 kg/ha, followed by Markaz 2009, which yielded 394 kg/ha. Groundnut varieties BARI 2011 and BARI 2016 performed on par with average yields of 1098 kg/ha and 1067 kg/ha, respectively. **Site 3 (Bhakkar)** **Chickpeas** Surprisingly, a chickpea variety from KPK, KK 1, performed excellently at site 3 with an average yield of 1175 kg/ha. Local variety Bhakkar 2011, with an average yield of 1129 kg/ha was almost on par with KK 1; however, due to the seed size, colour and market

				value, Bittle 2016 was amongst the most preferred varieties with a yield of 893 kg/ha and was at par with KK 2, having an average yield of 891 kg/ha. **Lentils** For lentil Markaz 2009 outperformed all other varieties with an average yield of 2164 kg/ha at site 3. NIAB Masoor was also a good performing variety with a yield of 1839 kg/ha, followed by Punjab Masoor with an average yield of 1170 kg/ha. **Site 4 (Karak)** **Chickpeas** Fakhr e Thal outperformed all chickpea varieties with an average yield of 1640 kg/ha at site 4. Bittle 2016 and Bhakkar 2011 were on par with yields of 1158 kg/ha and 1118 kg/ha, respectively. KK 1, KK2 and KK3 were on par with average yields of 1021 kg/ha, 1078 kg/ha and 1016 Kg/ha, respectively. **Groundnut** BARI 2016 was the best-performing groundnut variety at site 4 with an average yield of 2260 kg/ha, followed by Pothwar with a yield of 1730 kg/ha and BARI 2011 with an average yield of 1643 kg/ha. **Site 5 (Larkana)** **Chickpeas** Thal 2006 was the best-performing chickpea variety at site 5, with an average yield of 2375 kg/ha. Bhakkar 2011, with a yield of 2054 kg/ha, was second, while Bittle 2016 was among the top-performing varieties with an average yield of 1932 kg/ha. **Lentils** Lentil variety ShirAZ-96 performed well at site 5 with an average yield of 1813 kg/ha followed by NIAB Masoor, which yielded 1531 kg/ha.
1.2 PC	Farmer-led replicated trials to evaluate fungal disease management in the selected project areas (likely to be in all selected project areas).	Disease management field trials conducted. Data collected, analysed, reported and discussed with farm families for future application.	Oct 2019 to April 2021	**Chickpea** ***Root rot & Fusarium wilt*** The application of seed treatment fungicide resulted in a significant improvement in yield of about 21% across all sites on average compared to no treatment. ***Ascochyta Blight*** Foliar application of fungicide reduced crop damage due to Ascochyta blight, and a 16% higher yield was observed in

				the treated plot compared to the control. **Lentil** ***Root rot*** Due to the treatment of lentil seed with an effective fungicide, the lentil crop suffered 20% less damage, and a 34% increase in yield was observed in the treated plot compared to the control. **Groundnut** ***Root rot*** The results showed that the incidence of the disease three weeks earlier was observed in the control plot compared to the treated plot and that the severity of the disease was 14% higher in the control plot than the treated plot. This all contributed to a 22% increase in the overall grain yield of the treated plot compared to the control. ***Foliar disease*** Managing foliar disease with fungicide application resulted in a 35% increase in yield compared to the control plot.
1.3 PC	Farmer-led trials to evaluate weed management in the selected project areas.	Weed management field trials conducted, data collected, analysed, reported and discussed with farm families for future application.	Oct 2019 to April 2020	**Chickpea** The application of pre-emergence herbicide resulted in a 55% reduction in weed count at harvest time for the chickpea crop. The dry weed weight in the treated plot was 58% less than the control. On average, chemical weed management resulted in a 23% increase in overall crop yield compared to control across all sites. **Lentil** Lentil is a poor competitor due to its short stature. Applying pre-emergence herbicide resulted in a 51% increase in yield over the untreated plot. **Groundnut** About 43% less dry weed weight/sq. m at 150 days after emergence in the treated plot contributed to a 21% increase in overage grain yield.
1.4 PC	Farmer-led rhizobium inoculation trials in all selected project areas.	Rhizobium field trials conducted. Data collected, analysed, reported and discussed with farm families for future application.	Oct 2019 to April 2020	**Chickpea** The results revealed that New Edge Microbials (NEM) rhizobium inoculum contributed a 26% increase in yield over the control across all sites, while Biozote rhizobium inoculum contributed a 20% increase over the control. NEM performed better at sites 1 and 2, and Biozote was more productive at sites 3 and 4. At site 5, NEM and Biozote were on par in performance, with an 8% increase in yield over the control.

				Regarding nodule formation, NEM performed well at site 4 with 63% more nodule formation than the control while Biozote performed well at sites 1 and 2 with 71% and 52% increases, respectively, in nodule formation over the control. **Lentil** The results showed a 9% increase in yield in the plot where lentil seed was inoculated with rhizobium. No significant difference in 100 seed weight was noted; however, the number of pods per plant was more in the plot with inoculation, which resulted in increased grain yield. **Groundnut** An average yield increase of 12% was observed, partly due to a 16% increase in pods in plots treated with rhizobium inoculum. However, a significant increase of 43% in the number of nodules per plant was noted in the treated plot compared to the control.
1.5 PC	Farmer-led demonstration machinery trials where appropriate (likely to be in all selected project areas).	Farm machinery trials conducted. Data collected, analysed, reported and discussed with farmers for future application.	April 2020	**Chickpea** Different sowing methods were trialled with chickpea variety DG 92 at its recommended seed rate of 35 kg/acre. Seed Drill obtained the highest grain yield (2087 kg/ha), followed by Broad Casting (1894 kg/ha) and the zero tillage plot (1824 kg/ha). **Lentil** A trial with different sowing methods conducted for lentils showed the highest grain yield of 775 kg/ha in the zero tillage plot, followed by 650 kg/ha in drill sowing and 550 kg/ha in the broadcasting plot. **Groundnut** Farmers were very impressed with the performance of the imported (KMC) digger inverter, which showed 81% groundnut recovery compared to a local digger, which showed 67% recovery. They were also disappointed with blade performance, which showed a 53% recovery. Eleven pods were left per square metre by KMC, 22 pods per square metre by the local digger, and 33 pods per square metre on average on the ground. A 13.6% higher yield was observed in plots where groundnuts were sown on raised beds compared to plots where groundnut crops were planted on flat beds. In groundnut, a 14.7% higher yield was observed in laser-levelled plots compared with no levelling.

1.6 PC	Farmer-led plant nutrition trials where appropriate (target of at least two of the selected project areas).	Plant nutrition trials conducted (target of two trials). Data collected, analysed, reported, and discussed with farmers for future application.	April 2022	**Chickpea** This trial was conducted to study the impact of different nutrients on chickpeas. A high-yielding variety "Fakhar e Thal" was planted with five different treatments, including T_1 = control, T_2 = Boron (500 ml/acre), T_3 = Zinc (200 g/acre), T_4 = NPK (500 g/acre), and T5 = Amino Acid (500ml/acre). The mean values for days to 50% flowering ranged from 86 to 110. Delayed flower formation (110 days) was observed in T_4-treated plots and early flowering (86 days) in untreated (control) plots. The reason might be due to increased vegetative growth due to nutrient (NPK) applied to the plots in optimum dose, resulting in a delay in flowering. The data further showed that the crop treated with T_4 showed delayed maturity (177 days), while early maturity of 166 days was recorded for the control. This may be due to increased vegetative growth, which resulted in a delay in maturity. The tallest plants, 85.21 cm, were noted in plots applying T_4, while the shortest plants, 68.66 cm, were recorded in T_1 control plots. The plants produced the maximum of 127 pods plant-1 by application of T4 and the lowest of 77 pods/plant in control plots (T_1). The mean values for grain yield kg ha^{-1} ranged between 976–2321 kg ha^{-1}. The highest grain yield of 2321 kg ha^{-1} was gained by T_4, showing maximum utilisation of nutrients followed by T_5 with the average production of 2032 kg ha^{-1}, while the lowest grain yield (976 kg ha^{-1}) was recorded in untreated (T_1) plots. The results showed a significant effect of Fe on grain yield and related traits of chickpeas. The highest grain yield of 2029 kg ha^{-1} was gained by T4 (3 kg/ha), showing maximum utilisation of Fe, followed by T5 (4 kg/ha) with an average production of 1800 kg ha^{-1}, while the lowest grain yield (844 kg ha^{-1}) was recorded in untreated (T1) plots. Applying 3 kg/ha of Fe increased yield by 112% compared to non-treated (control) plots. The team thinks this trial should be further investigated. Compared to the control, a 26% increase in yield was observed in the plot after applying foliar organic fish fertiliser. **Groundnut** Gypsum application in groundnut showed a 26% improvement in crop emergence compared to the control

				plot, which is reflected as a 6% increase in overall crop yield.
1.7 PC	Farmer-led insect management trials on selected project sites.	Insect management trials conducted (target of two year trials). Data collected, analysed, reported, and discussed with farmers for future application.	Oct 2019 to April 2020	**Chickpea** **Pod borer** A better yield (31%) was observed in the plot where pod borer was managed with effective insecticide compared to untreated plots across all locations on average. **Groundnut** **Hairy caterpillar** With almost 12% less foliage damage in the trial's treated plot, an increase of 7% yield was observed. The larvae count reduced considerably after 14 days of spray, which helped reduce the damage to the foliage of groundnut plants.
1.8 PC	Farmer-led seed rate trials on selected project sites.	Seed rate trials conducted (target of two trials). Data collected, analysed, reported, and discussed with farmers for future application.	Oct 2019 to April 2020	**Chickpea** A higher population of 53 plants per square metre was observed in 175 kg per ha compared to 49, 38 and 35 plants per square meter in 100 kg, 125 kg and 150 kg per ha seed rates, respectively. No significant difference in number of pods per plant and 100 seed weight was observed for these treatments. However, a higher grain yield of 1855 kg/ha was observed in the 150 kg seed rate plot. Grain yield declined to 1727 kg/ha at a 175 kg/ha seed rate. This proved the concept of farmers putting higher seed rates as relevant, while the team thinks this phenomenon needs further investigation. **Groundnut** Although there was no significant difference in pods per plant and 100-grain weight for both treatments, the improved plant population in treatment one, which is 85 kg/ha seed rate, contributed to a 28% increase in the yield of the groundnut crop.
1.9 PC	Farmer-led chickpea green leaves harvesting trial at site 5.	Chickpea green leaves harvesting trial conducted (target of two trials). Data collected, analysed, reported, and discussed with farmers for future application.	April 2020	**Chickpea** The results from the trial showed a higher grain yield for treatments of harvesting Pali by hand, which is 1999 kg/ha, compared to sickle, which is 1768 kg/ha. However, the lowest yield of 1539 kg/ha was observed for plots where Pali was not harvested.

1.10 PC	Farmer-led seed primer trial of chickpea.	Seed primer trial of chickpea conducted. Data analysed, reported and discussed with farmers for future application.		**Chickpea** The results of the seed primer trial of chickpeas showed a higher yield of 315 kg/ha observed in the plot where the primer was applied to the seed, following 243 kg/ha in the plot where the seed was primed with water and a yield of 254 kg/ha was observed in the plot where the seed was sown without priming.
1.11 PC	Farmer-led trial to compare the use of methylcellulose as a binding agent for the rhizobium inoculation of seed in comparison to the sugar solution.	A trial comparing methyl cellulose and sugar solution as binding agents for seed inoculation was conducted. The data were analysed, reported, and discussed with farmers for future application.	April 2022	**Chickpea** The trial resulted in a higher nodule dry weight of 35100 mg/plant in the plot where methyl cellulose was used as an inoculating agent, compared to 33993 mg/plant where sugar solution was used. Although the number of nodules per plant improved in the plot where methyl cellulose was used, no significant improvement in crop yield was observed in both treatments. The grain yield where methyl cellulose was used was 1870 kg/ha, while the plot with sugar solution yielded 1864 kg/ha.
1.12 PC	In association with family farmers, study the impact of life saving irrigations on yield and yield components of chickpea.	A trial for life-saving irrigation was conducted at a farmer's field. The data were analysed, reported, and shared with family farmers for future application.	May 2022	**Chickpea** The trial was conducted with five treatments, including control, 01 irrigation, 02 irrigations, 03 irrigations, and 04 irrigations at critical stages of the chickpea crop. The data further showed that the crop that received three irrigations reached the maturity stage quite late (190 days), while an early maturity of 176 days was recorded in plots where no irrigation was applied. The plants produced the maximum 154 pods $plant^{-1}$ in plots irrigated three times and the lowest 98 pods $plant^{-1}$ in control plots. The mean values for grain yield ranged between 1432–2390 kg ha^{-1}. Plots with three irrigations gained the highest grain yield of 2390 kg ha-1, while the lowest grain yield was recorded for control plots with 912 kg ha^{-1}. This phenomenon needs further study.
1.13 PC	In association with research farm families carry out an economic analysis to determine the profitability of each adopted innovation.	Economic analysis conducted to determine the profitability of each adopted innovation. Report generated for the final review.		**Chickpea** In chickpeas, the use of insecticide to control pod borer yielded a net profit of PKR 35650, chemical weed management led to an additional income of PKR 29750, inoculating seed with rhizobium bacteria provided an additional income of PKR 32500, seed treatment with fungicide produced a profit of PKR 27860, and managing Ascochyta with foliar application of the fungicide supplied an additional advantage of PKR 25450.

				The nutritional trial of chickpeas showed a PKR 58069 increase in net profit by applying boron, compared to the control. Similarly, using zinc, NPK, and Amino acids increased the net profit by PKR 97100, 156849, and 117457 per ha, respectively. Compared to the 150 kg per ha chickpea seed rate trial, the 100 kg, 125 kg, and 175 kg trials showed a net loss of PKR 42018, 52522, and 73531, respectively. The lower yields mainly contributed to the loss. The green leaves (Pali) harvesting trial showed an increase in net profit of PKR 49778 by harvesting with hands compared to sickle. Hand-harvested Pali showed a profit increase of PKR 39323 compared to the control, where no Pali was harvested. No significant monetary benefit was observed in a trial where rhizobium inoculum binding agents, i.e., methylcellulose and sugar solution, were compared. An increase in profit was observed with the number of irrigations applied in the irrigation trial. PKR 77984, 99617,151263, and 104909 net profit was noted where 1, 2, 3, and 4 irrigations were used, respectively. **Lentil** The lentil sowing method trial showed a net per ha loss of PKR 12593 and 9065 in zero tillage and drill sowing, respectively, compared to the broadcasting method as a control. In lentil seed treatment, fungicide and weed management led to an additional profit of PKR 10890. **Groundnut** The groundnut inoculation trial resulted in a PKR 8575 increase in per ha net profit over the control where Biozote was applied and a PKR 10535 increase where New Edge inoculum was applied. In the groundnut fungicide-seed treatment trial, the fungicide cost was PKR 750, producing a net benefit of PKR 63000. The chemical weed management intervention cost was PKR 3600, providing a net profit of PKR 57600. Hairy caterpillar management intervention cost PKR 1000, yielding a net benefit of PKR 8300. The recommended seed rate cost PKR 3800

				extra but gave an economic advantage of PKR 115300. The Gypsum application showed a PKR 3418 increase in profit over the control. At the same time, the groundnut harvesting trial saved PKR 4201 and PKR 7803 by using local and KMC harvesters, respectively. Raised bed sowing of groundnut added a net profit of PKR 35900 over flat-bed sowing. Laser land levelling for groundnut gave a net profit of PKR 13000 over the unlevelled field.

Objective 2: To increase opportunities for farmers to undertake post-harvest value addition to chickpea, lentil and groundnut crops.

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1 PC	Determine current processing and marketing activities and the capacity of the community to expand those activities.	Outline current processing, marketing and capacity of community.	2019	A situational analysis was conducted with GCR family farmers to learn about pulses' prevailing farm-level value addition, revealing no commercial value addition of pulses was practised. However, limited value addition for domestic consumption was in practice. **Chickpea** Cleaning, grading, making splits and flour. **Lentil** Cleaning, grading and making splits. **Groundnut** Cleaning, grading, roasting and oil extraction. **(Appendix 2)**

2.2 PC	Introduce and evaluate the options in post-harvest value addition that are available through a workshop for Research Farm Families and other participants.	Evaluate options for post-harvest value-addition.	Feb 2020	Muhammad Nawaz Sharif University of Agriculture, Multan, organised plant-centric meals and DICE events. Farmers and industry people attended the events to link farmers with people from the pulse industry and let farmers understand the industry's quality requirements. Farmers were also apprised of different value-addition opportunities available for pulses—universities and institutes like BZU, Women University, Hamdard University Karachi, Govt. College of Home Economics, CTTS College, COTHM, Pak German Institute, ITHM, and MNSUAM participated. Peer Mehr Ali Shah Arid Agriculture University organized a one-day seminar at which GCR farmers shared their experiences with pulse value addition and experts from food technology shared their insights. A workshop was conducted in July 2022 where communication and linkages among peanut growers, processors, industry, academia, and researchers were facilitated. Thirty-five participants attended the workshop. The procurement manager from English Biscuit Manufacturers described the specifications and standards on which the industry will buy local peanuts. This required initial processing so the project could engage Lahore-based peanut processors named Nuts and Legumes Co. Capacity building of farmers for post-harvest peanut handling is needed to link them to the peanut value chain. A detailed report is attached **(Appendix 3.1)**. A workshop was conducted at site 3 to discuss the opportunity of the organic chickpea value chain. In the workshop, experts made farmers realise the potential of the organic value chain, the standards and practices required for organic chickpea production, post-harvest handling, and certification.

2.3 PC	Develop value addition demonstration projects in association with farming communities.	Design of value addition projects at each site.	Feb 2020	The Pulses Mango Festival was organised in Islamabad, where GCR farmers from Bhakkar showcased chickpeas, chickpea splits, chickpea flour, and lentils. The project organised a two-day Chickpea & Peanut Fest at Centaurus Mall, Islamabad, on the eve of World Pulses Day (Feb 10–11, 2020). Five GCR family farmers from Attock, Chakwal, Bhakkar, and Karak displayed their value-added products of international standards at different stalls. Peanut oil was displayed by GCR family farmers of Attock, Chakwal, and Karak, while GCR family farmers of Bhakkar displayed organic chickpeas (white and black) along with chickpea flour. Farmers experienced 60–90% value addition in their products. Thirty-five GCR family farmers were exposed to market interaction at the event. While preparing value-added products, the project guided them and assisted with different quality tests, grading, packaging, and branding. Farmers participated in showcasing events at Agri-Expos at Sargodha University and Lahore, at MNSUAM and NARC, where they showcased seeds of improved varieties and packed chickpeas, chickpea green leaves, chickpea flour, peanut oil, and peanut butter. **(Appendix 8)**
2.4 PC	Develop the capacity of participants in techniques relevant to value adding demonstration projects designed in Activity 2.3.	Capacity building activities completed to enable participants to engage in at least six value addition projects.	Feb 2020	Thirty-five GCR family farmers were exposed to Chickpea and Peanut Fest 2020 market interaction. The direct interaction with customers allowed GCR family farmers to understand the market requirements. During the preparation of value-added products for Chickpea and Peanut Fest 2020, together with GCRs, the process of value addition, including cleaning, grading, packaging, and branding according to international food standards, was learnt. Farmers were assisted with the quality test required to produce these value-added products. Six farmer field days were conducted on the post-harvest management of pulses attended by 513 farmers. **(Appendix 8)**

2.5 PC	Conduct value addition projects with a target of at least one value addition demonstration project per site.	A minimum of six value addition projects completed.	Jan–Feb 2020	Producing organic chickpea, pulse and organic chickpea flour was demonstrated to GCRs of sites 3 and 4. The production of aflatoxin-free high-quality peanut oil was demonstrated for sites 1, 2, and 4. Aflatoxin analysis was performed at the Food Testing Laboratories, NARC Islamabad. **(Appendix 14).** Peanut butter production was demonstrated to groundnut farmers at sites 1 and 2. Training of certified seed production was also provided at each site.
2.6 PC	Engage private sector companies in two workshops to evaluate the opportunity for a peanut oil industry, that sources product from small-scale producers, to operate at the national level.	Two workshops with edible oil manufacturer completed.	2019	A one-day Groundnut Stakeholders Linkages workshop was organised on March 14, 2023, by the ACIAR Pulses Project Team at PMAS-Arid Agriculture University Rawalpindi to promote and utilise the local groundnut produce, maximise the profitability of the growers and provide local peanut to the industry for its value addition. Mr Faheem Khan, Manager Procurement, English Biscuits Manufacturers, Karachi, shared his views with the growers and local traders about linking growers' networks with Industry, focusing on the potential and prerequisites. He shared the industry's marketing and procurement procedures and offered to buy the growers' produce in the required form with a good return. Mr. Hasaan Bilgrami, CEO of Biomasdar Pvt. Ltd., shared information about his ongoing and future initiatives in the value addition and processing of groundnut and other crops through his presentation**.** **(Appendix 3.2)** Two meetings, one with the Chairman of the Ghee and Oil Mills Association, Pakistan, Mr Waheed Chaudhry at, Islamabad and the other with the CEO of Shama Oil and Ghee Mill at Multan, were conducted to explore the opportunities for the peanut oil industry. The outcome of both meetings was to enhance the groundnut production and per acre yield to make available cheap and sufficient raw material for peanut oil production.

Objective 3: Develop and evaluate, in partnership with farmers, site-specific village-based seed production and dissemination systems to facilitate access to improved varieties.

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Identify in each experimental village one–two suitable seed producing farmers for recommended varieties.	A minimum of one seed producing farmer selected in each selected village.	Oct, 2019	After two years of varietal trials, the certified seeds of farmer-preferred varieties were provided to farmers. Willing farmers with irrigation facilities were identified for seed production. Seed production training was organised for the seed-producing farmers at each site.
3.2	Train and mentor seed producing farmers to achieve sustainable seed production activities.	A minimum of one improved variety of three crops is produced in the selected villages.	April 2020	This project ensured the availability of quality seed by establishing two village seed banks at Attock and Chakwal and engaging four private seed companies, Haji Sons, KanzoAg, Shoaib Seed Corporation, and RASCO Seeds. A total of 783 tonnes of quality seed of improved varieties was produced in the project life, comprising 609 tonnes of chickpea, 45 tons of lentil, and 129 tonnes of groundnut seed. (Appendix 9) The multiplied seed of chickpea varieties included Bittle 2016, NIAB Channa, Bhakkar 2011, Thal 2020, Fakhr e Thal, KK 1, Chattan, and DG 92. The multiplied seed of lentil varieties included Punjab Masoor 2009, Punjab Masoor 2019, Punjab Masoor 2020, and Markaz 2009. The multiplied seed of groundnut varieties included BARI 2016.
3.3	Communicate to the local communities the availability of locally produced seed via extension workers and NGOs. Make recommendations to policymakers regarding the availability of a seed certification system.	In association with other dissemination activities, six campaigns of communication completed (e.g., field days) and at least one printed promotional tool produced to promote the seed production system.	Oct 2020	Participating farmers of village seed banks were invited to the farmer field days and seminars organised under ACIAR and PSDP projects to communicate regarding seed availability. Seed availability was also shared in meetings within NRSP (NGO). A list of seed-producing farmer groups, varietal seed sale records, and the agreements with the farmer's group are attached. **(Appendix 4 & Appendix 5)** Private seed companies have their channel of marketing. Farmers also communicate on WhatsApp groups and Facebook pages about the availability of seeds.

Objective 4: ***Disseminate the learning and practices from the project activities to other farmers and private sector participants such as input suppliers and potential service providers.***

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Train Research Farming Families in communicating their learning and in facilitating the learning of FFS participants in culturally appropriate ways.	Train at least two research farming families from each site in communication and facilitation of learning for modified Farmer Field Schools.	Oct 2019	The learnings from tested technologies were demonstrated to 935 pulse farming families, including 115 female growers, in collaboration with local NGOs like the National Rural Support Program (NRSP), Sindh Rural Support Program (SRSO), and Baluchistan Rural Support Program (BRSP). Farmer-to-farmer learnings were encouraged on farmer field days where the GCR and expansion farmers shared their learnings by talking and practical demonstration. **(Appendix 7)**
4.2	Farmer Field Schools established and first activity completed and an evaluation of process carried out.	Modified Farmer Field Schools established and first activity completed at at least four sites.	Jan 2017	Collaborative research groups were established instead of farmer field schools, including 15 pulses farming families on each site, local partner research institutes, academia from partner universities, a coordination unit at NARC, project officers and project partners in Australia. So ninety pulse farming families on all sites were engaged in collaborative research.
4.3	Engage private sector participants in activities around the Farmer Field Schools.	Modified Farmer Field Schools include an expanded group of participants including private sector participants, universities and government departments.	Feb 2020	92 farmer field days, training, seminars, conferences, meetings, visits and showcasing events were conducted where project learnings were shared with 8796 farmers, researchers, academia, extension agents, input suppliers, service providers and industry representatives. **(Appendix 8)**
4.4	The impact of the Farmer Field Schools and related research activities and results validated through examination of the practice of farmers in neighbouring communities.	Evaluation of the impact of modified Farmer Field Schools on the practice of non-supported farmers in neighbouring communities.	June 2020	According to the impact analysis report, 90% of GCR farmers used certified seed, more than 50% of expansion farmers used certified seed, and almost 25% used certified seed at the non-beneficiary village, possibly due to the trickle-down effect of the project interventions. **(Appendix 6)**

4.5	Conduct workshops to strengthen women farmers' networks to learn their knowledge and preferences impacting productivity and profitability.	Series of workshops and on-farm meetings with women farmers undertaken.	August–September 2023	On-farm meetings and focus group discussions with the women pulse farmers were conducted at site 1 (Village Laniwala, Tehsil Fatehjang), site 2 (Village Kot Sarang, Tehsil Talagang), and site 3 (Village Saddar. Tehsil Mankera). However, at site 5, the focus group discussions were conducted at three villages, Lakki, Kamber Shahdad Kot, and Dhokri. The discussion revealed that women are involved in seed cleaning grading, manual weeding, manual harvesting, post-harvest management, and storage. During these activities, women are exposed to different health issues, ranging from skin and respiratory tract allergies to more significant health issues from using carcinogenic mercury for grain storage. Two workshops were conducted (one at PMASAAUR and the other at MNSUAM) for capacity building and exposure to safe options for field work and post-harvest management, including storage. The project developed innovative hermetic storage bags using domestic resources. These bags were distributed to farm families to avoid the risk of using mercury for safe grain storage with an extended shelf life. Twenty-three female farmers from sites 1 and 2 participated in the workshop held at PMASAAUR, while 28 female farmers from sites 3 and 5 participated in the workshop held at MNSUAM.

7 Key results and discussion

7.1 Varietal Trials (2017–18 and 2018–19)

Background: During the consultative workshop held at NARC in October 2015, the participants highlighted the non-availability of certified seeds. During the first stage of situational analysis conducted in December 2017, it was reasserted to engage the willing pulses farming families in Groups for Collaborative Research (GCRs). GCRs started varietal chickpea and lentil trial activities during the winter of 2017–18. Seeds of approved varieties were collected from research institutes in Pakistan. The trial plans were prepared and distributed to all six project sites, namely Attock, Chakwal, Bhakkar, Karak, Larkana, and Jafferabad, for sowing. The groundnut on-farm varietal trials were initiated In May 2018. In July, the second stage of situational analysis was conducted, clarifying further that there is a limited quantity of pulse seed produced by the public sector and that no private company was involved in the pulse seed business. The lack of formal and informal seed supply systems limited smallholder farmers' access to certified seeds of improved pulse varieties. Farmers did not know the name, yield potential and other attributes of improved varieties. The use of seed from last year's crop or purchasing from Aarh'ti (local SME) in the grain market was widespread, resulting in low yields and crop failures due to diseases.

Objective: To introduce the improved varieties to pulse growers and learn their requirements for future research.

Locations: Trials were prepared and distributed to all six project sites (Attock, Chakwal, Bhakkar, Karak, Larkana, and Jafferabad). However, the site six first-year trials (2017–18) were planted at the Agricultural Research Institute (ARI), Jafferabad, where soil and water were unsuitable, resulting in non-reportable results. The provincial extension department deployed a team member (Mr Zulfiqar Ali Rahujo) to site 6. His deputation period ended in no varietal trial at site 6 in 2018–19. To compensate for this, farmers from site six were invited to visit varietal trials at site 5 (Larkana), representing the same agroecological conditions for growing chickpeas and lentils as a "Dobari" crop after rice on both sites.

Methodology: To study the performance of released varieties, 14 chickpea genotypes (12 Desi type and 2 Kabuli type), 4 lentil varieties, and 3 groundnut varieties were collected from different research institutes. The randomised complete block design (RCBD) concept was introduced to the participating farmers. The seed of each variety was inoculated with rhizobia and fungicide at the recommended dose before seeding. The recommended protocols for chickpea crop production were used to manage each trial plot. Farmers and researchers visited the trials twice during the crop period. Details of experiments are as below.

Parameter	Chickpea	Lentil	Groundnut
No. of Test Entries	14	04	03
Design	RCBD	RCBD	RCBD
Replications	3	3	3
No. of Rows per Plot	6	4	6
No. of Seeds per Row	40	200	40
No. of Seeds per plot	240	800	240
Row Spacing (cm)	30	30	45

Row Length (cm)	4	4	4
Total Area of Plot Sq. m	7.2	4.8	10.8

Details of chickpea varieties:

Entry No.	Entry Name	Source	Type
1	Bhakkar-2011	AZRI, Bhakkar	Desi
2	Thal-2006	AZRI, Bhakkar	Desi
3	Bittle-2016	AZRI, Bhakkar	Desi
4	Noor-2013	AARI, Faisalabad	Kabuli
5	NIAB Channa 2016	NIAB, Faisalabad	Desi
6	KK-1	ARS, Karak	Desi
7	KK-2	ARS, Karak	Desi
8	KK-3	ARS, Karak	Desi
9	Fakhar-e-Thal	ARS, Karak	Desi
10	Chattan	ARS, Karak	Desi
11	DG-89	QAARI, Larkana	Desi
12	DG-92	QAARI, Larkana	Kabuli
13	Dasht	NARC, Islamabad	Desi
14	Parbat	NARC, Islamabad	Desi

Details of lentil varieties:

Entry No.	Entry Name	Source	Type
1	NIAB Masoor	NIAB, Faisalabad.	Microsperma
2	Markaz 2009	NARC, Islamabad.	Microsperma
3	Punjab Masoor	AARI, Faisalabad.	Microsperma
4	ShirAZ-96	BARDC, Quetta.	Microsperma

Details of groundnut varieties:

Entry No.	Entry Name	Source	Type
1	BARI 2011	BARI, Chakwal	Bunch Virginia
2	BARI 2016	BARI, Chakwal	Bunch Virginia
3	Pothwar	NARC, Islamabad.	Bunch Virginia

Results and discussion:

7.1.1 Chickpea results and discussion

Variety	Yield (Kg/ha) 2017-18				Yield (Kg/ha) 2018-19					Mean
	Site 1	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5	
Bhakkar-2011	2007	1083	833	2520	665	761	1175	1403	1588	1337
Thal-2006	1785	660	798	3271	677	762	974	1155	1479	1285
Bittle-2016	2137	636	798	2135	567	717	1150	1504	1728	1264
Noor-2013	2219	697	677	2292	714	823	965	1181	978	1172
NIAB Channa 2016	1828	656	793	2156	534	711	1000	886	1665	1137
KK-1	1535	1241	723	1188	448	633	1109	1318	1374	1063
KK-2	1612	1000	723	1969	463	650	782	1433	1156	1088
KK-3	1422	692	644	854	498	679	764	1387	1011	883
Fakhar-e-Thal	2112	466	975	1760	600	735	747	2305	1790	1277
Chattan	2260	920	854	1750	587	732	681	1037	956	1086
DG-89	1618	719	822	1323	410	430	770	1082	1247	936
DG-92	2030	902	789	1594	346	404	517	1092	1028	967
Dasht	1533	737	807	1088	427	502	636	1054	1508	921
Parbat	2008	692	750	948	428	469	646	875	1795	957

Site 1 (Attock)

Average yield data of the chickpea varietal trial conducted at site 1 for two years (2017–18 and 2018–19) revealed that Noor 2013 outclassed other varieties with a 1467 kg/ha yield. Chattan was in second position with an average yield of 1424 kg/ha, whereas Fakhr e Thal and Bittle were similar with an average yield of 1356 kg/ha and 1352 kg/ha, respectively.

Site 2 (Chakwal)

At site 2, Noor 2013 performed best, with an average yield of 823 kg/ha, whereas Thal 2006 and Bhakkar 2011 were similar, with an average yield of 762 kg/ha and 761 kg/ha during 2018–19. Fakhr e Thal was also among the top-performing varieties, with an output of 735 kg/ha. The farmer abandoned the trial in 2017–18.

Re-envision:

Despite Noor 2013, a kabuli chickpea variety, performing exceptionally on sites 1 and 2, farmers preferred Bittle 2016, a desi chickpea variety, based on seed properties, market value, and taste. Heavy rains during the months of February to April 2019 caused damage to the chickpea crop. It was observed that all varieties showed more vegetative growth, lodging, incidence of Ascochyta blight disease and pod borer infestation. All these factors resulted in low yields. Chattan, a variety from KPK, also performed well but showed iron chlorosis when there were heavy rains. This situation requires a focus on the development of climate-resilient varieties and agronomic practices. It was also established that regardless of yield performance farmers preferred varieties with better market value and size of the grain.

Site 3 (Bhakkar)

Surprisingly a desi chickpea variety from KPK, KK 1, performed outstandingly at site 3 with an average yield of 1175 kg/ha. Local variety Bhakkar 2011, with an average yield of 1129 kg/ha, was almost on par with KK 1; however, Bittle 2016 was also among the top performing varieties with a yield of 893 kg/ha and was on par with KK 2, having an average yield of 891 kg/ha.

Re-envision:

When the results were discussed in GCR at site 3, and KK1 from KPK performed better over local varieties, farmers asked about the seed of KK1. Local partners from AZRI were reluctant and wanted to promote local varieties. However, the project intervened, convinced local partners and facilitated the procurement of certified seed from the Agricultural Research Station, Karak, KPK. So the seed of chickpea varieties KK1, Bhakkar 2011, Thal 2006, and Bittle 2016 was multiplied at this site. KK1, however, was not acceptable to farmers despite its good yield as it had a small size and was not fetching good returns.

Site 4 (Karak)

Fakhr e Thal a desi chickpea variety outperformed all varieties with an average yield of 1640 kg/ha at site 4. Bittle 2016 and Bhakkar 2011 were on par with yields of 1158 kg/ha and 1118 kg/ha. KK1, KK2 and KK3 were on par with average yields of 1021 kg/ha, 1078 kg/ha, and 1016 kg/ha, respectively.

Site 5 (Larkana)

Thal 2006 was the best-performing variety at site 5, with an average yield of 2375 kg/ha. Bhakkar 2011, with a yield of 2054 kg/ha, was second in position, while Bittle 2016 was also among the top performing varieties with an average yield of 1932 kg/ha.

When the results were discussed with GCR farmers and local partners at site five, the best-performing varieties like Thal 2006 and Bhakkar 2011 were Desi types from Punjab. The project facilitated farmers in procuring the seeds of these varieties. The following year, during a field visit of project officers, farmers complained about the difficulty of selling Desi chickpeas. According to them, the value chain for Kabuli chickpeas is well established at this site, and buyers are reluctant to purchase desi chickpeas. This was reported and corrected. Consequently, the following year, pure seed of the local Kabuli variety DG 92 was provided for seed multiplication. Also, this variety is semi-erect with a bushy plant type, and local communities use the green leaves of chickpea plants as vegetables. This was another reason for the farmers' preference for this variety. However, this variety, which was released in 1992, requires improvement.

Site 6 (Jafferabad)

At site six, chickpea varietal trials failed for two consecutive years. However, GCRs from this site were facilitated to visit the trials at site 5, as both sites have rice-based cropping systems. Chickpea is grown on the residual moisture of rice. Seeds of varieties from Punjab, like Bittle 2016 and Parbat, were provided to the farmers. Although it increased the farmers' per acre yield, farmers were still reluctant to replace the local landrace called Lalrhi. Lalrhi has unique properties making it suitable for roasting. It has a strong value chain developed as it is transported and traded to all parts of Pakistan. Unfortunately, the local landrace, Lalrhi, is facing multiple challenges as it is susceptible to seed and soil-borne diseases. It is genetically impure and thus requires research to achieve actual varietal status.

7.1.2 Lentil results and discussion

Variety	Yield. 2017–18 (kg/ha)			Yield. 2018–19 (kg/ha)			Mean
	Site 1	Site 3	Site 5	Site 1	Site 2	Site 3	
NIAB Masoor	1155	2451	1531	429	467	1226	1210
Markaz 2009	1946	2326	1109	387	394	2001	1361
Punjab Masoor	1738	133	1038	358	360	2206	972
Shiraz 96	1137	1465	1813	350	343	111	870

Site 1 (Attock)

The lentil variety Markaz 2009 performed best on average, with an average yield of 1361 kg/ha, followed by Niab Masoor (1210 kg/ha) and Punjab Masoor (972 kg/ha).

During the 2017-18 season, Markaz 2009 also yielded higher (1946 kg/ha) than Punjab Masoor (1738 kg/ha) and NIAB Masoor (1155 kg/ha). However, during the growing season 2018-19 that was severely affected by significantly higher rainfall, All the four tested varieties had low grain yield. NIAB Masoor produce 429 kg/ha),Markaz 2009, 387 kg/ha, and Punjab Masoor (358 kg/ha). On average basis Markaz 2009 performed better with an average yield of 1167 kg/ha.

Site 2 (Chakwal)

Site 2 was also affected by significantly higher rainfall during 2018-2019. Compared to the other three varieties NIAB Masoor performed relatively better with an average yield of 467 kg/ha, followed by Markaz 2009, yielding 394 kg/ha.

At sites 1 and 2, although farmers regularly grow lentils for domestic consumption, they are reluctant to increase their area due to wheat being a competitive crop and due to issues like lack of availability of chemical weed control and mechanized harvesting in lentils. Changing climatic conditions also affect the productivity of lentils, especially the erratic rains during the months of March and April when the crop is heading towards maturity, causing severe damage to the quantity and quality of grains. During the growing season of 2018-19, in the month of March 2019, the country received more rain, which was 47% above the normal (Anonymus, 2019). Hence, it needs more focus on breeding climate resilient varieties and developing the production technologies to mitigate the effect.

Site 3 (Bhakkar)

Markaz 2009 outperformed all other varieties with an average yield of 2164 kg/ha at site 3. NIAB Masoor was also a good performing variety with a yield of 1839 kg/ha, followed by Punjab Masoor with an average yield of 1170 kg/ha.

At Bhakkar, lentils are grown in the area where most of the farmers belong to families that migrated from central Punjab. They irrigate the lentil crop. Most of them grow lentils for domestic consumption. They also produce split lentils domestically in a manually operated mill. The Bhakkar region offers the possibility of an increased lentil production at commercial levels.

Site 5 (Larkana)

Shiraz-96 performed well at site 5 with an average yield of 1813 kg/ha, followed by NIAB Masoor, which yielded 1531 kg/ha. Later, farmers did not show a willingness to cultivate lentils as a competitive crop to chickpeas. The chickpea crop provides vegetables during the growing season, which is a preferred food in the area. A value chain has also been developed for the chickpeas.

7.1.3 Groundnut results and discussion

Variety	Yield in Year 2018 (kg/ha)			Yield in Year 2019 (kg/ha)			Mean
	Site 1	Site 2	Site 4	Site 1	Site 2	Site 4	
BARI 2011	2309	2275	1667	1333	1098	1619	1717
BARI 2016	1992	2376	2732	1050	1067	1788	1834
Pothwar	2105	2180	2460	892	720	999	1559

Site 1 (Attock)

Groundnut variety BARI 2011 was the best-performing variety at site 1 with an average yield of 1821 kg/ha, followed by BARI 2016 with an average yield of 1521 kg/ha.

Site 2 (Chakwal)

At site 2, groundnut varieties BARI 2011 and BARI 2016 performed similarly with average yields of 1098 kg/ha and 1067 kg/ha, respectively.

Site 4 (Karak)

BARI 2016 was the best-performing variety at site 4 with an average yield of 2260 kg/ha, followed by Pothwar with a yield of 1730 kg/ha and BARI 2011 with an average yield of 1643 kg/ha.

All the available groundnut varieties are high in oil content, with no current value chain to exploit the industrial production of edible peanut oil. The primary market for peanuts is a roasted nut. Rancidity due to the oxidation of free fatty acids spoils the aroma and taste over a period. The peanut industry also demands groundnut varieties with low oil content. The issue is that groundnut is placed under oilseed crops in the National Research System. So, breeders are breeding varieties for higher oil content. The project communicated this situation to the respective research institutes and policymakers on many platforms. So far, the industry is importing groundnut from other countries as current groundnut varieties despite their acceptable taste are not suitable due to high oil contents. New varieties with low oil content are needed to strengthen the value chain domestically. Due to better taste, farmers grow low-yielding local desi groundnut varieties for local consumption and, at the same time, improved varieties for domestic markets. .

7.2 Technology Trials

7.2.1 Chickpea

Rhizobium inoculation trial of chickpea

Background: It is established that rhizobium bacteria play a vital role in enhancing soil productivity by improving the soil's nutrient profile through nitrogen fixation. It fulfils the nitrogen demand of legumes being grown but leaves ample nitrogen for successive crops.

Situational analysis conducted under an ACIAR pulse production project in Pakistan in 2017 revealed that chickpea, lentil, and groundnut farmers did not know about using rhizobium inoculation. So, to let farmers test the use of rhizobium inoculation, this trial was conducted with GCR family farmers at their farms.

Objective: To test the effect of rhizobia inoculation on chickpea nodulation and yield and select the best-performing inoculum for each site.

Locations: Attock, Chakwal, Bhakkar, Karak, and Larkana. The experiment was planted with GCRs on these sites at their respective paddocks.

Methodology: One acre, subdivided into three equal plots, each having one treatment.

T1 = Biozote chickpea inoculum
T2 = Nodule N chickpea inoculum of New Edge Microbials
T3 = Control (No inoculum)
Row spacing = 30 cm
Fertiliser = 50 kg DAP per acre
Weedicide = S-Metolachlor (Pre-emergence)= 800 ml/acre
Chickpea varieties used:
Site 1,2 and 3 = Bittle 2016 (Desi)
Site 4 = Fakhr e Thal (Desi)
Site 5 = DG-92 (Kabuli)

Trial period: Two years

Results:

Effect of rhizobium inoculation on yield of chickpea

Site	Active Nodules per plant			Yield (Kg/ha)		
	New Edge	Biozote	Untreated	New Edge	Biozote	Untreated
1	27	45	13	1060	713	600
2	28	44	18	900	740	584
3	65	66	46	1635	1805	1420
4	65	52	24	1872	1938	1303
5	62	69	44	2060	2059	1893
Mean	49	55	29	1505	1451	1160

Discussion: The results revealed that New Edge rhizobium inoculum contributed a 26% yield increase over the control across all sites, while Biozote rhizobium inoculum contributed a 20% yield increase over the control. New Edge performed better at sites 1 and 2, while Biozote was more productive at sites 3 and 4. At site 5, New Edge and Biozote performed similarly, with an 8% increase in yield over the control. Regarding nodule formation, New Edge performed well at site 4 with 63% more nodule formation than the control, while Biozote performed well at sites 1 and 2 with a 71% and 52% increase in nodule formation, respectively, over the control.

Seed/soil-borne disease management trial in chickpeas

Background: During the situational analysis conducted under the ACIAR pulses project in Pakistan, farmers informed the project team that some plants in their chickpea crop die at the seedling stage. Some farmers believed it could be a termite attack, but most reported it as a disease. The project team further investigated and found that the plants die due to dry and wet root rot disease, depending on the site where crops are planted. In some areas, Fusarium wilt was also reported. So, to learn and manage these seed/soil-borne diseases, this trial was conducted with family farmers of Groups for Collaborative Research (GCRs) at different project sites for two years – 2018–19 and 2019–20**.**

Objective: To manage the seed and soilborne diseases in chickpeas through seed treatment with an effective fungicide.

Locations: Attock, Chakwal, Bhakkar, Karak, and Larkana.

Methodology: The trial was conducted as participatory research with one GCR farmer at each site. One acre was divided into two plots. The seed of one plot was treated with fungicide (Thiophenate methyl @ 2gm per kg of seed), and one plot was farmer practice, which was a control with no use of any seed treatment fungicide. The project team and participating farmers visited the trial at different crop stages. The yield data of both plots were recorded for comparison.

Row spacing = 30 cm
Fertilizer = 50 kg DAP per acre
Weedicide = S-Metolachlor (Pre-emergence)= 800 ml/acre
Chickpea varieties used:
Site 1, 2 and 3 = Bittle 2016 (Desi)
Site 4 = Fakhr e Thal (Desi)
Site 5 = DG-92 (Kabuli)

Year of trials: 2018–19 and 2019–20

Results:

Effect of seed treatment fungicide on disease spread and grain yield of chickpea.

Treatment	Yield (Kg/ha)					Mean
	Site 1	Site 2	Site 3	Site 4	Site 5	
Thiophenate methyl	580	360	1198	1830	1745	1143
Untreated	550	323	843	1307	1487	902

Discussion: A significant improvement in yield of about 21% was recorded across all sites on average in plots where the seed was treated with fungicide to manage root rot and fusarium wilt over the untreated one. At sites 3 and 4, the results were very promising because due to the drought period, often there is an attack of termites. The plants damaged by termites usually get infected by soil-borne fungal diseases. These results were significant enough to convince farmers to treat their seeds with effective seed treatment fungicides. At first, farmers perceived root rot with termite attack, but after two years of repeated trials, they can now easily differentiate between termite attack and root rot.

Weed management trial of chickpea

Background: Weed management was one of the major issues highlighted during situational analysis in 2017. In the absence of post-emergence weedicide, weed management was a daunting task in chickpea crops. It is labour-intensive and the most expensive activity during the crop cycle. At site 5, farmers said it costs about 20,000 PKR of labour for manual weeding. This reduces the profitability of chickpea crops significantly. This issue was converted into a researchable question, and later this trial was planned with GCR family farmers at all project sites.

Objective: Chemical weed management in chickpea crops through pre-emergence herbicide.

Locations: Attock, Chakwal, Bhakkar, Karak, Larkana, and Jafferabad.

Methodology: One acre was divided into two plots. One plot (treated plot) was treated with a pre-emergence weedicide (S-Metolachlor) after sowing chickpeas, and the other plot was kept as a control with no pre-emergence herbicide. Weed counts were done at regular intervals during the cropping period, and the dry weight of weeds per square metre was also measured until harvest.

Seed treatment: Thiophenate methyl @ 2g per kg of seed
Seed Inoculation: Biozote @ 500 g for one-acre seed
Row spacing = 30 cm
Fertilizer = 50 kg DAP per acre
Chickpea varieties used:
Site 1, 2, 3 and 6 = Bittle 2016 (Desi)
Site 4 = Fakhr e Thal (Desi)
Site 5 = DG-92 (Kabuli)

Years of trial: 2018–19 and 2019–20.

Results:

Effect of pre-emergence herbicide on weed count over crop period.

Sites	**Treatment**	**Weed count per m^2 (DAE*)**						**Weed dry weight(g) per m^2 (DAE)**					
		30	60	90	120	150	Harvest	30	60	90	120	150	Harvest
	Pre-emergence herbicide	3	5	8	9	11	13	25	60	81	102	132	148
	Control	12	16	19	23	25	29	146	196	217	283	306	355

Effect of pre-emergence herbicide on yield of chickpea crop.

Site	Yield (Kg/ha)		% increase in yield
	Pre-emergence herbicide	Untreated	
1	588	485	18
2	577	464	20
3	1013	630	38
4	1093	869	20
5	1704	1471	14
6	1372	985	28
Mean	1058	817	23

Discussion: The result showed that a 55% reduction in weed count in the treated plot (pre-emergence herbicide) at harvest of the chickpea crop resulted in a 23% increase in overall yield compared to the control across all sites on average. The dry weed weight in the treated plot was 58% less than the control. Farmers at site 5 said this intervention reduced the weed management cost from PKR 20000 per acre to 2000 per acre. This intervention was widely adopted as the sales manager from the company reported that our sales in the area have increased due to the application of this chemical on chickpeas.

Pod borer management trial of chickpea

Background: It was interesting and shocking to learn during the situational analysis conducted in 2017 that there is a myth among farmers that no chemical of any sort whether insecticide or herbicide, can be sprayed on chickpea crops as this will burn the whole crop. So, they were not spraying any chemicals to manage the pod borer insect. When shown on cards, farmers recognised pod borer (*Helicoverpa spp.)* as a significant insect pest of chickpea crops. This trial was planned and planted with GCR family farmers to address the pod borer issue.

Objective: Management of pod borer in chickpeas through effective insecticide.

Locations: Attock, Chakwal, Bhakkar, Karak, Larkana, and Jafferabad.

Methodology: One acre was divided into two plots. Together with GCR farmers, the process of pest scouting was learned to spray the insecticide when it is most effective on insects like the early larval stage. Bifenthrin @ 350 ml per acre was applied upon the appearance of pod borer larvae. During trials, pest scouting techniques and recognition of insect pests in the field were demonstrated to the farmers.

Seed treatment fungicide: Thiophenate methyl @ 2g per kg seed
Seed inoculation: Biozote rhizobium inoculum @ 500g for one-acre seed
Row spacing: 30 cm
Fertilizer: 50 kg DAP per acre
Weedicide: S-Metolachlor (Pre-emergence)= 800 ml/acre
Chickpea varieties used:
Site 1, 2 and 3 = Bittle 2016 (Desi)
Site 4 = Fakhr e Thal (Desi)
Site 5 = DG-92 (Kabuli)

Years of trial: 2018–19 and 2019–20

Results:

Effect of pod borer management on yield of chickpea crop.

Site	Yield (Kg/ha)		% increase in yield
	Insecticide	Untreated	
1	657	485	26
2	469	352	25
3	1390	1019	27
4	1925	1210	37
5	1670	1406	16
6	950	420	56
Mean	1177	815	31

Discussion: On average, a 31% better yield was observed in the pod borer-managed plot using effective insecticide compared to the untreated plots across all locations. Farmers were convinced in this trial that insecticide does not burn the crop but effectively manages the pod borer population, resulting in improved grain yield. At sites 1 and 2, early chickpea crop escapes the pod borer attack while significant damage is done if not managed at sites 3, 4, 5 and 6. At sites 3 and 4, there is a need for an option of organic insecticide as most of the crop is grown organic. At sites 5 and 6, the project worked on the time of application of insecticide as the green leaves are used as vegetables.

Chickpea Pali (green leaves) harvesting trial

Background: The local Larkana, Karak, and Jafferabad communities consume green chickpea leaves as vegetables. Farmers harvest this Pali three to four times from the early seedling to flowering stages. They consume it domestically and sell it to a middleman who takes it to the urban markets. Farmers consider it as a source of income. During a situational analysis of the value addition of pulses in 2018, farmers at site 5 (Larkana) revealed that they were experiencing reduced grain yield due to cutting green leaves for domestic use and selling to the market. Senior farmers said they used to harvest these green leaves by hand, while presently, farmers use a sickle to gather the chickpea leaves to get more for an increased income. So, the project team decided to conduct this trial with GCRs to study the phenomenon.

Objective: To study the impact of different methods of Pali harvesting on grain yield.

Locations: Larkana
Methodology: One acre was divided into three equal plots, each having one treatment. Three treatments were applied in the trial.
T1= harvesting Pali by hand
T2= harvesting Pali with a sickle (C-shaped iron cutter with teeth)
T3= Control (Pali was not harvested)
Row spacing = 30 cm
Seed treatment: Thiophenate methyl @ 2g per kg of seed
Seed inoculation: Biozote @ 500 g for one-acre seed
Fertiliser = 50 kg DAP per acre
Weedicide = S-Metolachlor (Pre-emergence)= 800 ml/acre
Variety used = DG-92 (Kabuli)
Years of trial: 2019–20 and 2021–22
Pali was harvested one month after the emergence of the chickpea crop, i.e., early December.
Results

Table-: Effect of different Pali harvesting techniques on grain yield

Treatment	Seed yield (kg/ha)
Harvesting by Hand (T1)	1999
Harvesting by Sickle (T2)	1768
No harvesting (T3)	1539

Discussion: The results from the trial showed a higher grain yield for treatments of harvesting Pali by hand (1999 kg/ha), compared to sickle harvesting (1768 kg/ha). The lowest yield of 1539 kg/ha was observed in the plot where Pali was not harvested. Nipping a tender branch with leaves using a hand results in the production of two to three lateral branches, which bear pods, resulting in an increase in production. However, using a sickle, more foilage is cut, resulting in stress on the plant, thereby reducing yield. This activity is done for domestic use and for sale also. This pali has great market value and is sold in cities.

Chickpea seed rate trial

Background: A surprisingly high seed rate practice in chickpea crops was revealed during the 2017 situational analysis at sites 5 and 6. For the project team, it was almost double the standard recommended seed rate for the chickpea cultivars. So, to study this phenomenon, a seed rate trial was planned and conducted with GCR family farmers using their paddocks.

Objective: Optimisation of seed rate of chickpeas for the recommended cultivars.

Locations: Larkana and Jafferabad.

Methodology: A one-acre plot was divided into four equal plots, one for each treatment (seed rate). Four treatments were decided after discussion with GCR family farmers, including 150 Kg per ha practised by the farmers.

T1= 100 kg per ha seed rate
T2=125 kg per ha seed rate
T3= 150 kg per ha seed rate
T4= 175 kg per ha seed rate
Seed treatment fungicide: Thiophenate methyl @ 2g per kg seed
Seed inoculation: Biozote rhizobium inoculum @ 500g for one-acre seed
Row spacing = 30 cm
Fertiliser = 50 kg DAP per acre
Weedicide = S-Metolachlor (Pre-emergence)= 800 ml/acre
Varieties used:
Site 5 = DG-92 (Kabuli)
Site 6 = Bittle 2016 (Desi)
Years of trial: 2019–20 and 2020-21.

Results

Effect of different seed rates on yield and yield components of chickpea.

Treatment	No. of plants/m^2	No. of pods/plant	100 seed weight (g)	Grain yield (kg/ha)
100	35	42	37	1395
125	38	42	36	1517
150	49	44	36	1855
175	53	39	35	1727

Discussion: A higher plant population of 53 plants per square metre was observed in 175 kg per ha compared to 49, 38, and 35 plants per square metre in 100 kg, 125 kg, and 150 kg per ha seed rates, respectively. No significant difference in the number of pods per plant and 100 seed weight was observed for these treatments. However, a higher grain yield of 1855 kg per ha was observed in the 150 kg seed rate plot. Grain yield declined to 1727 kg/ha with a 175 kg/ha seed rate. This proved the concept of farmers putting higher seed rates as relevant, while the team thinks that this phenomenon needs further investigation.

Comparison of methylcellulose and sugar solution as the binding agent for seed inoculation

Objective: To assess the best method of binding agent for seed inoculation (methylcellulose vs. sugar solution).

Methodology: The trial was conducted during the Rabi season in 2021–22 in District Suhbatpur through the ACIAR Pulse Project. Before sowing the crop, a one-acre plot was divided into two equal plots (half-acre). The inoculation of seed one plot with Biozote was done using methyl cellulose, while the other was inoculated using a sugar solution. The data of collected nodules at the time of flowering and the yield contributing parameters during the crop cycle were recorded. The seed of both plots was also treated with the following fungicides/weedicides:

Seed treatment fungicide: Thiophenate methyl @ 2g per kg of seed

Weedicide: S-Metolachlor (Pre-emergence)= 800 ml/acre

Results

Inoculants	At flowering stage					At maturity stage			
	Root length (cm)	Root dry mass (mg/ plant)	Shoot dry mass (mg / plant)	Nodules/ Plant (No.)	Nodule dry wt. per plant (mg/plant)	No. of pods/plant (No.)	100-seed wt (g)	Stover yield (T/ha)	Seed yield (T/ha)
Methylcellulose	13.76	1100	11230	31	35100	80	34.01	2.305	1.870
Sugar solution	14.33	1125	10201	29	33993	78	32.9	2.430	1.864

Discussion: The results indicated no significant differences in different parameters recorded between methyl cellulose and sugar solution. This suggests that methylcellulose or sugar solution cannot affect the efficacy of the inoculum.

Impact of life-saving irrigations at critical crop stages on Chickpea yield

Objective: To select the best level of irrigation for chickpea growth and performance.

Material and methods

A high-yielding desi variety, “Fakhar e Thal” was planted in the field at site 3 with five treatments: control, 1 irrigation, 2 irrigations, 3 irrigations, and 4 irrigations. Irrigation are applied using the surface irrigation method. This trial was sown in a randomised complete block (RCB) design, having three replications. Each subplot comprised six rows, planted 30 cm apart, while row length was kept at 4 metres. Normal cultural practices were followed during the crop growth, and the crop was kept weed free during the entire season. All the necessary data were recorded and statistically analysed using the computer package of STATISTIX 8.1. Economical analysis was also done.

Results and discussion

The collected data showed significant differences for all the parameters studied in this trial. The mean values for days to 50% flowering ranged from 97–110. Delayed flower formation (110 days) was observed with 3 irrigations and early flowering (97 days) in the control. The data further showed that the crop that received 3 irrigations reached the maturity stage quite late (190 days). In contrast, early maturity of 176 days was recorded in plots where no irrigation was applied. It might be due to increased crop growth resulting from delays in maturity. The tallest plants (89.6 cm) were noted in plots having 3 irrigations, while the shortest plants (61.66 cm) were recorded in the control plots. The plants produced a maximum of 154 pods plant-1 in plots with 3 irrigations, and the least pods per plant (98) were in the control plots. The mean values for grain yield kg ha^{-1} ranged between 1432–2390. The highest grain yield (2390 kg ha^{-1}) was in plots that had 3 irrigations, while the lowest grain yield was for the control plots (912 kg ha^{-1}).

Most of the chickpea-growing area in KPK lies in the upper Thal region, where the crop depends on rains. Unlike lower Thal (Bhakkar), where underground water is shallow, the water table in upper Thal is very deep, and the cost of pumping underground water is high. However, in some areas, like Takht Nusrati, water is available for irrigation. Farmers here get a good chikpea crop and also use green leaves for vegetable purposes.

Mean values for different parameters recorded in chickpea irrigation trial

Treatments	Days to flowering	Days to maturity	Plant height (cm)	Pods/ plant	Yield (kg/ha)
0	97 c	176 d	61.66 d	98 e	912 e
1	106 bc	184 c	79.66 c	107 d	1612 d
2	106 bc	186 b	83.00 b	126 c	1872 c
3	110 a	190 a	89.66 a	154 a	2390 a
4	107 b	184 c	84.33 b	137 b	2133 b
LSD	**1.630**	**1.752**	**4.520**	**7.153**	**152.80**

Means showing different letters differed significantly $p \leq 0.05$

Zero tillage chickpea sowing trial in comparison with farmer practice and full tillage sowing method for chickpea

Objective: This trial aims to demonstrate the impact of different methods of sowing, especially zero tillage, on yield and its components.

Methodology: A trial was conducted at Damrah village, Larkana (site 5) to check the impact of different methods of sowing, especially zero tillage, on crop yield and its components. This demonstration trial aimed to make farmers aware of the impact of other forms of sowing, especially zero tillage, on yield and its components, to help increase their profitability and minimise input costs. This type of trial was conducted for the first time in the area. The variety of chickpea used was DG 92 (Kabuli type). Three types of sowing methods were used: zero tillage, seed drill, and broad cast (the traditional method). For the trial, seed rate of 85 kg per ha was used. Zero tillage drill was used for the treatment. For normal drill mehod soil was opened with disc harrow followed by rotary tillage to prepare seed bed. Broad casting is done after opening soil with disc harrow and rotary tillage is done to cover the seed.

Results:

Treatment	Plant height (cm)	Branches per plant	Pods per plant	Seed yield (kg/ha)
Broad casting (By hand)	48	15	59	1894
Drill (afer seed bed preparaion)	51	18	54	2087
Zero tillage	43	14	51	1824

Discussion: The sowing methods significantly influenced chickpea grain yield. The highest grain yield (2087 kg/ha) was obtained using seed drill sowing afer proper seed bed preparation followed by broad casting (1894 kg/ha) and zero tillage (1824 kg/ha). The crop is grown on residual moisture of rice crop. There is lots of moisture in soil after harvesting rice and some time farmers have to wait to let is dry to optimum moisture condition for sowing the crop. This leads to delay in sowing of crop. Zero tillage was tested to let farmers have chance to sow the crop timely with minimum cost.

7.2.2 Lentil

Lentil rhizobium inoculation trial

Background: Lentil is considered an orphan crop as after sowing wheat on good land, lentils are planted in whatever land is left where wheat cannot grow. Farmers seldom apply fertiliser to the lentil crop. Rhizobium inoculation provides an opportunity to improve lentil productivity. This trial was planted with GCR family farmers on their land to allow them to experience the role of rhizobium inoculation in enhancing lentil productivity.

Objective: To test the rhizobia inoculation effect on nodulation and lentil yield.

Locations: Chakwal and Jafferabad.

Methodology: One acre was divided into two plots, each with one treatment.

T1 = New Edge inoculum of lentil
T2 = Control (Without inoculation)
Variety = Markaz 09 (Microspora)
Row spacing = 25 cm

Fertiliser = 50 kg DAP per acre
Weedicide = S-Metolachlor (Pre-emergence)= 800 ml/acre
Year of trial: 2019–20

Results

Table: Effect of rhizobium inoculation on lentil yield and yield components, 2019–20

Treatment	Nodules per plant	Pods per plant	100 seed weight	Yield (kg/ha)
Inoculum	5	69	3	703
Untreated	2	53	2.7	640

Discussion: The results showed a 10% increase in yield in the plot where lentil seed was treated with rhizobium inoculum. No significant difference in 100 seed weight was noted; however, the number of pods per plant was more in the plot with inoculation, which resulted in increased grain yield. The count of nodules per plant was also considerably better in inoculated plots than in the control, resulting in soil improvement. With little labor and inoculum cost, the improvement in yield is significant.

Seed treatment fungicide trial of lentils

Background: Dry root rot was reported by farmers after recognising the symptoms from cards shown to them during a situational analysis in 2017. So, to address this issue, the project team planned a trial with GCRs using fungicide-treated seed to manage the seed and soil-borne diseases in lentils.

Objective: To manage the seed-borne and soil-borne diseases in lentils through seed treatment with an effective fungicide.

Location: Chakwal.

Methodology: One acre was divided into two plots, each having one treatment. The seed of one plot was treated with fungicide (Thiophenate methyl), and one plot used farmer practice, which was the control with no use of any seed treatment fungicide. Random sampling using quadrate was done from each treatments to count number of infected plants in comparison with healthy plant count in each sample.

Seed inoculation= Biozote Rhizobium inoculum @ 2g per kg of seed
Variety = Markaz 09 (Microspora)
Row spacing = 30 cm
Fertiliser = 50 kg DAP per acre
Years of trial: 2019–20 and 2020–21
Results
Effect of seed treatment fungicide on disease spread and grain yield of lentils.

Treatment	**Disease percentage (%)**	**Damage due to disease (%)**	**Seed yield (kg/ha)**
Thiophenate methyl	40	10	429
Untreated	25	30	282

Discussion: With 20% less damage to the lentil crop due to the treatment of lentil seed with effective Thiophenate methyl fungicide, a 34% increase in yield was observed in the treated plot compared to the control. Farmers also reported fewer dried plants in the treated field than the control and the rest of their crops.

Weed management trial of lentil

Background: There is no post-emergence weedicide for lentils available in Pakistan. Weeding is done manually, which is labour-intensive. This has contributed to the reduction of area under this crop in Pakistan in recent years. Farmers, during the situational analysis of 2017, said that wheat was the more competitive crop during the Rabi season. Although lentils fetch a better price in the market than wheat, wheat is an easy crop with chemical weed control and mechanised harvesting, so farmers prefer wheat over lentils. This trial was planned and planted with GCR family farmers to give them an option of chemical weed control.

Objective: Chemical weed management in lentil crops through pre-emergence herbicide.

Locations: Chakwal and Bhakkar.

Methodology: One acre was divided into two plots. After sowing lentils on one plot (the treated plot), a pre-emergence weedicide, S-Metolachlor, (800 ml/acre)was applied, and the other plot was kept as a control with no pre-emergence herbicide.

Treatment T1: Application of pre-emergence, S-Metolachlor
Treatment T2: No treatment, control
Variety = Markaz 09 (Microspora)
Row spacing: 30 cm
Fertiliser: 50 kg DAP per acre
Years of trial: 2019–20 and 2020–21

Results

Table : Effect of pre-emergence herbicide on weed management in lentil crops.

Treatment	Weed count/m^2 at 60 DAE*	Weed count/m^2 at 150 DAE	Weed dry weight (g/m^2) at 150 DAE	Pods per plant	Grain Yield (Kg/ha)	% increase
Herbicide	7	12	109	93	1252	
Untreated	16	25	248	69	619	51

Discussion: Data for the weed count per metre square gradually decreased due to the strong effect of weedicide (S-Metolachlor). This pre-emergence weedicide produced the best results because it was applied when the soil was in a moist (“wattar”) condition. Compared with the check/control or farmers’ practices, the weedicide-treated plot showed fewer weeds per unit area, thus impacting the yield due to less competition. It was concluded that weedicide application provides more space for the emergence of lentil seeds and the provision of a proper photosynthesis mechanism. Due to this intervention, there was 51% grain yield increase compared to the control.

7.2.3 Groundnut

Inoculation trial of groundnut

Background: Groundnut, a leguminous crop, forms a symbiotic relationship with rhizobium bacteria resulting in nitrogen fixation, which ultimately contributes to the productivity of the soil and yield of the crop. A situational analysis in 2017 revealed that groundnut farmers did not know about rhizobium inoculation. This trial was planned and conducted with GCRs to learn together the beneficial effects of rhizobium inoculation on groundnut.

Objective: To test the effect of rhizobia inoculation on groundnut nodulation and yield component.

Locations: Attock and Chakwal.

Methodology: One acre was divided into two equal plots, each having one treatment.

T1 = Groundnut seed treated with rhizobium inoculum (Biozote)
T2 = Untreated (Groundnut seed with no inoculation)
Variety = BARI 2011
Row spacing = 30 cm
Fertiliser = 50 kg DAP per acre
Weedicide = S-Metolachlor (Pre-emergence) 800 ml/acre
Years of trials: 2019 and 2020
Results
Effect of rhizobium inoculation on yield of groundnut 2019

Treatment	Nodules per plant	100 seed weight (g)	Yield (kg/ha)
Biozote	61	57	2068
Untreated	35	49	1820

Discussion: An average yield increase of 12% is observed, contributing to a 16% increase in pods in plots treated with rhizobium inoculum. However, a significant increase of 43% in the number of nodules per plant is noted in the treated plot compared to the control.

Seed treatment fungicide trial of groundnut

Background: The farmers in the groundnut area practised the already low seeding rate, as mentioned to the project team during situational analysis in 2017. Furthermore, they said that some plants get dried before flowering, contributing to reduced groundnut production. Scientists from the Barani Agriculture Research Institute (BARI) revealed that Aspergillus and Rhizoctonia species are mainly causing root rot disease in the groundnut area. So, this trial was planned and conducted with GCRs to manage root rot by treating seeds with an effective fungicide.

Objective: To manage seed and soil-borne diseases through effective seed treatment fungicide.

Locations: Attock and Chakwal.

Methodology: One acre was divided into two plots, each having one treatment.

T1 = Seed treated with Thiophenate methyl (fungicide) 2g/kg of seed
T2 = Control (Seed not treated with fungicide)
Variety = BARI 2011
Fertiliser: 50 kg of DAP

Row spacing: 45 cm
Years of trial: 2019
ResultsEffect of seed treatment fungicide to reduce crop damage in groundnut.

Treatment	Disease incidence (DAP*)	Damage due to disease (%)	Grain yield (kg/ha)
Thiophenate methyl	58	14	950
Untreated	40	28	738

Discussion: The results showed that the incidence of the disease three weeks earlier was observed in the control plot compared to the treated plot and that the severity of the disease was 14% higher in the control plot than in the treated plot. This all contributed a 28% increase in the overall grain yield of the treated plot compared to the control.

Weed management trial of groundnut

Background: Managing weeds manually or with the tines of different ploughs was complex, labourious, and expensive. With the increase in per day labour cost, deploying labour for manual weeding is presently not feasible. So, farmers asked for some chemical solutions to weeds during the situational analysis in 2017. So, this trial was planned to give a complete weed management package during the cropping season.

Objective: To manage weeds of groundnut through pre and post-emergence weedicides.

Locations: Attock and Chakwal.

Methodology: One acre was divided into two plots, each having one treatment.

T1 = Spray of pre-emergence weedicide (S-Metolachlor) @ 800 ml per acre and post-emergence weedicides (Haloxyfop p ethyl & lactofen @ 350 ml and 300 ml, respectively)
T2 = Control (No spray of chemical weedicide)
Seed treatment fungicide: Thiophenate methyl @ 2g per kg seed
Seed inoculation: Biozote rhizobium inoculum @ 500g for a one-acre seed
Variety = BARI 2011
Row spacing: 45 cm
Fertiliser: 50 kg DAP
Years of trials: 2019 and 2020

Results:
Effect of pre and post-emergence herbicide in managing weeds in groundnut.

Treatment	Dry weed weight/sq. m at 150 DAE (g)	Yield (kg/ha)
Herbicide	2.37	950
Untreated	4.15	746

Discussion: About 43% less dry weed weight/sq. m at 150 days after emergence in the treated plot contributed to a 27% increase in average grain yield. According to farmers, heavy weed infestation in untreated plots hindered peg entrance into the soil, which negatively affected the yield of untreated plots.

Seed rate trial of groundnut

Background: During the situational analysis in 2017, the farmers mentioned a lower-than-recommended seed rate for groundnuts. Old varieties were spreading types, while the new, improved varieties like BARI 2011 and BARI 2016 are bunchy and semi-erect. Farmers were applying seed rates according to the old practices, which resulted in a smaller plant population and reduced yield. To address the issue, this trial was planned and conducted with GCRs so that farmers could see the yield difference between the recommended seed rate and what they were practising.

Objective: Effect of optimum seed rate on yield of groundnut.

Locations: Attock and Chakwal.

Methodology: One acre was divided into two plots, each having one treatment.

T1 = 85 kg/ha seed rate (Recommended)
T2 = 65 kg/ha seed rate (Farmer practice)
Seed treatment fungicide: Thiophenate methyl @ 2g per kg seed
Seed inoculation: Biozote rhizobium inoculum @ 500g for one acre seed
Variety = BARI 2011
Row spacing: 45 cm
Fertilizer: 50 kg DAP
Pre emergence herbicide: S-Metolachlor @ 800 ml per acre
Post emergence herbicides: Haloxyfop p ethyl and Lactofen @ 350ml and 300 ml, respectively
Year of trial: 2019

Results

Effect of different seed rates on yield and yield components of groundnut.

Treatment	Plants per sq. m	Pods per plant	100 seed weight (g)	Yield (kg/ha)
85 kg per ha (Recommended)	10	40	48	1333
65 kg per ha (Farmer practice)	7	45	50	936

Discussion: There was no significant difference in pods per plant and 100-grain weight for both treatments. However, the improved plant population in treatment one, which was an 85 kg/ha seed rate, contributed to a 42% increase in the yield of the groundnut crop.

Insect management trial of groundnut

Background: Hairy caterpillar was mentioned during the situational analysis in 2017 as a devastating insect causing massive damage to the groundnut crop. Farmers describe that damage due to these caterpillars in their field as in the form of spots. Although some farmers do apply insecticide, they mentioned that most of the insecticides available locally were adulterated, and the farmers observed no effect of these insecticides. Hence the project, along with GCRs, planned and conducted this trial.

Objective: To manage hairy caterpillars with the help of effective insecticides.

Locations: Chakwal.

Methodology: One acre was divided into two plots, each having one treatment.

T1 = Spray of insecticide-Bifenthrin @ 350 ml per acre
T2 = Untreated
Seed treatment fungicide: Thiophenate methyl @ 2g per kg seed
Seed inoculation: Biozote rhizobium inoculum @ 500g for one acre seed
Variety = BARI 2011
Row spacing: 45 cm

Fertiliser: 50 kg DAP
Pre-emergence herbicide: S-Metolachlor @ 800 ml per acre
Post-emergence herbicide: Haloxyfop p ethyl and lactofen @ 350 ml and 300 ml, respectively
Year of trail: 2019

Results

Effect of insecticide on larvae population and reduction of crop damage

Treatment	Larvae Count (No.)/m^2			Foliage damaged (%)	Grain yield (kg/ha)
	24 Hrs. before spray	3 days after spray	14 days after spray		
Bifenthrin	24	12	3	12	915
Untreated	23	19	7	24	853

Discussion: With almost 12% less foliage damage in the treated plot of the trial, an increase of 7% yield was observed. The larvae count reduced considerably after 14 days of spray, which helped reduce the damage to the foliage of groundnut plants. Looking at the promising results of insect management, authorized dealers and franchises of multinational and national pesticide companies were identified in the area, and farmers were asked to buy from those sale points.

Gypsum application in groundnut trial

Objective: To check the effect of gypsum on groundnut crop productivity.

Gypsum: Gypsum (calcium sulphate) is far more soluble than lime and can penetrate various types of soils deeper. The calcium in gypsum enhances the formation of soil aggregates. This process tends to counteract soil crusting and carpophore penetration, enhancing pod formation.

Methodology: The experiment was conducted in collaboration with the participating farmers at site 1 using a randomised block design with a plot size of 0.2 ha and gypsum application of 400kg/ha. Data were recorded for different parameters: emergence percentage, root length, shoot length, nodules per plant, and seed yield. The groundnut variety used was BARI 2011.

Results

Effect of gypsum application on groundnut yield at site 1 during 2021

Treatments	Emergence (%)	Root length (cm)	Shoot length (cm)	Nodules/ plant	Pod yield kg/ha	Pod yield increase over control (%)
Gypsum	85	22	56	285	1120	14.5
Control	76	13	46	276	978	--

Discussion: The data analysis showed gypsum had a positive effect on all the parameters studied. There was a significant increase of 14% in pod yield in the treated plot compared to the control.

Levelled vs unlevelled field trial of groundnut

Objective: To check the difference between levelled and unlevelled fields on pod yield.

Methodology: The experiment was conducted at sites 1 and 2 using a randomised block design with a plot size of 0.2 ha. Data were recorded for different parameters: emergence percentage, root length, shoot length, nodules per plant, and seed yield. The groundnut variety used was BARI 2011.

Results

Comparison of levelled and unlevelled field on groundnut yield

Treatments	Pod yield kg/ha	Pod yield increase over unlevelled field (%)
Levelled	1278	14.78
Unlevelled	1113	--

Discussion: Data analysis revealed that pod yield was 14.78% higher in levelled fields than in unlevelled fields. However, more efforts are required to convince farmers to invest in levelling their paddocks for better financial returns.

Efficiency of groundnut diggers

Objective of the trial: The objective of this trial was to compare the efficiency of different diggers.

Methodology: A one-acre field of selected farmers was divided into three equal parts at sites 1 and 2. One part was harvested with the traditional digger fitted with a conventional blade, one with a locally fabricated digger/inverter, and one with a KMC (imported) digger/inverter. The groudnut variety used was BARI 2011. The data of leftover pods were taken using quadrate. Three samples were taken from each treatment, and the average was calculated.

Results

Different harvester efficiency comparison on groundnut field

KMC Digger			Digger Inverter (local)			Blade		
No. of pods left per m^2			No. of pods left per m^2			No. of pods left per m^2		
Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
11	14	16	30	19	26	40	31	35
Average 11.01			Average 22.165			Average 33.15		

Discussion: Project activities included several demonstrations of specific groundnut harvest machinery and preparations for the farmers at sites 1 and 2. It is evident from the results that the KMC digger proved the best, leaving only 11 pods per square metre in the soil, followed by the local digger inverter, as fewer pods were left in the soil compared to the conventional blade type. Despite the availability of funds to manufacture a KMC type digger/harvester with modifications to suit local conditions, the project faced challenges in initiating manufacturing due to consistent inflation costs linked with the devaluation of Pakistani rupees. This situation led to inflated costs that were financially unfeasible for the project and the manufacturers.

Raised-bed vs flat-bed groundnut cultivation trial

Objective: The objective of this trial was to compare raised vs. flatbed groundnut cultivation.

Methodology: The experiment was conducted using a randomized complete block design with a plot size of 0.2 ha. Parameters, including emergence percentage, root length, shoot length, number of nodules per plant, and pod yield, were recorded. The groundnut variety used was BARI 2011.

Results & Discussion

Comparison of raised vs flat-bed for groundnut yield

Treatments	Emergence (%)	Root length (cm)	Shoot length (cm)	Nodules/ plant	Pod yield kg/ha	Pod yield increase over control (%)
Raised Bed	83	28	59	296	1371	13.6
Flat Bed	85	16	17	270	1184	

A 13.6% higher yield was observed in plots where groundnut was sown on raised beds compared to plots where the groundnut crop was sown on flat beds.

7.3 Seed Production

Non-availability of quality seed pulses was one of the major constraints indicated in situational analysis by the farmers. There were no companies for seed multiplication of pulses and public institutes have limited resources for seed multiplication. Hence access to improved pulses varieties was limited to influential farmers. Project was able to test all available varieties of chickpea, lentil and groundnut at farmer's field on all six project sites which are the major pulses growing areas of Pakistan. After two years of varietal trial farmers selected varieties of their choice. Project facilitated farmers by providing the basic and certified seed of farmer preferred varieties for multiplication. Project was able to organize farmers for establishment of village seed banks at two project sites namely Attock and Chakwal. Project was also able to engage two seed companies for seed multiplication and distribution at Sindh and Baluchistan.

Seed multiplication by seed producing farmers operating village seed banks and those linked by the project with seed producing companies produced a total of 783 tons. A record of the village seed banks is attached. **(Appendix 5)**

Site	Crop	Seed produced (tons) per year					Total
		2018–19	2019–20	2020–21	2021–22	2022–23	
1	Chickpea	0.6	5	21	24.8	59	110.4
	Groundnut	1.3	2.02	7	9.3	21.2	40.82
2	Chickpea	0.8	5.2	24.8	27	47	104.8
	Lentil	0.5	1	0.2	3.5	7	12.2
	Groundnut	1.7	3.12	6.7	11.7	25	48.22
3	Chickpea	2	16.33	40	50	85.4	193.73
	Lentil	0.7	3.27	1	8	10	22.97
4	Chickpea	1.8	9.6	12	14	14	51.4
	Groundnut	2.7	3	10	12	12	39.7
5	Chickpea	1.3	3.2	5.2	10.5	58.6	78.8
6	Chickpea	0.3	4.8	9	26	30	70.1
	Lentil	1	1.3	0.12	2.7	4.84	9.96
Total							783.1

Year-wise total seed produced (tons)				Total
Year	Chickpea	Lentil	Groundnut	
2018–19	6.8	2.2	5.7	14.7
2019–20	44.13	5.57	8.14	57.84
2020–21	112	1.32	23.7	137.02
2021–22	152.3	14.2	33	199.5
2022–23	294	21.84	58.2	374.04
Total	609.23	45.13	128.74	783.1

7.4 Value Addition

7.4.1 Biochemical analysis of groundnut varieties

As per objective 2 of the project, which provides increased opportunities for farmers to undertake post-harvest value addition to chickpea, lentil, and groundnut crops, the Arid Agricultural University, Rawalpindi (AAUR), conducted a laboratory analysis of the BARI 2011 and BARI 2016 groundnut varieties/cultivars.

This analysis provided information about these selected varieties in terms of their oil content and other qualities that made them preferable to different available types. This activity helped explore groundnut varieties suitable for oil extraction.

Table: Biochemical analysis of groundnut varieties BARI-11 and BARI-16.

Trait	BARI-2011	BARI-2016
Oil content %	55	56
Crude protein %	26.26	27.13
Crude fibre %	48.40	43.60
Total aflatoxin (ppb)	06	05
Kernel size (g)	Bold	Medium

7.4.2 Impact of adding food emulsifier on peanut butter top surface oil

Oil separation on top of peanut butter in bottles was observed after some days of peanut butter making and storage. Need of using a natural emulsifier was observed. Soya lecithin is often used as an emulsifier to prevent the separation of oil in peanut butter.A laboratory experiment was designed to determine the impact of adding soya lecithin in a peanut butter recipe prepared from 5 different groundnut varieties – BARI-16, BARI-11, Desi-334, Desi Gujjar khan, and Fakhar e Chakwal. Separated oil was measured using graduated cylinder.

The recipe used to prepare the peanut was:

- **Peanuts (**BARI-16, BARI-11, Desi-334, Desi Gujjar Khan, and Fakhar e Chakwal)
- **Salt (Na Cl 1.5%)** (fine particles)
- **Hydrogenated vegetable oil 5–10%** (Hydrogenated vegetable oil acts as a stabiliser, preventing the oil from accumulating at the peanut butter's top surface in jar.)
- **Sugar (2%)** (fine particles) is added to the product to improve smoothness, spreadability, and flavour
- Soya lecithin was added to this recipe in three concentrations along with a control:
  T0 (No soya lecithin)
  T1 (1% soya lecithin)
  T2 (2% soya lecithin)
  T3 (3% soya lecithin)

The machine used for preparing peanut butter was a Peanut Collider Mill (Peanut Grinder).

Results

Effect of soya lecithin on the accumulation of oil on the top surface of peanut butter in 5 groundnut varieties

S.No.	Variety/soya lecithin (%)	BARI-16	BARI-11	Desi-334	Desi-Gujjarkhan	Fakhare Chakwal	Total
1	T1: 1 % soya lecithin	4.2 ml	4.0 ml	6.8 ml	6.4 ml	1.8 ml	23.2 ml
2	T2: 2% soya lecithin	3.0 ml	3.6 ml	5.0 ml	4.0 ml	3.0 ml	19.4 ml
3	T3: 3% soya lecithin	5.4 ml	5.0 ml	5.4ml	5.0 ml	3.8 ml	24.6 ml
4	T0: Control 0% soya lecithin	4.4 ml	4.4 ml	7.4 ml	6.2 ml	4.4 ml	28.2 ml
	Total	23.0 ml	22.8 ml	18.0 ml	17.2 ml	15.4 ml	

The table shows the minimum oil accumulation at the top surface in the case of T2, i.e., 19.4 ml (2% soya lecithin). In contrast, the minimum oil quantity on the surface of peanut butter is recorded in the case of the Fakhr e Chakwal variety (15.4 ml), and the maximum is in BARI-16 (23.0 ml).

7.5 Value addition projects

At the beginning of the project, farmers were demonstrated and encouraged for the value addition of pulses. However, there was reluctance in the adoption of value addition on the part of farmers. So, local SMEs were made part of the workshops and seminars to communicate the value of the work done in the project. The project demonstrated cleaning, grading, packing, and branding of chickpeas and oil extraction and peanut butter making, packing and branding. Local SMEs can take up these projects for their commercial activity.

Concerning the preparation and promotion of value-added products of groundnuts like peanut butter and peanut oil, the AAUR component planned this initiative as follows:

1. Preparation of value-added products in the university laboratories.

2. Promotional activities for value-added products by engaging growers for enhanced profitability

- Motivating growers for value-added products through meetings and field days

- Organising competitions/displays for value-added groundnut products

-Organising groundnut stakeholders linkages workshops on value addition

-Progressive showcasing of value-added products at agri-expos, Chickpea Peanut Fest, World Pulses Days, Plant Centric Meal and DICE competitions, with the participation of farmers, local processors and industry partners, academia, and researchers.

Peanut oil

Peanut oil, also called groundnut oil, is a vegetable-derived oil made from the edible seeds of the peanut plant. Depending on processing, peanut oil can have a wide range of flavours, varying from mild and sweet to strong and nutty. To get cold-pressed peanut oil, the peanuts are crushed in an oil press machine to force out the oil. This low-heat process retains much of the natural peanut flavour and more nutrients. These oil press machines were provided to the growers' groups.

Peanut butter

Growers usually do not get any reasonable compensation for their groundnut produce. Despite working tirelessly to produce peanuts, they have to sell them cheaply in the local market. Considering this, the Pir Mehr Ali Shah Arid Agriculture University Rawalpindi project team and students, along with selected farmers, started work on the value addition of groundnut.

Among three groundnut varieties, groundnut variety No. 334 (Spreading type) gave the best results compared to BARI-16 and BARI-11 in peanut butter preparation, using 3% soy lecithin and other ingredients.

Machine used: Peanut Colloidal Mill (Peanut Grinder)

Preparation of peanut butter

1) Ingredients

- **Peanuts (Variety: BARI-2016)**
- **Salt (NaCl 1.5%)** (fine particles)
- **Hydrogenated vegetable oil 5–10%** (Hydrogenated vegetable oil acts as a stabiliser, preventing the oil from accumulating at the peanut butter's top surface in the jar.)
- **Sugar (2%)** (fine particles) is added to the product to improve smoothness, spreadability, and flavour.
- **Soya lecithin (3%)** is added to prevent extra oil from coming to the surface of the peanut butter.

2) The manufacturing process

- Making peanut butter is a long but easy step-by-step process.
- Peanuts are shelled and dry-roasted.
- They are coolled and blanched, which gets the nuts ready for grinding.
- Lastly, the ground peanut paste is filled into jars.

a) Cleaning of peanuts

During the cleaning process, a blower is used to remove

- Dust
- Sand
- Stems
- Leaves
- Empty shells.

b) Shelling

- Peanut shelling is by cracking with the help of a series of rollers.
- The cracked peanuts are then repeatedly passed through screens and blowers.
- Peanuts are shaken gently and air is blown until all the shells and rocks are removed.

c) Sorting and grading

After shelling, the peanuts are graded for

- Size.
- Colour.
- Defects.
- Broken skin.

The peanuts with defects are discarded, while the healthy ones are sorted, ready for processing.

d) Dry roasting of peanuts

- Peanuts are roasted by dry heating in an oven set at 150–180 °C.
- During roasting, the peanuts pass through a hot air roaster in a continuous rocking motion.
- During this process, the nuts are roasted evenly.
- This process continues until the peanuts' colour changes from white to golden.

e) Cooling

- The peanuts have to be rapidly cooled to stop the cooking process.
- This helps retain moisture and oil in unshelled peanuts and prevent them drying out.
- For cooling, the hot peanuts are passed directly from the roaster to a perforated metal cylinder, where suction fans pull through a large volume of air.
- The peanuts are brought to a temperature of 30 °C.

f) Removing of outer skins

The outer skins of the peanuts that remain after roasting are removed by thorough mechanical rubbing.

g) Grinding/milling

After removing the outer skins, peanuts are fed into a hopper of the colloidal mill, which grinds the peanuts into a paste while incorporating other ingredients (about 1.5% salt, 5–10% hydrogenated vegetable oil, 2% sugar, and 3% soya lecithin) into the mixture.

- This milling process produces a very fine particle size with a maximum size of less than 0.01 inch (.025 centimetre).
- The machine’s combined action of shearing and grinding transforms the hard peanuts into a smooth paste.
- Peanuts are kept under constant pressure from the start to finish of the grinding process to ensure uniform grinding and protect the product from air bubbles.
- Furthermore, after grinding, the peanut butter is considered de-aerated, stabilised, and ready for packing.

h) Packing

- During packing, the newly formed peanut butter is delivered into jars.
- To prevent oxidation, vacuum packing should be used when the peanut butter jars are sealed.
- After dispensing into final containers, the peanut butter remains undisturbed until completely crystallised.
- Jars are then labelled and stored correctly.

7.6 Cost-benefit analysis of different interventions in chickpea, groundnut, and lentil crops in 2020–21 and 2021–22

2020–21

Chickpea					
intervention	Cost of intervention	Yield increase	Per kg price	Additional benefit	Net profit
Insecticide	1150	368	100	36800	35650
Weedicide	2650	324	100	32400	29750
Rhizobia	900	334	100	33400	32500

Foliar fungicide	1150	266	100	26600	25450
Seed treatment fungicide	740	286	100	28600	27860
Groundnut					
intervention	**Cost of intervention**	**Yield increase**	**Per kg price**	**Additional benefit**	**Net profit**
Rhizobia	900	430	150	64500	63600
Seed treatment and foliar fungicide	740	940	150	141000	140260
Lentil					
intervention	**Cost of intervention**	**Yield increase**	**Per kg price**	**Additional benefit**	**Net profit**
Seed treatment fungicide	740	49	120	5880	5140
Weedicide	2650	70	120	8400	5750

2021–22

Chickpea					
intervention	**Cost of intervention**	**Yield increase (kg)**	**Per kg price**	**Additional benefit**	**Net profit/Loss per ha**
Nutritional trial					
Control	0	0	125	0	0
Boron	3000	200	125	25000	53900
Zinc	900	320	125	40000	95795
NPK	2400	520	125	65000	153370
Amino Acid	5000	400	125	50000	110250
Seed rate trial					
40 kg	17150	-113	137.5	0	-42017.5
50 kg	21437.5	-139	137.5	0	-52521.875
60 kg (control)	25725	0	137.5	0	-63026.25
70 kg	30012.5	-188	137.5	0	-73530.625
Green leaves harvesting trial					
By hand	9800	188	137.5	25850	39322.5
By sickle	15680	83	137.5	11413	-10455.375
Control	0	0	137.5	0	0
Binding agent for inoculum trial					
Methyl cellulose	411.6	3	137.5	412.5	2.205
Sugar solution (control)	122.5	0	137.5	0	-300.125
Irrigation trial					
0	0	0	125	0	0
1	3920	286	125	35750	77983.5
2	7840	388	125	48500	99617
3	11760	588	125	73500	151263
4	15680	468	125	58500	104909
Sowing method trial					
Zero tillage	2940	-16	137.5	-2200	-12593
Drill	14700	80	137.5	11000	-9065

Broad casting (control)	13230	0	137.5	0	0
Groundnut					
intervention	**Cost of intervention**	**Yield increase**	**Per kg price**	**Additional benefit**	**Net profit per ha**
Rhizobium inoculation trial					
Biozote	1225	20	200	4000	6798.75
New Edge	1225	24	200	4800	8758.75
Control	0	0	200	0	0
Nutrient trial					
Gypsum	2205	18	200	3600	3417.75
Control	0	0	200	0	0
Harvester trial					
Blade (control)	15190	0	200		0
Local harvester	13475	0	200		4201.75
KMC (imported)	12005	0	200		7803.25
Sowing method					
Raised bed	3000	187	200	37400	35900
Flat bed	1500				
Land levelling					
Laser levelled	20000	165	200	33000	13000
Unlevelled	0				

7.7 Storage of pulses using hermetic bags

After interacting with the families of GCR farmers, it became clear that pulse storage presents a complex problem because pulses are susceptible to stored grain insect damage. Additionally, female workers at site five, who are in charge of cleaning, grading, and storing the grain, informed the project team that they store their grains in mud bins and use mercury to keep stored grain pests from invading. In light of this concerning discovery, where women were directly exposed to carcinogenic mercury, the project team embarked on a project to provide a safe storage solution. In promoting awareness among farmers regarding effective grain storage practices, the project introduced hermetic storage technology to empower farmers with sustainable and efficient methods for

preserving their harvests. Regarding this, a market search revealed that only one business, Haji Son, was offering these hermetic bags for sale. These imported bags were expensive, costing PKR 835 for a 50 kg bag. This initiative was aimed to collaborate with the corporate sector to produce these hermetic bags locally. In this context, Lahore-based company Express Packaging (Pvt) Ltd. was contacted, and they consented to manufacture these bags at a farmer's retail price of PKR 250 for each 50-kg bag. Three times lower price than the imported one. The project organized a scientific experiment to test these bags in addition to giving them to farmers for testing. Two experiments are underway: one at Sindh Agricultural University, Tandojam, and the other at NARC. Research conducted at the sites and the feedback from the farmers will be used to determine how effective the bags are.

To facilitate successful communication, female trainers arranged training at the distribution sites. Subsequently, gender workshops were arranged to raise knowledge of job safety among the female members of the family.

7.7.1 Preliminary trial to evaluate the effectiveness of hermetic bags against pests.

Insect pests damage chickpeas and lentils during postharvest storage, causing significant grain losses. One of the insects is bruchids (*Callosobruchus chinensis*). Indigenously produced hermetic bags produced by the project were tested for their capacity to inhibit grain pest bruchid (*Collosobruchus Chinensis*) infestation of lentil seed.

Fifty kilograms of lentil seed infested with a store grain pest bruchid (*Collosobruchus Chinensis*) was placed in locally manufactured hermetic bags shown to be impervious to outside moisture and the exchange of oxygen and carbon dioxide gases inside. The sealed bags that were opened after one month demonstrated lentil seeds free of any living pest. These outcomes are deemed great success for the project and an excessive confidence for the farmers to store and market their grains for increased profitability. Trials are in progress to ascertain the long-term storage capacity of imported and indigenously manufactured hermetic bags against non-hermetic bags as a control.

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8 Impacts

8.1 Scientific impacts – now and in 5 years

The involvement of researchers and students in on-farm research activities with farmers has co-created knowledge and made a lasting and significant impact on farm profitability and sustainability. The generated knowledge has provided considerable information for future research on traits such as maturity, nutritional quality, and response to biotic and abiotic stresses, particularly in chickpea and peanut crops.

Newsletters – 13 articles. **(Appendix 10)**

Brochures – 10 **(Appendix 11)**

Research Papers – 4

Published thesis – 2

The ACIAR Pulses Project partially supported scholars in conducting thesis research at PMAS-Arid Agriculture University Rawalpindi

Degree Program	Thesis title	Name of the scholar	Supervisory committee	Status
PhD (Plant Breeding & Genetics)	Genetics of early maturity in peanuts under rain-fed conditions	Sammyia Jannat	Dr. Mahmood -Ul –Hassan Prof. Dr. Kausar Nawaz Shah Dr. Mukhtar Ahmed	2022
PhD (Plant Breeding & Genetics)	Genetics of nutritional quality attributes in peanuts	Sannia Kabir	Dr. Mahmood -Ul –Hassan Prof. Dr. M Kausar Nawaz Sh ah Dr. Kashif Sarfraz Abbasi	Continued
PhD (Plant Breeding & Genetics)	Breeding for improved nutritional quality of peanut haulm	Ahsan Hammad	Dr. Mahmood -Ul –Hassan Dr. Rifat Mahmood Dr. Talat Mahmood	Continued
PHD (Plant Breeding & Genetics)	Genetics of early maturity in peanuts under rain-fed conditions	Sammyia Jannat	Dr. Mahmood -Ul –Hassan Prof. Dr. Kausar Nawaz Shah Dr. Mukhtar Ahmed	Continued
MSc (Hons) (Plant Breeding & Genetics)	Morphological and biochemical responses of peanuts to drought stress	Muhammad Zargham Ali	Dr. Mahmood -Ul –Hassan Mr. Muhammad Zeeshan Dr. Rashid Mehmood Rana Dr. Muhammad Sheeraz Ahm ad Dr. Shahid Riaz Malik	2022

MSc (Hons) (Plant Breeding & Genetics)	Evaluation of elite exotic groundunt lines for morphometric traits under rain-fed conditions	Ahsan Hammad	Dr. Mahmood -Ul –Hassan Muhammad Jahanzaib Dr. Rifat Mahmood Dr. Talat Mahmood Dr.Taj Nasseb Khan	2022
MSc (Hons) (Plant Breeding & Genetics)	Response of chickpea genotypes for various hormone concentrations under in vitro culture conditions	Masooma Riaz	Dr. Fahad Masoud Wattoo Dr. Mahmood -Ul –Hassan Dr. Irfan Ali Dr. Salman Saleem	2020
MSc (Hons) (Plant Breeding & Genetics)	Studies on character association and path analysis for yield and its components in peanuts	Usman Saeed	Dr. Mahmood -Ul –Hassan Dr. Riffat Hayat Dr. Ghulam Rabbani Dr. Rashid Mehmood Rana	2020
MSc (Hons) (Plant Breeding & Genetics)	Effect of temperature on pollen viability in peanuts	Sehrish Riaz	Dr. Mahmood -Ul –Hassan Dr. Farid Asif Shaheen Muzammil Hussain Prof. Dr .M.Kausar Nawaz Sh ah	2017
MSc (Hons) (Plant Breeding & Genetics)	Screening of peanut genotypes for early maturity through morphological and molecular markers	Malik Zahoor Ahmed	Dr. Mahmood -Ul –Hassan Dr. Rashid Mehmood Rana Dr. Ghulam Abbas Shah Dr. Muhammad Yousaf	2020
MSc (Hons) (Plant Breeding & Genetics)	Evaluation of chickpea germplasm for yield and biochemical traits under rain-fed conditions	Muhammad Arif	Prof. Dr. Zahid Akram Dr. Ghulam Shabbir Prof. Dr. Asif Ahmad Dr. Ghulam Rabani	Continued
MSc (Hons) (Plant Breeding & Genetics)	Estimation of genetic variability among chickpea genotypes at different locations in Potohar	Muhammad Yasi r	Dr. Ghulam Shabbir Dr. Mahmood-ul-Hassan Dr. Rifat Hayat	2020

The ACIAR Pulses Project partially supported scholars in conducting thesis research at MNS University of Agriculture, Multan

Student	Degree	Year	Degree status	Thesis title
M. Asad Iqbal	MSc (Hons) PBG	2022	Degree completed	Genetic variability among EMS induced mutants of chickpea for beta carotene and yield related traits
M. Tayyab	MSc (Hons) PBG	2022	Degree completed	Genetic diversity in chickpea (Cicer arietinum L.) germplasm based on yield traits
Zulkifl Ashraf	MSc (Hons) PBG	2023	Degree completed	Diversity analysis of chickpea (Cicer aratinum L) Germplasm on the basis of zinc and iron
Muhammad Asif Mansoor	MSc (Hons) PBG	2021	Degree completed	Diversity analysis of chickpea for the yield related traits and the nodule formation bacteria
Kausar Parveen	MSc (Hons) Biotech	2023	Thesis under progress	Genome wide analysis of Glutathione Peroxidase (GPX) gene family in chickpea (Cicer arietinum L.) under salinity stress

The ACIAR Pulses Project partially supported scholars in conducting thesis research at Sindh Agricultural University, Tandojam, Sindh

S.No.	Name of the student	Registration No.	Degree status with year	Title of the research studies (thesis)
1	Zafarullah Jessar	2K16-AG-55	Completed in 2019	Evaluation of different varieties of chickpea (Cicer arietinum L.) under agro-ecological conditions of Naudero (District Larkana)
2	Faisal Ul Nabi Buriro	2K18-AG-10	Completed in 2020	Effect of pre-emergence herbicide and inoculums on growth and yield of chickpea variety DG-92
3	Naveed Ali Dhakan	2K19-AG-40	Completed in 2021	Effect of weed management methods and cutting times on growth and yield of chickpea (Cicer arietinum L.)
4	Shahzad Ali Jatoi	2K19-AG-49	Completed in 2021	Effect of post emergence herbicide and cutting times on growth and yield of chickpea (Cicer arietinum L.)
5	Abdul Hakeem Jamro	2K20-AG-001	Completed in 2022	Evaluation of chickpea variety DG-92 at different farmers' fields of Tandojam surroundings
6	Waqar Ali Morio	2K20-AG-047	Completed in 2022	Impact of laser levelling on the growth and yield of chickpea/gram (Cicer arietinum L.)

8.2 Capacity impacts – now and in 5 years

Farming families

Capacity building was achieved at different levels, including (1) GCR farming families (as 1st stage beneficiaries), (2) Researchers, expansion farmers (as 2nd stage beneficiaries), and (3) Community farmers who visited trials and participated in farmer field days, seminars, and workshops.

The development-led inquiry (DLI) approach resulted in the capacity building of participating members of GCRs at each site where the trials were planted. Forty-two improved production technology trials of chickpeas, 12 of lentils and 23 of groundnuts were tested with 90 farmers in GCRs using a DLI approach at six project sites. Learnings from the tested technologies were demonstrated to 935 pulse farming families, including 115 female growers, in collaboration with local NGOs like the National Rural Support Program (NRSP), Sindh Rural Support Program (SRSO) and Baluchistan Rural Support Program (BRSP). **(Appendix 7)**

To improve farmers' understanding of the pulses value chain, 7 stakeholder workshops and events were organised – these were attended by 421 farmers, academia, the public and industries like Volka Foods, Nuts and Legumes, English Biscuit Manufacturers (EMB), and Biomasdar Pvt. (Ltd). Ninety farmer field days, training events, seminars, conferences, meetings, visits, and showcasing events were conducted. The project learnings were shared with 8349 farmers, researchers, academia, extension agents, input suppliers, service providers, and industry representatives. Seed production training was provided to 371 farmers across all project sites. **(Appendix 8)**

Learnings of the project were shared by the demonstration of tested technologies by GCR farmers to the expansion farmers of the third sector organisations NRSP, SRSO, and BRSP at farmer field days and workshops.

The training was imparted in dealing with particular situations faced by farmers. At site 1, groundnut farmers shared the issue of wild bores and porcupine infestation. The project arranged special training with experts in farmers' fields to manage these pests. The training on using hermetic storage technology across all sites will have a lasting impact.

Project team

The project significantly impacted the team members' capacity building. The project activities, which included a situational analysis, GCR farmers and contact growers' meetings, conducting field trials with growers, the demonstration of production technology, participation in project review and planning meetings, and organising farmers' days, seminars, and workshops, etc., directly impacted the learning and performing capabilities of team members. During these activities, the project team directly engaged at each step. This enhanced their confidence, independent thinking, and practical knowledge. These activities also had a positive influence on the decision-making process of team members, which ultimately had a positive effect on the project outcomes. The project team directly interacted with the farmers and all the potential stakeholders, which enhanced their understanding of teamwork; getting firsthand knowledge about various farming issues enabled them to suggest possible solutions to those problems.
The project also supported developing an international approach among the team members through working with an international organisation (ACIAR) team. They participated in various meetings, seminars, webinars, and workshops, including their Australian counterparts. These frequent interactions also helped in developing their professional growth. Moreover, 9 researchers visited Australia during the project and got exposed to pulse farming systems, research systems, and the pulse industry.

Strengthening research institutes: Farm machinery like multi-crop seed and fertiliser drill, thresher, laser land leveller, and seed cleaner graders procured for the participating research institutes will enhance their capacity for future research.

8.3 Community impacts – now and in 5 years

The project had a multi-dimensional impact on the participatory members, including farming families, researchers, academia, input suppliers, and local SMEs. The researchers admit they were working for the farmers, but now understand their research has changed. Now we steer our research based on inputs from farmers and industry demands. Adopting new technology resulted in the reduction of the cost of production and an increase in profitability for farming families.

8.3.1 Economic impacts

The use of quality seeds of improved varieties combined with improved production technologies like seed inoculation, fungicide treatment of seed, weed and insect management, nutrition management, and appropriate machinery resulted in an 18.5% increase in the productivity of chickpea, lentils, and groundnut crops and was reflected in the profitability of about PKR 30,000 per acre.

The profitability of 371 seed-producing farmers linked with village pulse seed banks can be gauged by the fact that the seed is sold at their doorstep as people contact them and pay premium prices for their produce.

At site 4 (Karak), one farmer said that when he harvested the groundnut crop, a seed business representative in the village came with cash and paid the whole payment in advance to purchase his produce.

A female farmer told a similar story. She said that after harvesting a chickpea crop, she prepared a sample for her husband to go to the market to get a price for their produce. She said that when her husband showed the harvested chickpea sample to the first broker, he closed the shop and came along with payment to purchase the produce from their doorstep at a premium price.

Providing multi-crop seed cleaners and graders to village seed banks will ensure a sustainable supply of pulse seeds after the project’s life and develop entrepreneurship locally, improving the area's economic activity and positively impacting the rural economy. Similarly, training for peanut oil extraction, filtration, packing and labelling, and the provision of small oil extraction units to GCR farmers at sites 1 and 2 will help local businesses to value-add, which will also contribute to the rural economy.

Weed management is a great challenge in chickpea and lentil crops. Farmers faced problematic weed infestation in their chickpea crops at sites 5 and 6, where chickpea is grown on the residual moisture from rice crops. During the situational analysis, a farmer said that he spent about PKR 20,000 per acre for weed management with hired labour. With the introduction of pre-emergence herbicide, the cost has been reduced to PKR 3000. This has helped increase the profitability of chickpea production.

8.3.2 Social impacts

The introduction of chemical weed management and mechanised harvesting has enabled female households to have reduced workloads, allowing them to direct their energies to undertake other household chores efficiently. At the start of the project, female members of the farming families used hoes for weeding groundnut at site 4 (Karak). Groundnut is a summer crop growing in hot and sultry conditions. Additionally, due to cultural and religious obligations, women wear a veil while working under the sun in their fields, making it a challenging job. With the introduction of pre and post-emergence herbicides, these female members are not required to weed in summer, positively impacting their lives.

During the situational analysis, the female members of pulse growing families were involved in seed cleaning, grading, and storage. Moreover, crude seed and grain storage methods were practised in the Lakki region of Sindh province. Female farmers said that they put grains in bags and dump them under wheat straws. At Dhokri, female members of pulse growing families said that they store chickpeas in mud bins in which extremely harmful mercury and leaves of Indian lilac (Neem plant) are mixed with the grain or seeds to prevent outbreaks of stored grain pests. However, introducing hermetic storage technology minimised the health risks to female households of pulse farming families, thereby improving their quality of life.

Before the groundnut digger/inverter was introduced, a tractor-mounted digging blade was used for harvesting groundnut pods. This digging method leaves about 50% of the groundnut pods in the soil. Consequently, female members of smallholder farming families used to retrieve the leftover groundnut manually. The produce collected in the first attempt was considerable, so it was sold along with the primary produce by the farming families. The second round of further leftover groundnut collection is tiring as they have to find the groundnut pods. They do this because it is the local tradition that the income received by selling this left-over produce will be used to buy the clothes for the children and female members of the farming families. This is the incentive given to them for trying to clear the remaining groundnut seed.

For big landlords, deploying labour to dig the groundnut from fields takes months. During this time, these leftover groundnut pods become infected with aflatoxin-producing Aspergillus species fungus as they remain in the ground for an extended period. However, when these aflatoxin-tainted pods are mixed at broker level with good produce, they become unsuitable for industry, negatively impacting the groundnut value chain.

Farm workers were available in the past to manage seasonal groundnut harvesting, but due to increased urbanisation, there is a shortage of farm labour, especially in the Pothwar region. This factor is limiting the expansion of groundnut in the area. The introduction of an improved groundnut digger inverter addressed most of the issues. It will help reduce the workload of female members of farming families, reduce the chances of aflatoxin development, and manage the labour shortage issue, which will help the expansion of this crop in the area.

8.3.3 Environmental impacts

An environmentally friendly approach was adopted during the experimentation and expansion of the project, wherein rhizobium inoculum was used during the seed treatment. This resulted in a significant increase in the yield of crops (chickpea, lentil, and groundnut) along with soil fertility restoration. This approach reduced the cost of production, thereby increasing the profitability per unit area. Moreover, it is environmentally friendly and positively impacts the microflora of soil. Chickpeas have a relatively low carbon footprint compared to other foods. It takes around 0.64 kg CO_2 to produce 1 kilogram of chickpeas, much less than other field crops.
Seed treatment with fungicides was another intervention used in the production technology of the pulses and groundnuts, which increased the yield of these crops. As seed treatment involves selective pesticide use, it does not allow air and water pollution from the hazardous pesticides and provides relative safety for non-target organisms, including humans.

With the introduction of hermetic storage bags, the use of mercury for pulse storage was discouraged to prevent the farming families from the hazardous impact of direct contact with the storage chemicals. This will result in long-term health benefits and reduce impacts on the environment.

As 90% of the chickpea crop is grown on the dunes of Thal, the demonstration of compatible organic production technology and a low-cost, efficient irrigation system has provided farmers with an environmentally sustainable production system. In Thal, the water table is high in chickpea-growing areas. Groundwater is 15 to 20 feet below the surface. There is a trend to level the land and grow high-value crops with high carbon footprints with flood irrigation. There is a gradual reduction in chickpea crops in this area. Once the ground is levelled, the farmers go for other highly input-intensive crops. With pesticides and inorganic fertilisers, the day is not far away that the groundwater will become contaminated. So, a low-cost-efficient irrigation system was demonstrated to reverse and slow the trend of land levelling and crop replacement. Furthermore, with the demonstration of organic production technology for chickpeas, the project has attempted to promote environmentally sustainable chickpea production.

8.4 Communication and dissemination activities

In the final years the project teams have shown shown marked improvement in communicating with all stakeholders. However, future projects must specifiy roles of each participating research partners in achieving project objectives and their understanding of the overall purpose of the project.

Ninety-two farmer field days, training, seminars, conferences, meetings, visits, and showcasing events were conducted. Project learnings were shared with 8796 farmers, researchers, academia, extension agents, input suppliers, service providers, and industry representatives.

Communication in Project team: Emails, weekly site meetings on Zoom, an annual review and planning meetings, and WhatsApp were the modes of communication among project team members.

Communication in GCRs: Participatory field trials remained the primary source of learning in GCRs, and communication was done by visiting field trials, reflecting on the results of field trials, field days, and workshops to share learning with other farmers.

Communication with expansion farmers: Third-sector organisations remained the primary resource for contact with expansion farmers. Farmer-to-farmer learning was facilitated by organising farmer field days and workshops where GCR farmers demonstrated the tested technologies to the NRSP, SRSO, and BRSP expansion farmers.

Communication with other ACIAR projects under the Aik Saath umbrella: A two-step communication strategy was practised. The project team participated in Aik Saath and alumni events, the ACIAR Pulses Policy, Small Ruminant, and Pulses Value Chain projects, followed by inviting them to Pulses Production Project events to facilitate the dissemination of learning from these different projects to the participating farmers. The second step links project farmers with small ruminants and the Pulses Value Chain project activities.

Communication with policy personnel and other government officials: Publication of the online project newsletter “The Pulse” and emailing the newsletters to all stakeholders and government officials**. (Appendix 10)**

Communication with the public: Distribution of brochures, pamplets, procedures, fact sheets. **(Appendix 11)**. Production of short videos and telecasting them on a cable network to disseminate learning and communication of ACIAR investment in Pakistan. **(Appendix 12)**

9 Conclusions and recommendations

9.1 Conclusions

This project has contributed significantly to its capacity and identified future actions to improve Pakistan's pulses sector. Thus, it merits continuity of its participatory research approaches, aligned with the needs of small landholder families. There is a strong need to enhance communication between production, storage, marketing, and extension teams, contributing to the growth of the entire supply chain. Furthermore, instead of breeders determining the quality of the released crop varieties, their acceptability must depend entirely on farmers' and markets' preferences. The government's policy to support wheat, rice, sugarcane, and cotton has not changed, and the increased demand for pulses is being met through imports. More research is required to achieve increased domestic pulse production. Learnings from the project, including ACIAR pulses policy and value chain projects, have opened new areas for research and approaches to gender-specific community development.

There are clear indications that female farmers are actively involved in collective decision-making related to spending and some production decisions, signifying their role in shaping agricultural practices and resource allocation within their households and communities. However, the cultural norms limit their direct interaction with unrelated men involved in agribusiness, resulting in women farmers' limited access to critical agricultural knowledge and practices. Thus, there is a deep need to develop and implement training and knowledge-sharing programs in culturally safe environments specifically designed for female farmers. These settings have proven highly effective in facilitating learning and information exchange among women, enhancing female farmers' participation and engagement in diversifying their income stream and acquiring marketing knowledge.

An integrated approach is required to address production, storage, marketing, and extension issues. Regarding storage, the project has developed awareness of the health impacts of toxic mercury traditionally used in grain storage bins and substituted with airtight or hermetic storage bags. However, most farm families have limited knowledge about the health risks associated with chemicals used in agriculture, including those related to animals, plants, and livestock diseases like brucellosis. Women lack the agency to purchase chemicals due to concerns about suicide risks, necessitating male involvement. It is unclear whether men fully know these chemical risks and whether this knowledge is shared adequately with women. A significant portion of future projects must include extensive awareness campaigns on developing and implementing on storage and associated chemical risks.

Although the results of pre-emergence herbicides in chickpeas and lentils were promising, farmers are still looking for post-emergence herbicides. The lack of compatibility of lentil varieties with existing harvesting machinery is also a bottleneck to increasing the area under lentil crops. Although experiments have proved that 2 to 3 lifesaving irrigations using rain gun technology in chickpeas can ensure a good harvest of chickpea crops in Thal, more effort is required to adopt this low-cost technology. The imported groundnut digger inverter of the KMC company has impressed the local farming community. Still, it is costly and requires high traction power, so there is a need for the local manufacturing of such machinery with some alterations. However, the project tried to engage local manufacturers. Still, it could not achieve much, mainly due to the instability of imported raw material prices due to the fast decline in the value of the Pakistani rupee against the US dollar.

The project encouraged the farmers to value addition activities. It linked them directly to industry and retailers by skipping local SMEs while learning the importance of the role of local SMEs, thus engaging these local SMEs differently. Farmers were reluctant to store produce and invest in machinery required for value addition. The project learned that at the farmer level, value-addition activities require a suitable variety with a locally developed value chain based on industry needs, good production practices, and post-harvest crop handling.

The project worked on developing a seed system for pulse crops, which was missing in Pakistan's pulse sector. Establishing two village seed banks and engaging four private companies for pulses seed production has and will contribute to the pulses sector, but there is a need to work on some missing links. At some sites, the varieties preferred by farmers are local landraces with purity, diseases, and production issues. The private sector faced problems obtaining the basic seed for certified seed production for some varieties. For groundnuts, the varieties bred for high oil are not per industry requirements or consumer preference. In this regard, after consultation with local research institutes, the project has acquired 960 accessions, including 62 peanuts, 318 lentils, and 560 chickpea accessions from the Australian Grain Genebank. Acquisition of these accessions, including a wealth of indigenously collected germplasm, allows for building local breeders' capacity to develop indigenous breeding programs to produce farmer-preferred, market-driven, and climate-resilient pulse varieties.

Development-led inquiry and farmer-led participatory approaches have contributed to collaborative, participatory research and learning both ways as far as farmers and researchers are concerned. Farmers were exposed to new pulse varieties and production technologies, and researchers were exposed to farmer preferences, market demands and bottlenecks hampering the increase in pulse production. However, to achieve a significant shift for improved outcomes, there is a need to connect knowledge to practice and develop new interventions or strategies.

Despite project teams showing significant improvement in the project's final years, there is a strong need for better communication strategies to optimise the collaboration between diverse stakeholders necessary to undertake diverse activities involving research, extension and marketing. Thus, there is a strong need for innovative communication approaches so that all stakeholders, including farmers, are on the same page on the accessibility, credibility, and simplicity of the information to be actionable, trustworthy, and timely. Working with some partner universities under the current project had been a significant challenge, primarily due to their lack of communication skills required to conduct farmer-led collaborative research. On the other hand, interactions with Pakistan's agricultural research institutes suggest that for future ACIAR projects, partnering with federal and provincial agricultural research institutes would be more meaningful and productive. This potentially viable affiliation is due to their proximity, established contacts with farmers and intra-institutional linkages.

9.2 Recommendations

The project observed the need to develop high-input responsive, site-specific, farmer and market-preferred pulse varieties to place them at competing levels in existing cropping systems. Value chains at some sites are developed for specific types, but those varieties need improvement. Besides that, when private companies were involved in the seed business, it was observed that research institutes developing the improved varieties could not produce basic seeds of those varieties according to the requirements of seed companies for certified seed production. There is a need to enhance the capacity of research institutes to produce enough basic seeds to meet the demand of seed companies. The involvement of third-sector organisations like the NRSP has contributed a lot in disseminating project learning without any extra cost. This relationship needs to be strengthened and further explored to harvest the maximum benefit for farmers by placing them in a better position in pulses value chains by enhancing their buying and selling powers. The private sector needs to be engaged differently for future projects. Opportunities explored in this project for future engagement of the private sector include research and development for pulses machinery manufacturing and service provision, foliar fertilisers, herbicides, their availability and demonstration, mobile irrigation service providers in pulses growing regions, and the development of rental storages in pulses growing areas.

Since women farmers are playing a critical role, there is a strong need to develop training and knowledge-sharing programs designed explicitly for females where female farmers and their spouses could undertake practical training on mechanised farming equipment, chemical safety, marketing opportunities, modern-day communication tools such as Facebook, Whatsapp specifically for information dissemination, and crop disease diagnostics.

Communication approaches tailored to different stakeholder groups are needed to improve communication within project teams. Training critical stakeholders on technology tools is necessary to ensure seamless communication, collaboration, and document sharing.

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10.2 List of publications.

Currently, multiple publications are at different submission stages to different journals or conferences.

1. Waqar Ali, Aijaz Ahmed Soomro , Ghulam Mustafa Laghari, Wajid Ali Jatoi , Niaz Hussain Ujjan , Ata -ur Rehman , Shahid Riyaz Malik , Abdul Naeem Shaikh , Israr

Hussain (2024). Laser Leveler Maximized Chickpea's Growth and Yield Traits (Cicer arietinum L.). J. Appl. Res Plant Sci. Vol. 5(2), 190-199

2. Parveen, K., M.A.B. Saddique, Z. Ali, B. Farid, M.U. Waqas, I.H. Shamsi, and M.A. Khalid. (2023). MMP9 and Mafa protein molecular docking with novel derivatives of isoflavone from Cicer arietinum L. as anti-diabetic and anti-inflammatory agents. Int J Bot Hor Res, 1(1), 125-135
3. Kauser Parveen, Muhammad Abu Bakar Saddique , Muhammad Umair Waqas, Kotb A. Attia, Muhammad Rizwan, Asmaa M. Abushady, and Imran Haider Shamsi (2024). Genome-wide analysis and expression divergence of protein disulphide isomerase (PDI) gene family members in chickpea (Cicer arietinum) under salt stress. Functional Plant Biology 51, FP23253. doi:10.1071/FP23253
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5. Ata Rehman, Gavin Ramsay, Israr Hussain, Shahid Riaz Malik, and Christopher Blanchard (2023). Transformation of village-based seed production system into a formal seed production structure for increased productivity and profitability of chickpeas in Pakistan
6. Saima Rani, Israr Hussain, Shahid Riaz , Ata ur Rehman, Gavin Ramsay, Abdul Manan, Niaz Hussain and Naeem Shaikh (2023). Constraints and Opportunities for Pulses Production in Pakistan. (Accepted: Cogent Food and Agriculture).
7. Abdul Manan Khan, Zulfiqar Ali, Ata ul Mohsin, Muhammad Rafiq, Aijaz Somroo, Zahid Ikram, Niaz Hussain, Muhammad Ijaz, Muhammad Naeem Shaikh, Israr Hussain, Shahid Riaz Malik, Ata ur Rehman, Gavin Ramsay and Chris Blanchard (2021). Exploring genotype x environment interaction for chickpea grain yield and related traits by a mixed model approach. Frontiers (Under review).
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12. Saddique, M.A.B., Waqas, M.U., Rehman A, and Khalid, M.A. (2023). Identification and characterization of salt stress-responsive NHX gene family in chickpea. (Ready for Submission).

Miss Ifrah Chaudhry is doing an MPhil in Public Health, and her research work titled “Uncovering the gender-based drivers of food insecurity and malnutrition in Bhakkar, Pakistan: Empowering women to enhance household nutritional security” is related to Bhakkar GCR families.

Student	**Degree**	**Year**	**Degree status**	**Thesis title**
M. Asad Iqbal	MSc (Hons) PBG	2022	Degree completed	Genetic variability among EMS induced mutants of chickpea for beta carotene and yield related traits
M. Tayyab	MSc (Hons) PBG	2022	Degree completed	Genetic diversity in chickpea (Cicer arietinum L.) germplasm based on yield traits
Zulkifl Ashraf	MSc (Hons) PBG	2023	Degree completed	Diversity analysis of chickpea (Cicer aratinum L) germplasm on the basis of zinc and iron
Muhammad Asif Mansoor	MSc (Hons) PBG	2021	Degree completed	Diversity analysis of chickpea for the yield related traits and the nodule formation bacteria
Kausar Parveen	MSc (Hons) Biotech	2023	Thesis under progress	Genome wide analysis of Glutathione Peroxidase (GPX) gene family in chickpea (Cicer arietinum L.) under salinity stress

11 Appendixes List

Appendix 1. Constraints and Opportunities for Pulses (Chickpea and Lentil) in Project Area under the ACIAR Pulses Productivity Project (CIM/2015/041)

Appendix 2. Current status of farm level value addition of chickpea, lentil and groundnut in Pakistan, opportunities and socio-economic barriers based on the situational analysis conducted under ACIAR Project CIM/2015/041

Appendix 3 Workshop to impart industry specifications to Pothwar region peanut growers

Appendix 3.2. Press Release: One-day Groundnut Stakeholders Linkages workshop at PMAS-AAUR

Appendix 4. Report on Visit of ACIAR-041 Project team to Village Seed Bank at PD Khan, Punjab, Pakistan

Appendix 5. Village Seed Banks Documents/Records Project Sites 1 and 2

Appendix 6. Impact Assessment of Project Interventions (pdf)

Appendix 7. Project beneficiaries list (excel)

Appendix 8. List of Events-ACIAR-041 (excel)

Appendix 9. Seed Production-FInal report (excel)

Appendix 10. Project Newsletters.

Appendix 11. Education material

Appendix 12. Project Videos

Appendix 13. Germplasm Exchange Documents Between Australian Grain Gene Bank and Pakistan

Appendix 14. Aflatoxin test report

11.1 Appendix 1: Constraints and Opportunities for Chickpea and Lentil Production in Pakistan: A Knowledge, Attitude, and Practice Approach

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Abstract

Pulses are an important crop and a significant source of proteins and essential micronutrients in human nutrition worldwide, especially in South Asia. However, compared to significant and substitute crops in Pakistan, pulses have been subjected to years of neglect in research, development, and extension services. Consequently, pulse productivity has decreased over the years, whereas demand has continuously increased due to population growth, causing increased imports and, thus, a rise in import costs. This study highlights the constraints and opportunities in producing chickpeas and lentils in Pakistan. Primary data were collected from six project sites representing pulse-specific districts in four provinces and based on each province's contribution to pulse production in Pakistan. The data were analyzed using SPSS and Excel. The results indicate that production-related issues, low prices obtained by the farmers, neglect in overall agriculture research, low-yielding varieties, a lack of farmer access to good quality seed, low adoption of modern production technologies, poor crop management, labour shortage, poor harvesting mechanization, vulnerability to climatic stress, insect and pest attack, and water shortage are the major constraints in the study area. The outcome of the situational analysis was the implementation of several interventions to resolve these multifaceted issues using farmer-led participatory approaches. The aim was to provide improved pulse varieties, certified seed production systems, crop production technologies, crop management, improved irrigation, and farm-level value addition.

Keywords: Pulses, Constraints, Opportunities, Pakistan

Introduction

Pulses are an essential food crop worldwide, especially in South Asia, where they are considered a significant source of plant proteins and micronutrients, including iron, particularly for the economically disadvantaged segments of the population (Kahraman et al., 2015; Nair et al., 2013). In Pakistan, pulses are traditionally grown in rain-fed areas and less fertile soils. Chickpeas, lentils, mung beans, and mashed beans are the major pulse crops in the country. Chickpeas (Kabuli and Desi) and lentils are winter legumes (Rabi season crops) and thus are considered alternative crops to wheat. The area under pulse cultivation is around 1169.9 thousand hectares. Of this, 1119.60 thousand hectares are devoted to the major pulses, and annual production is 510.40 thousand tons. This area represents about 5% of Pakistan's cropping area (Government of Pakistan, 2019). Chickpeas occupy 73% of the total area devoted to pulse production, whereas lentils occupy 5% of the total area (Government of Pakistan, 2016). Rani et al. (2012) indicated that from 1976 to 2010, the price for chickpea and lentil crops increased by 9.87% and 11.09%, respectively, with fluctuating yearly prices beyond the farmers' control. The growing area, yield, and production of pulse crops decreased during this period, primarily due to the discontinuation of intercropping pulses with wheat. Consequently, the pulse-growing regions gradually shifted to the marginal areas of the country.

Chickpeas are a drought-tolerant cash crop and, thus, a significant source of wealth for farmers in rain-fed areas of Pakistan. However, there has been a wide gap between potential and actual yield, which may be attributed to various constraints, for example, crop management, labour management, and a lack of infrastructure (Pankaj et al., 2001; Sharif et al., 2004). There have been minor changes in the area under pulse production, suggesting farmers have been allocated limited fixed portions of land due to unstable chickpea and lentil yields. This fact is evident from the extreme fluctuations in production and productivity, which have negatively influenced the area allocated. For example, the area for lentil production had the highest reduction in size cropped during the last three decades compared to other pulse crops (Rani et al., 2012). However, some factors behind the decrease in production and productivity are attributed to poor crop management and ineffective policies. For example, the decline in pulse cultivation has eroded the production knowledge base (Rani et al., 2014). Although technological factors between 1975 and 2011 have positively impacted the yield and production of the main pulse crops, a more substantial effort to establish sustainable legume cropping systems effectively has yet to be developed (Kumar & Bourai, 2012).

Consequently, yields have remained stagnant for decades, and supply trails demand, producing increased prices. Hence, these inexpensive sources of protein and micronutrients became inaccessible primarily to the country's poor (Kumar & Bourai, 2012; Rani & Raza, 2012; Srivastava et al., 2010). The decline in the production area and a lack of interest in reintroducing lentils and chickpeas have been attributed to factors such as poor marketing, reduced yields, price fluctuations, high labour costs, inefficient labour use, and a lack of adoption by farmers of modern-day technologies and cropping methods. As a result, farmers have not had access to improved, high-yielding, disease-resistant varieties developed and tested in research stations (Qasim et al., 2013). In addition, the government has recently considered greater price control to prevent price fluctuations, thereby incentivising increased pulse production in all areas of the country and different farming systems.

However, the cost of pulse imports is rising to meet the ever-increasing gap between domestic production and requirements. This situation is exacerbated by low production and a slow growth rate of pulse production (Chaudhry et al., 2002; Government of Pakistan, 2016b). The increasing prices have reduced the consumption of protein-rich pulses, mainly among the lower economic class of the population (Rani et al., 2012; Rani et al., 2014). Consequently, the country is missing out on all the benefits that legumes bring to farming systems, including nutritional security, crop diversification, soil health, disease control, and risk reduction.

In Pakistan, wheat and rice are the most important staple food crops, occupying most cultivated areas and contributing 22% of added value to agriculture and 4.5% to the GDP (Government of Pakistan, 2020). Despite being an important staple food crop and supported through government policies to ensure food security in the country, the profitability of wheat is decreasing, especially for small farmers. In Pakistan, economic analysis shows that chickpeas and lentils compete with wheat in the winter season and return an excellent net profit compared to competing crops. Ullah et al.(2020) identified opportunities for increasing lentil and chickpea production in Pakistan through the availability of certified seeds of high-input responsive varieties, adoption of conservation agriculture to conserve resources, strengthening system of certified seed distribution and provision of crop-specific farm machinery, The International Food Policy Research Institute (2009) concluded that the cultivation of pulses could bring many benefits to farming communities in Pakistan, with primary beneficiaries being people experiencing poverty, especially children and women, who lack much-needed protein and iron in their diet. Furthermore, it would provide a good source of income and better nutrition to small landholder farmers.

A situational survey was conducted to capture farmers' on-farm involvement in enhancing the production and profitability of pulses in their existing cropping systems. Several farm families in six agro ecological regions across the country were included in the initial survey to provide insights into farming communities and their farming systems. This paper describes the results of establishing participatory research groups or groups of collaborative research (GCR) involving farmers and researchers to prioritize and carry out farm research activities in an integrated fashion. This study will help identify circumstances under which new technologies are compatible with farmers' production practices, resources, and goals. It will also help identify farmers' attitudes toward technologies, their system knowledge, and preferences to determine the acceptability of new technologies.

Materials and Methods

1. Study Population and Data Sources

The research teams or groups for collaborative research (GCR) that included selected research farm families were established so that the researchers and farmers at each of the six sites could work together using the Farmers' Participatory Approach (FPA). This approach has been discussed by Howeler (2020) as an alternative and complementary element to more conventional research on sustainable land use and rural development. The research sites were selected based on pulse productivity and are shown in the national-level agriculture statistics. Representative sample farm families were selected through focus group discussions. They had to have sufficient area for pulse production to demonstrate the project activities at the initial stage in the project. Six project sites were selected for chickpea crops and four sites for lentil crops in Pakistan. The six project sites covering four provinces were selected to capture the ongoing situation of farm families, including their practices and constraints limiting pulse production under different agro-climatic conditions. The six project sites, representing pulse-specific districts in four provinces, were selected based on each province's contribution to pulse production in Pakistan. The primary data were collected through the farm families' one-to-one interviews with male and female household members and focus group discussions in all six sites.

- Sites 1 and 2 are in the rain-fed region of Potohar in the Punjab province, in the districts of Attock and Chakwal, respectively. The Potohar region already contributes a significant share to the national economy and has great potential to increase pulse production. Supple et al. (1985) and Zia and Baig (1997) estimated that the major share of pulse production is obtained from the rain-fed areas of Pakistan.
- Site 3 is in the district of Bhakkar, in the Thal region of the Punjab province. The Thal is considered the home of chickpea production – 80% of the country's crop comes from this region (Government of Pakistan, 2017).
- Site 4 is in the rain-fed district of Karak, a major chickpea-growing area in the province of Khyber Pakhtunkhwa.
- Site 5 is in the district of Larkana, in Sindh province. Chickpeas are mainly grown here in the residual moisture after the rice season.
- Site 6 is in the districts of Jaffarabad and Nasirabad in Baluchistan province.

2. Study Design and Data Collection

The concepts of knowledge, attitudes (or perceptions), and practices (KAP) were applied, resulting in a questionnaire using the KAP concept (Muleme et al., 2017; Schreinemachers et al., 2017; Rani et al., 2018). **Knowledge** refers to farmers' understanding of pulse production and consumption in the study, while **Perceptions** refer to their beliefs about challenges and opportunities, like perceived constraints in producing the crop, including pictorial identification of insects and pests that attack pulse crops. In contrast, **Attitude** refers to farmers' actual behaviour (decisions, actions) that demonstrate their knowledge and perceptions. The multistage sample technique is adopted in the research. In the first phase, pulse farmers are interviewed from all six sites, and then in the second stage, chickpea and lentil farmers are selected through focus group discussions with the pulse farmers. Lastly, the potential farmers willing to work with the project team are selected from the second-stage farmers. A detailed questionnaire was designed to help identify possible farm-level constraints, opportunities for expanding pulse production, and cropping patterns used during the past 12 months. Detailed information about production practices, such as the source of seed, sowing method, weeding, harvesting, pest management practices, labour use, agrochemicals, and outlets for selling the produce, were noted for each farm family. Estimated crop yields, revenues, and input costs were also recorded.

3. Data Analysis

The situational analysis also provided information about the knowledge level of 90 farm families regarding value addition. Data were also collected on household characteristics, such as operational land holding, family size, education, household farm inventory, source of information, and community collaboration, to evaluate the relative wealth status of the farm families. Statistical Package for Social Scientists (SPSS) and Microsoft Excel software were used for data analysis for mean, standard deviation, graphical representation, and descriptive statistics. The data obtained were compiled, processed, and analyzed, and the outcomes are presented below.

Results and Discussion

1. Socio-Economics Characteristics

The literature indicates that socio-economic characteristics play a role in farming, especially farmers' attitudes and behaviour toward new technology (Khursheed et al., 2008). Table 1.1 highlights these features in the project sites.

Table 1.1: Socio-Economic Characteristics

Characteristics	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6

Age of respondents (years)	38	53	43	53	40	45
Education of respondents (years)	11	12	12	10	8	10
Household size (no)	10	7	8	17	7	16
Farm labor involvement (male)	1	2	2	2	1	2
Farm labor involvement (female)	1	1	2	1	-	2
Total Operational Land (Acres)	13	17	23	6.5	6	52

The average age of respondent farmers was between 38 and 53 years. The average family size ranged from 7 to 17 family members in the different sites. Farmers mostly live in nuclear family settings, except in Karak and Jafferabad, where they mostly live as an extended family, having many family members in one residence. The education level of the respondent farmers at Sites 2 (Chakwal) and 3 (Bhakkar) was highest at year 12 level; it was lowest at Site 5 (Larkana) at the year 8 level. The results also indicated that the farm families hired male and female labourers for agricultural activities. Studies have shown the importance of dependence on agriculture and its allied industries, demonstrating the positive impact on household income (Chaudhry et al., 2002; Jan et al., 2008). Therefore, data were also collected to determine the effect of different sources of income on the household. For example, in Sites 3, 4, 5, and 6, farmers mostly meet their household expenses through crop and livestock production income. At Sites 1, 2, and 4, farmers primarily depend on off-farm revenue generated through employment. The small landholdings and the fact that all crops at these sites are grown under rain-fed conditions are reasons for the low dependency on agriculture. Although farmers in Bhakkar and Karak grow chickpeas under the same conditions, in Bhakkar, they have large landholdings and fewer opportunities for other sources of income. In summary, the significant sources of income across all the sites are crops, livestock, and employment.

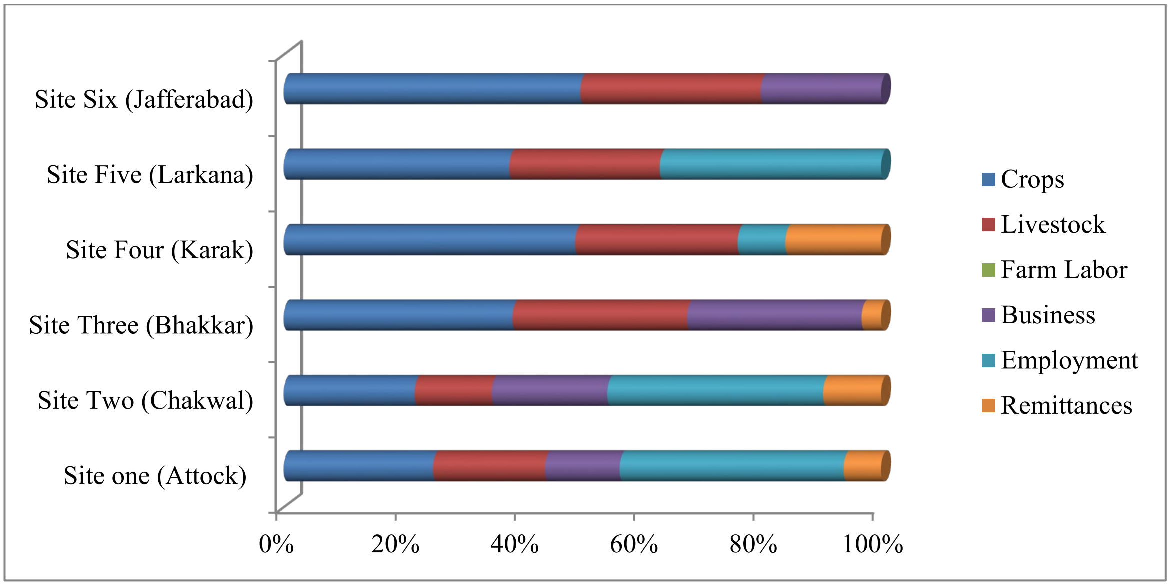

Figure 1.1: Source of income of the farmers at each project site

2. Cropping Patterns

All six project areas are defined by two cropping seasons. Summer or Kharif crops are sown in the Kharif season, from May to October. The dry winter season crops or Rabi crops are planted in the Rabi season, from November to April. In all the project sites, wheat, chickpea, and fodder crops are the important Rabi crops, while in the Kharif season, maize, millet, mungbean, and rice are the main crops. The share of crops and cropping patterns at the different sites are depicted in Table 2. Wheat occupies most of the total cropped area in all the project sites. The relatively low share of wheat in Bhakkar is due to the higher size devoted to chickpeas (29.5%), which is explained by the high proportion of sandy soils unsuitable for growing wheat. In the other project sites, the area allocated to chickpeas is less than for wheat, as farmers prefer wheat due to its price stability. Therefore, if pulse profitability and productivity are stable, farmers will allocate more land to the cultivation of pulses than alternative crops (Petersen et al., 2018).

Table 2.1: Cropping pattern (% of the total cropped area) on the project sites

Crop	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Rabi crops						
Wheat	38.5	26.7	13.6	25.0	16.7	14.4
Chickpea rain-fed	7.7	6.7	29.5	23.1	16.7	32.7

Chickpea irrigated	-	-	3.8	-	-	-
Lentil	-	3.3	-	-	4.2	-
Mustard	-	6.7	-	-	4.2	-
Fruits & vegetables	-	-	2.3	-	-	-
Rabi fodder	3.8	6.7	0.8	1.9	8.3	2.9
			Kharif crops			
Groundnut	3.8	-	-	-	-	-
Rice	-	-	-	-	50.0	11.5
Millet	-	-	13.6	15.4	-	-
Maize	-	6.7	-	-	-	-
Mungbean	-	13.3	-	-	-	-
Mash	-	-	-	-	-	-
Kharif fodder	3.8	6.7	2.3	-	-	2.9
Vegetables	-	-	-	-	-	1.0
Fallow	42.3	23.3	34.1	34.6	-	34.6
Total Cropped Area	100	100	100	100	100	100

In Larkana, wheat and chickpeas occupy almost the same area. In the Kharif (summer) season, most of the land remains fellow at sites 1, 2, 3, and 4 due to the rain-fed conditions. In Larkana and Jafferabad, during Kharif, rice is grown. Groundwater and canal water are mainly used to irrigate high-value crops like wheat, rice, fruits, and vegetables.

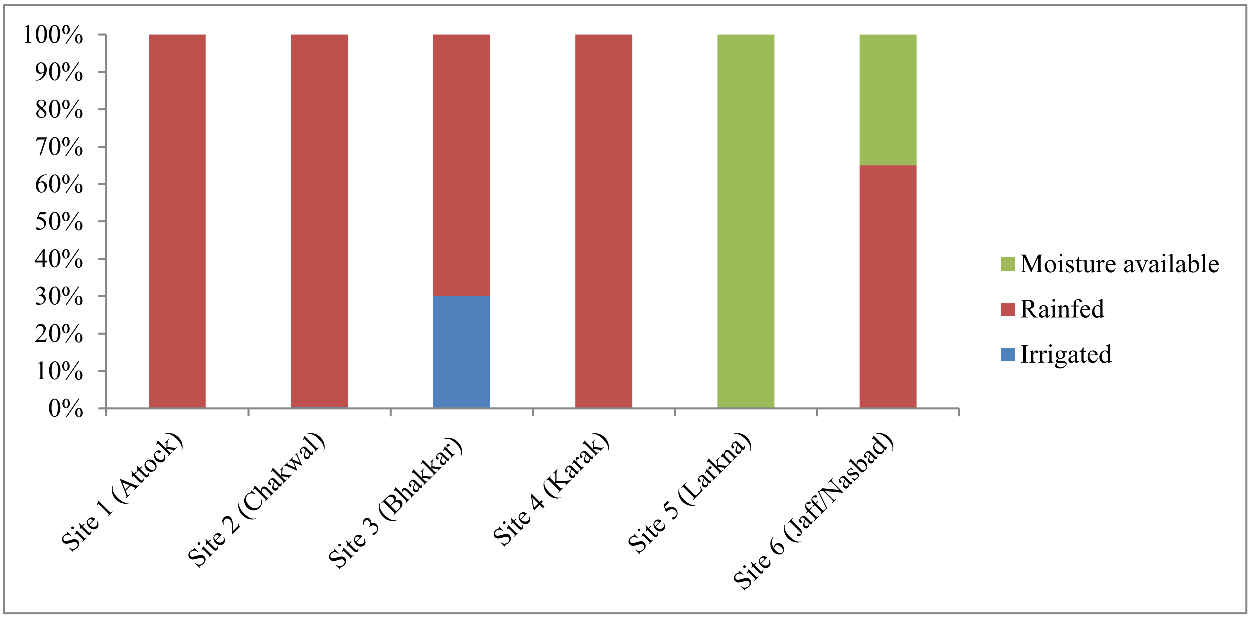

Figure 2.1: Type of land (irrigated, non-irrigated) in all six sites

Soil moisture is an important environmental factor controlling germination and establishment of seedlings (Tylor et al., 1982). High seed emergence and seedling establishment contribute directly to the crop yield (Maiti & Moreno, 2001). In chickpeas, rapid seed emergence, fast plant growth, and early maturity substantially contribute to increased yield under drought conditions (Gupta, 1985. In contrast, a lack of adequate soil moisture in the seedbed significantly hinders the establishment of chickpea crops. Inadequate soil moisture can reduce seed germination, slow seedling growth, and diminish yield in rain-fed crops (Ceyhan et al., 2012; Kahraman et al., 2016). Figure 4 illustrates the yield of chickpea production at the farm level at each site over three years, highlighting the difference between the sites with available moisture and those under rain-fed conditions. At Site 5 (Larkana) and in parts of Site 6 (Jafferabad), seasonal irrigation (canal water) is available for the rice as a Kharif crop, sown in summer.

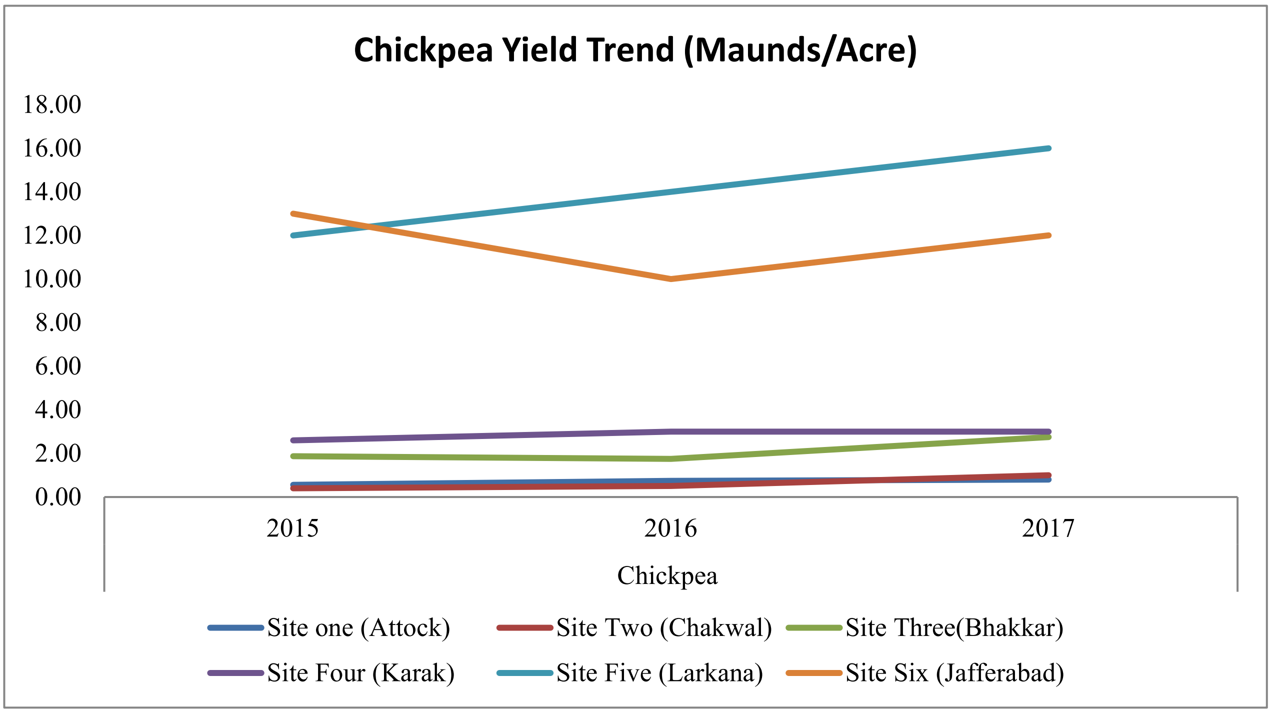

Figure 2.3: Chickpea yield trend over three years in project sites (Maund/Acre)

Although water is not available for the winter season chickpea and lentil crops, the availability of residual moisture after the rice harvest significantly affects yield compared to the other regions of chickpea production, as shown in Figures 2 and 3. On average, at Sites 1, 2, 3, and 4, the chickpea yield is less than four maunds per acre. Apart from low moisture, this can be due to inferior-quality seeds and a lack of awareness about new production techniques. However, the average yield for lentils in all sites is less than ten maunds per acre, which has been reasonably stable over three years. Larkana has previously grown lentils, but farmers are not growing them now due to the unavailability of good seeds, weed management, and poor crop practices. Therefore, the expectation is that with new techniques, the farmers may be able to increase production, thereby allocating more area for pulses.

3. Production Practices

Identifying farmer practices and their potential improvement through implementing appropriate interventions can drastically improve production. Table 5 shows all chickpea production practices at all the project sites. The Rabi season sowing and harvesting time are almost the same at Sites 1, 2, 3, and 4 (Attock, Chakwal, Bhakkar, and Karak) where farmers grow crops on fallow land; they have time to prepare and sow chickpeas using a drill seeder. However, in Sites 5 and 6 (Larkana and Jafferabad), the crop sowing time is slightly delayed because of rice harvesting activities.

Table 3.1: Production practices for chickpeas in different project sites

Production Practices	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
			Sowing			
Sowing time (W/M)	2nd October	2nd October	2nd October	1st October	1st November	4th October
Harvest time (W/M)	4th April	4th April	2nd April	1st April	2nd April	4th March
Broadcast seed	0.29	0.00	0.00	0.00	1.00	1.00
Sow manually in lines	0.00	0.00	0.00	0.25	0.00	0.00
Sow line with machine	0.71	1.00	1.00	0.75	0.00	0.00
			Harvesting			
Scythed by hand	1.00	0.10	0.99	1.00	1.00	1.00
Machine harvesting	0.00	0.00	0.01	0.00	0.00	0.00
Threshing						
Thresh by hand	0.40	0.60	0.00	0.10	0.00	0.00
Thresh by machines	0.60	0.40	1.00	0.88	1.00	1.00

Crop Residue						
Collect it and feed it to animals	0.50	0.80	0.50	0.50	0.70	0.08
Collect it and sell it	0.00	0.00	0.50	0.25	0.20	0.83
Let animals feed in the field	0.00	0.00	0.00	0.00	0.10	0.08
Plough it under	0.33	0.20	0.00	0.25	0.00	0.00

Consequently, farmers in these two sites, due to a lack of time, sow a chickpea crop by broadcasting seeds in fields cleared after the rice harvest. Thus, the project has opportunities to introduce sowing methods to farmers at Sites 5 and 6 to improve yield. Harvesting is done manually at all sites and primarily by community women. At Sites 1 and 2, the crop is threshed manually as well as by mechanized methods. The threshing of crops is undertaken manually only where the crop area is minimal, primarily for household consumption. However, on a large scale, the separation of grain is done by a chickpea harvester. According to Tharanathan (2003), Voisin et al. (2014) and Topalak and Ceyhan (2015), pulses play a central role at the food system level, providing plant proteins for humans and animals.

Furthermore, the capacity of pulse crops to fix atmospheric nitrogen makes them potentially highly suitable for inclusion in low-input cropping systems. It is, therefore, essential to explore the use of pulse residuals at the farm level. The results indicate that most farmers at all the sites except Site 6 collect crop residues as dry fodder for animal feed. At Site 6, the farmers sell the pulse residues for extra income. Table 3.2 shows the lentil production practices in the project sites. The results indicate that lentils are mainly grown manually. Lentils are the traditional crop in Chakwal, while they are new additions to the cropping patterns in Sites 3 and 6. At Site 3, lentils are cultivated under irrigated conditions with three-time irrigation to the crop

Table 3.2: Production practices for lentils in different project sites

Production Practices	Site 2	Site 3	Site 6
# of years to cultivated	Forefather	4	6
Variety name	NIAB 2006, Markaz 2009	Punjab Masoor-2006 and Desi	DK, Desi

Sowing practices			
Sowing time (W/M)	1st/November	2nd/October	3th/October
Harvest time (W/M)	2nd/March	1st/April	4th/March
Broadcast seed	0.95	0.90	1.0
Sow manually in lines	0.05	0.10	-
Sown line with machine			
Harvesting practices			
Scythed by hand	1.0	1.0	1.0
Machine harvesting	-	-	-
Threshing practices			
Thresh by hand	0.01	0.05	-
Thresh by machines	0.99	0.95	1
Irrigation			
Flood irrigation	-	1	-
# of irrigation	-	3	-
Crop residue			
Collect it and feed it to animals	0.2	0.8	0.9
Collect it and sell it	0.8	0.2	
Let animals feed in the field			0.1

Chakwal is the traditional lentil-growing area in Pakistan where farmers have grown lentils for generations. But at the other sites, it is new in their cropping patterns. In all the sites, lentils were sown using the seed broadcast method, scythed by hand, and threshed using a mechanical thresher. Weed control is the central issue at all sites, but farmers have limited knowledge and awareness of different weed control methods and are thus restricted to manual weeding across all locations. However, due to high labour costs, farmers often leave the weeds to grow alongside the pulses. At Sites 5 and 6, farmers stated that handling weeds was the biggest challenge. As a result, they must use hired labour, increasing their production costs. The primary issue is the availability, access, and knowledge of the input use, especially pre-emergence weedicide, insecticide, pesticide, and rhizobia for different pulses at almost all the sites. The effectiveness of farm chemicals is also a big issue attributed to some generic companies operating in the project areas. However, the products of multinational insecticide/pesticide and weedicide-producing companies are unavailable or inaccessible to farmers.

Similarly, no single commercial product for rhizobium inoculum from a national or international company is available on the market. Some public organizations selling rhizobium inoculants cannot fulfil even the local demand. Moreover, an awareness of selecting and using the required chemicals against insect pests and diseases and pre-emergence herbicides to control desired weeds is necessary to improve farmers' yields. In Site 6 (Jafferbad/Naseerbad), the seed rate per acre is relatively high compared to the other sites. Fertilizers such as urea and DAP are used only at Site 3 (Bhakkar), where lentils are grown under rain-irrigated conditions (Ulker & Ceyhan, 2006; Varankaya & Ceyhan, 2012).

4. Labor Input

The data was collected about labour, considering its essential role in crop production. For example, a labour time of 95 hours per acre or 11 labour days is required for chickpea production. The labour includes male and female household workers and seasonal or permanently hired male and female workers. Both farm and employed female workers are actively involved in the harvesting, weeding, and cleaning of the seed in chickpea production. These tasks are laborious, especially harvesting and weeding. The workers are also involved with other tasks, such as livestock management and household chores (Figure 4.1). There is a strong need to train and build females' capacity, like value addition and seed preparation, which can potentially contribute to the productivity and profitability of the pulses. Most of the farm family labour is done by males, from purchasing seeds to selling the crop. Hiring outside labour, primarily males, is expected for land preparation, weeding, harvesting, threshing and cleaning, and sorting.

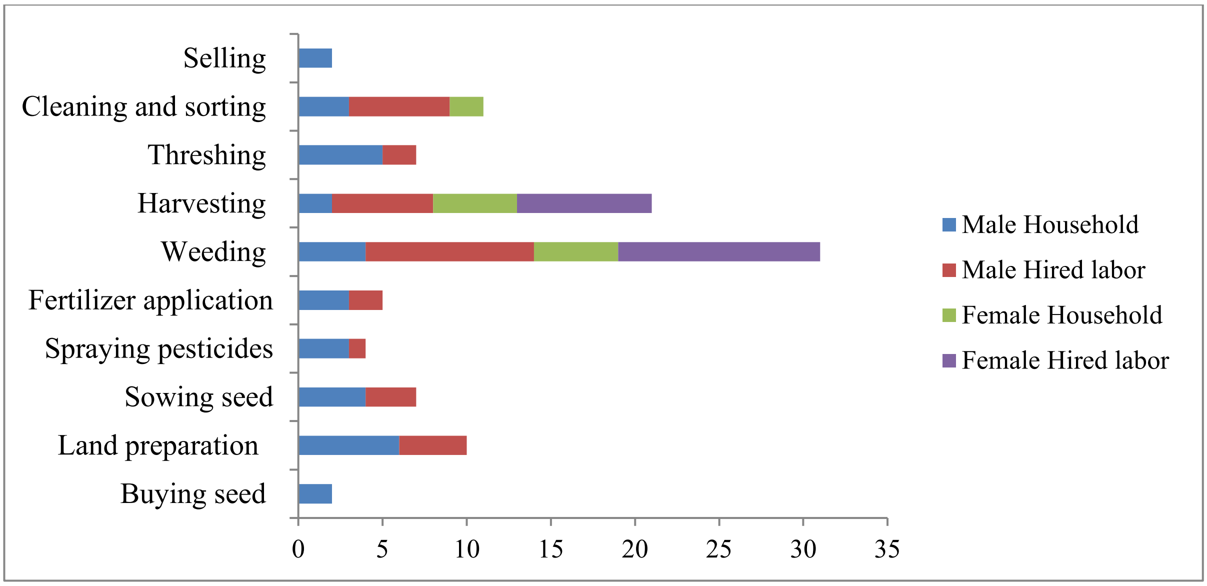

Figure 4.1: Average labor use (hour/acre) in pulse production in all project sites

Children also work with their families to harvest, thresh the bean pods, and clean the grain. The farmers also reported a shortage of labour during the harvesting season. In addition, hiring labour for harvesting and weeding increases input costs.

5. Constraints in Pulse Production

Growers mentioned a long list of constraints to chickpea production at all project sites (Table 5.1 and Figure 5.1). The most frequently cited problems were plant diseases, insect pests, poor seed quality, the unavailability of seeds, labour shortage, weed management, and low yields. These results are similar to those mentioned by Ulker and Ceyhan (2006), Varankaya and Ceyhan (2012), Petersen et al. (2018), and Rani et al. (2018) for the production constraints of pulses. The figures below show the significant limitations in lentil production at four sites. The low production and decreasing area in the different sites are due to labour shortages, unavailable good seeds, and weed control problems. Insect and pest attacks are also an issue in three locations where the lentils are grown.

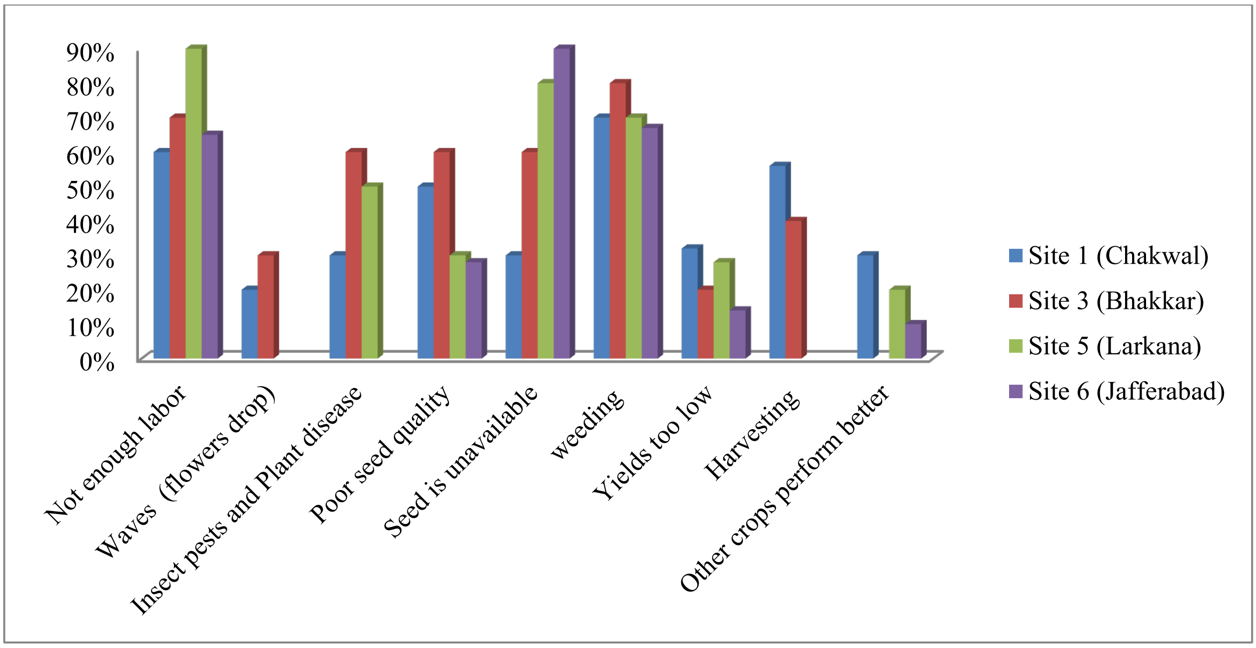

Figure 5.1: Major constraints in lentil production in project sites

Although the Larkana district is a potential new area for lentil production, farmers reported that their forefathers had once grown lentils there. However, biotic and abiotic stresses contributed to the exclusion of the crop from their cropping pattern. Access to quality seeds of different varieties was reported as the biggest constraint for the farmers at all the sites, especially Bhakkar, which represents 80% of the total area devoted to chickpeas. Current chickpea yields at Sites 1, 2, 3, and 4 are excessively low. Agro-climatic conditions like heat waves and rains with no defined pattern also affect pulse production. At all project sites, a few farmers demonstrated knowledge of pre-and post-emergence herbicides, pointing to the importance of improved varieties with better resistance to biotic and abiotic stresses.

Table 5.1: Major constraints in chickpea production in project sites

Constraints	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All
			Resource constraints				
Not enough labor	0.34	**0.67**	**0.56**	0.50	**0.56**	0.33	**0.52**
Not enough cash or credit	0.00	0.00	0.14	1.00	0.40	0.00	0.11
Not enough water							**0.44**
Lack of awareness of improved production technology	0.00	0.00	**0.71**	**0.75**	0.00	0.17	

Abiotic constraints							
Erratic rainfall	**0.53**	**0.67**	0.29	0.27	0.40	0.00	0.35
Waves (flowers drop)	0.00	0.00	**0.50**	**0.67**	0.00	0.00	0.00
Soil fertility too low	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Land too saline	0.00	0.00	0.00	0.00	0.05	0.17	0.04
Biotic constraints							
Insect pests	**0.60**	**0.67**	**0.43**	**0.57**	**0.60**	**0.67**	**0.56**
Plant diseases	0.25	0.67	0.40	0.13	0.17	0.14	0.11
Weed management	0.24	0.34	**0.50**	**0.43**	**0.83**	**0.76**	**0.51**
High storage losses	0.00	0.00	0.14	0.00	0.00	0.00	0.04
Seed constraints							
Poor seed quality	**0.80**	**0.80**	**0.71**	**0.63**	**0.57**	**0.40**	**0.62**
Seed is unavailable	**0.67**	**0.58**	**0.80**	**0.42**	**0.37**	**0.42**	**0.45**
Economic constraints							
Lack of market demand	0.00	0.00	0.00	0.00	0.20	0.25	0.08
Input costs are too high	0.20	0.25	0.13	0.25	**0.60**	**0.83**	**0.37**
Yields too low	0.80	0.75	0.57	0.88	0.20	0.00	**0.54**
Selling prices too low	0.00	0.00	0.29	0.11	0.80	0.44	**0.34**
Unavailability of machines for chickpea harvesting	0.20	0.33	**0.56**	0.11	0.40	**0.29**	**0.36**
Other crops perform better	0.20	0.33	0.00	0.13	0.00	0.00	0.09

6. Seed Sources

Crop production begins with the seed; therefore, quality seed is essential for the production of any crop. Data have been recorded for different seed sources in all the project sites. According to Emadi & Rahmanian (2020), two systems are adopted widely for seed supply to farmers. First, the formal, highly regulated supply system involving a chain of activities leads to the production of certified seeds of verified varieties. Also, an informal system primarily operational in developing countries like Pakistan entails farmers either producing their seed and saving it for the next season or buying it from local seed dealers (Food and Agriculture Organization, 2016).

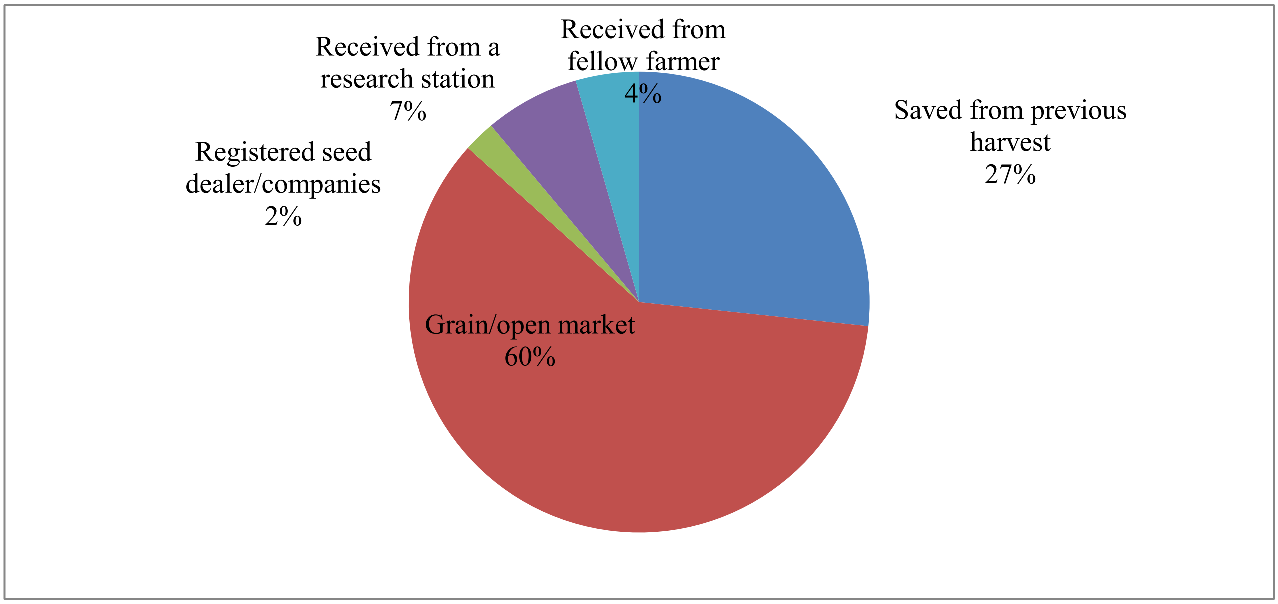

Figure 6.1: Sources of seed for pulses in the project area in Pakistan

Without a formal seed production system, accessibility to quality seed is minimal and thus a significant production constraint at all the sites (Figure 8). The results have shown that 60% of farmers are getting seeds from the local grain market in the guise of graded grain offered as a quality seed in all the sites. However, a few farmers in Site 3 (Bhakkar) and Site 4 (Karak) have been reported to be using chickpea varieties CM-44 and Bittle 98, while for lentils, only graded grain is being used as lentil seed. It has also been observed that some farmers are saving the previous harvest as seed, and only a few are acquiring seed produced under controlled conditions from a research station or registered seed companies. Hence, there is a strong need to involve private and public seed companies to fill the large gap between the supply and demand of certified seed. Village-based seed production systems at project sites are in line with those developed by Food and Agriculture

Organization (2016), which could be a solution to fulfill the seed demand and empower the local community, especially the women.

7. Insect, Pest, and Disease

Leguminous pulses are predisposed to many insect pests and seed-borne diseases, and if not managed properly, an outbreak of these pests and diseases can destroy the crop. Singh et al. (2013) and Singh et al. (2014) indicated that *Fusarium* wilt is widespread in legume-growing regions. Also, pests can cause heavy damage to legume grains during storage. Legumes are generally pest-free crops if grown under normal crop rotation conditions. However, pod borer, *Ascochyta* blight, and wilt (*Fusarium oxysporum* sp lentils) are major insect and disease pests of pulses identified by the farmers at the project sites. Figure 7.1 shows pests and diseases as perceived by chickpea growers identified from color photographs of common pests and signs of damage at all project sites.

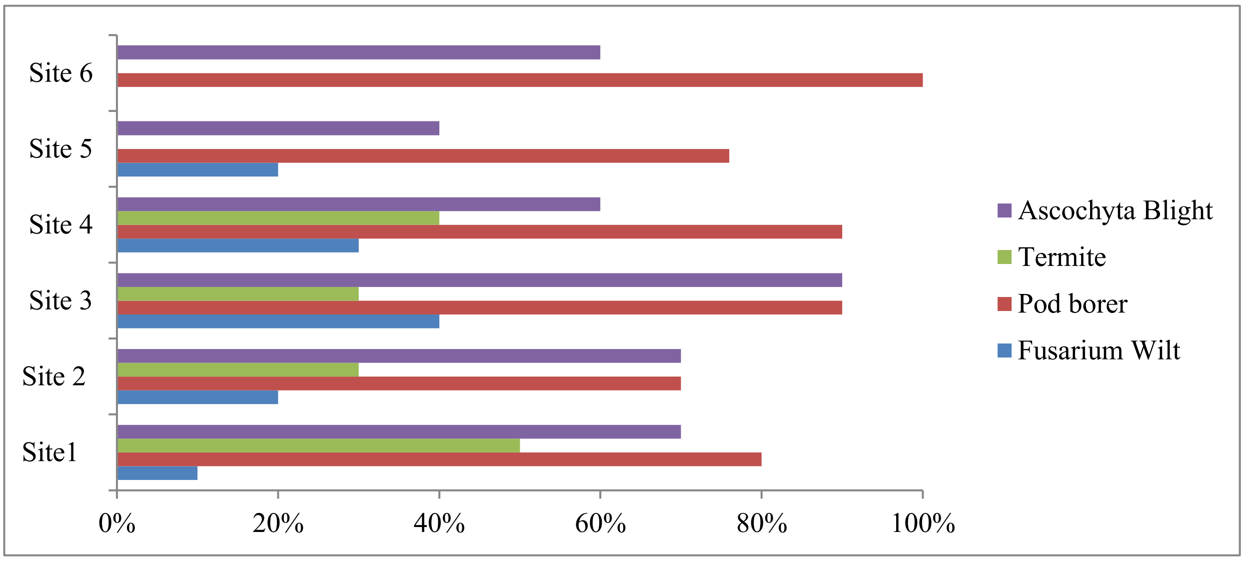

Figure 7.1: Insect and pest attacks on different sites, farmers' response in chickpea areas (%)

Pod borer is a significant pest, and *Ascochyta* blight is the primary disease affecting the pulse crops at the project sites. A combination of improved varieties and good agricultural practices can address these issues.

Discussion

The results indicate that the average area of land allocated to chickpeas is less than for the alternative wheat crop. Wheat is a significant source of food security; the government protects and subsidizes prices for the farmers. Hence it is one of the reasons that pulses are cultivated on marginal lands. However, farmers in Bhakkar and Jafferabad have large landholdings and thus grow chickpeas in larger areas under rain-fed conditions than other sites. The crop yields, except for Larkana and Jafferabad, are very low at all the project sites. At Sites 1, 2, and 4, farmers mainly grow pulses for their consumption, primarily due to the low yields.

Consequently, a low proportion of their harvest is sold locally in the market, mostly to middlemen, called Beoparis. The local grain market is also a selling point for farmers at Sites 1, 2, and 4. Despite banking infrastructure across all sites, farmers tend not to access banking credit because of their poor resource base and a lack of risk-bearing capacity. Consequently, their only source of inputs for the next season and cash is from Beopari to fulfil their household needs and cover agricultural expenses. Also, there is no marketing and credit policy by the government. However, at Site 3, farmers take credit or input from the Beoparis (middlemen) or seed or grain market with consent that they will sell their farm output to them and pay back their credit along with interest. Likewise, at Site 4, farmers do not prefer to take loans; instead, they borrow inputs with the consent that they will sell their crop grain to those they borrow from. Most people here prefer to borrow inputs from their relatives and give it back to them after selling their produce. Several studies have suggested that with pulses, the delivery of improved technology, inputs, and credits needs streamlining through appropriate policy interventions, and crop insurance benefits must be extended to pulse farmers (Petersen et al., 2018; Singh et al., 2013). This information is essential and valuable for all stakeholders for appropriate interventions to improve farmers' knowledge, which could enhance their ability to increase pulse production in different regions of Pakistan. Seed treatment is a strategy to reduce losses from diseases in pulse crops. Farmers have limited knowledge of seed treatments and their application in treating seed before sowing in all the project sites. Most pulses are grown under rain-fed conditions, so their yield is affected by less rainfall. In regard to insect pest management (IPM) techniques, only farmers in Site 3 (Bhakkar) were aware of such techniques owing to training provided by the Arid Zone Research Institute, Bhakkar. A concerted effort is required to impart IPM knowledge to farmers about the combination of cultural, physical, biological, and chemical-proven cost-effective, environmentally sound, and socially acceptable methods. The survey shows that insects, weeds, and diseases are significant constraints in all the project sites and thus warrant awareness among farmers of different methods of seed treatment, IPM, and the introduction of drought-resistant plant varieties. Farmers get their information regarding agriculture and its allied sectors mainly from the research institutes, followed by the input suppliers, neighbouring farmers, and agricultural extension departments. The input supplier is also the credit agency for many farmers from the project sites. The survey indicates that agricultural research stations are the most commonly accessed source of new knowledge for farmers at all project sites. Farmers identified a list of constraints to growing pulses at each site, such as low prices obtained by the farmers, neglect in overall agriculture research, low-yielding varieties, a lack of access to good quality seed, low adoption of modern production technologies, poor crop management, labour shortage, high labour cost (especially for weeding and harvesting), vulnerability to climatic stress, insect and pest attacks, weeds, and water shortage.

Furthermore, accessibility and availability of quality seed certification are one of the ways to enhance crop productivity. Consequently, good seeds will enhance production and encourage farmers to allocate more land to producing chickpea and lentil crops. Furthermore, improved pulse production technologies like seed treatment, pre- and post-emergence weedicides, and insecticides control the insects and pests in pulse crops. However, moisture availability is essential for rain-fed crops because it enhances productivity. Therefore, introducing new technology for better moisture in the field is necessary because farmers perceive that supplementary irrigation will help with crop security. Also, better crop management practices will be introduced, like mechanized harvesting, threshing, improved sowing methods, and zero tillage techniques, Additionally, market incentives such as market price stability, including the capacity of all market stakeholders to work efficiently together, will increase the area planted for pulse crops and, therefore, production in the country. Farmers also perceived that the availability of small-scale machinery, especially for harvesting, would enhance farm profitability. Farmers grow pulses on marginal land and are unaware of the crops' potential profitability compared to competing crops. Knowledge to better manage the crop can also potentially increase productivity and profitability.

Conclusion and Recommendation

Currently, Pakistan is encountering serious issues in food production. In Pakistan, there is decreasing profitability and increasing stockpiles of wheat and rice, while the country's import bills for pulses and edible oils are rising alarmingly. This situation is attributed primarily to the neglect of pulse production in the agricultural research plan over the past few decades. With no support policy backup, resulting in consistently low prices, this has created a long-term disenfranchising environment that has led to numerous production-related issues that are limiting the production of pulses. Some problems faced are low-yielding varieties, no access to good quality seeds, low adoption of modern production technologies, poor crop management, labour shortage, vulnerability to climatic stress, insect and pest attacks, farmers' limited knowledge of pulses' nutritional benefits, and a water shortage. Addressing these limitations can reverse the decline in pulse production in Pakistan's cereal-based farming system, significantly improving crop productivity and consequent income gains. Exploiting this potential would require each constraint to be addressed.

Testing of approved lentil and chickpea varieties across all six research sites, using a participatory approach with farmers as its core partners, has already been initiated. In addition to providing information on the performance of the varieties under local conditions, the trials also form the basis for establishing local village-based seed production systems, which is one of the main constraints limiting productivity. The farmers have identified potential varieties based on their yield, disease, and pest resistance. The same trials continue for a second season to confirm the current results. Replicated agronomical trials of selected varieties identified during the first varietal trials have been sown to address the earlier constraints. The success of these trials would ensure the introduction of proper mechanization in solving labour shortages during harvesting, which may reduce the drudgery of farm work, especially for women. These activities, in turn, may involve them in more sustainable and productive practices like value addition, seed sorting, and management. Furthermore, there is a solid need to disseminate the learning and practices of the farm families working on the project to other farmers and private sector participants, such as input suppliers and potential service providers. In this regard, the project involves ongoing training of farm families in facilitating their learning to the maximum number of neighbouring farmers.

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11.2 Appendix 2: Current status of farm level value addition of chickpea, lentil and groundnut in Pakistan, opportunities and socio-economic barriers based on the situational analysis conducted under ACIAR Project CIM/2015/041

Introduction

Over the last three decades, there has been a rapid decline in the production of pulses in Pakistan despite a considerable increase in the population. The reduction in pulse production has resulted in an extra burden on the country's economy by increasing the import bill. It has also reduced the per capita availability of pulses, leading to poor nutrition at the family level. The government of Pakistan, realising the importance of increasing the domestic production of pulses, launched the project “Increasing the productivity and profitability of pulse production in cereal-based cropping systems in Pakistan” with the help of the Australian government through the Australian Centre for International Agricultural Research (ACIAR).

A two-step situational analysis under the ACIAR pulses project-041 was undertaken at six selected project sites in Pakistan to understand the reasons for the decline in pulse production and possible opportunities for improvement. The sites include three districts of Punjab province: Attock, Chakwal, and Bhakkar, Karak from Khyber Pakhtunkhwa province, Larkana from Sindh, and Jafferabad from Baluchistan. These are the central pulse-producing districts of Pakistan. The objective of the situational analysis was to obtain detailed information to be able to address the project research questions:

1. What are the barriers to adoption of the proposed innovations for pulses?
2. Which agronomic practices, technologies, and available improved varieties can increase the productivity and profitability of chickpeas and lentils?
3. How to mitigate the effect of farm labour shortage on pulse production?
4. How to add value to lentil, chickpea, and groundnut crops at the village level?
5. How do we ensure the availability of a quality seed supply for chickpea and lentil growers?

Methodology

Fifteen farm families involved in growing pulses were selected at each site to form groups of collaborative research (GCR). These groups included researchers from local partner research institutes and the project team. In the first step of the situational analysis, a facilitation running sheet was developed in a workshop at the NARC with the help of project team members, including a representative from the partner research institutes working on pulse research in the pulses growing districts of Pakistan, Dr. Ata-ur Rehman, and Dr. Gavin Ramsay from Charles Sturt University, Australia. The facilitation running sheet included all topics to answer the project research questions. Three groups, including one facilitator and two note-takers, were constituted to discuss the facilitation running sheet with the members of farm families who were grouped into male, female and youth. The results were analysed and reconfirmed with each farm family during a subsequent visit.

The second part of the situational analysis was a detailed study involving individual GCR farm families at each site. The project team developed a detailed facilitation running sheet involving researchers from the Agricultural Economics Research Institute and Pulses Research Program of the NARC, provincial partner research institutes of Pakistan, and partners from Charles Sturt University, Australia. The project team and representatives of local partner research institutes conducted the farm-level situational analysis.

Results and discussion about the current status of farm-level value addition of chickpeas, lentils and groundnuts in light of the situational analysis

During both situational analyses, everybody complained about the instability of pulse market prices and the exploitative behaviour of intermediaries. When asked about value addition, most participants realized the importance of value addition but told the project team about various barriers. We will discuss the current status of value addition, opportunities at each project site, and socio-economic and other obstacles.

Site 1 (Attock) is a crucial chickpea and groundnut production district. As far as chickpeas are concerned, it is common practice to sell the crop at the green pod stage and after harvesting the mature crop in the form of grains. At the green crop stage, the crop is sold to a middleman who harvests the plant with green pods and sells it to the markets of Rawalpindi and Islamabad. After harvesting, the farmer sells the grain to brokers in the local market. They keep some grain for domestic consumption and for gifts to friends and relatives. The produce (whole grain) they keep for domestic consumption is consumed as curry or pulao. Daal (splits) and basin (flour) are purchased from local markets for domestic consumption. Groundnuts are harvested and dried for two days under the sun and sold to the local grain market. Part of the harvest is also kept for domestic consumption and gifts.

It is used as roasted nuts, especially during winter. This shows that there is no concept of value addition to chickpeas and groundnuts for commercial purposes at site 1. However, opportunities for value addition include grading, packing, branding, making daal, basin, and puffing for chickpeas. Groundnut value addition opportunities include grading, branding, roasting, and packaging. Some socio-economic barriers also exist, significantly impacting various aspects of this site. Generally, farmers face common barriers such as a lack of skills, time constraints, and the need for initial investments in machinery.

Furthermore, roasting or selling daal, flour, or puffing at the farm level is not considered socially acceptable. Selling groundnuts immediately after harvest without storing them for value addition is a common practice primarily influenced by the requirement of paying pending bills soon after the harvest.

The situation at site 2 (Chakwal) is similar to site one regarding chickpea and groundnut crops. Both these sites are also significant lentil-producing districts in Pakistan. Lentils are harvested when they reach maturity. Harvesting involves collecting the mature pods and separating lentils from the pods.

Farmers often sell a portion of the lentils to local grain markets as a source of income. The sale of lentils contributes to the economic well-being of farmers and supports the local agricultural economy.

Lentil crops are harvested after maturity, and grains are sold whole to local grain markets after reserving a portion of the harvested lentils for domestic consumption in curries served with rice or chappati. It's a common cultural practice to share a part of the harvest, including lentils, with friends, family, and neighbours to strengthen community bonds and support for one another.

Opportunities exist for value addition like grading, packing, roasting, and making splits, but most farmers do not pursue these options. One reason is that the production is usually deficient, and the economic circumstances of lentil-producing farmers are generally not good. So, they do not consider it feasible to invest in value addition.

Project site three is located in the Bhakkar district of Punjab, which contributes to about 90% of Pakistan's chickpea production, sown as a sole crop. It is a matter of great concern that value addition in this district is practised neither at the farmer nor commercial levels. Apart from the reason that most farmers have little knowledge of value addition, they are bound to sell their chickpea produce soon after harvest to the broker of the grain market from whom they take a loan for the crop production while saving some for domestic use throughout the year. Farmers cannot wait and store for value addition as they must pay off loans. Brokers in Bhakkar sell chickpeas in the Faisalabad city value addition markets such as split chickpea and basin (chickpea flour) production. Lentils are produced mainly for domestic consumption in one pocket of Tehsil Mankera in this district. So, opportunities for value addition are at the farmer and commercial levels. Although the middleman role cannot be eliminated in a village social system, there is still a need to educate farmers about financial management to reduce their dependency on the middleman.

Site 4 (Karak) differs from the other sites in many aspects, as farming is not the community's primary income source. The district ranks second when it comes to the literacy rate in Pakistan. Also, the underground water is unsuitable for agriculture, so agricultural enterprises depend solely on rainwater. So, the community prefers to send their children to schools to prepare them to work in big cities. Most of the population is in the service sector. There is no tradition of taking loans for crop production. This community has the leverage of storing and selling the produce when market rates are reasonable. Some people make splits at the domestic level using old grain mills, resulting in recovery losses and broken grain that could only be used domestically in making curries served with chapatti or rice pulao. There is a trend to use the chickpea plant's tender leaves as a vegetable.

Only a small quantity is sold at markets as farmers allow nipping by neighbours, relatives and friends. Making the fresh leaves available as a vegetable all year round is a value-adding opportunity. When farmers were asked why they did not install small machines for grading, splitting, and making flour, they said the availability of electricity in the area was unreliable. An alternative energy source would need to be available to enable value addition.

Farmers in the Chontra Valley of Karak grow groundnuts and sell the non-graded groundnut pods after drying for two to three days. However, some business-oriented people from other areas undertake the drying, grading, roasting, and packing of groundnuts, which are then sold in roadside stalls all year round, especially in the Lachi and Banda Daood Shah areas.

Only chickpea is grown at site 5 (Larkana) Sindh, using the residual moisture of rice crops. Farmers cultivate chickpeas for various purposes, and their versatile nature makes them an important crop. Chickpeas tender leaves, locally known as Palli, are considered a food from paradise. About 15 maunds of these tender leaves are hand-nipped in three separate nippings per acre per season. The middleman purchases it from the farm gate for 30 Rs per kg and sells it in urban markets for 80 Rs per kg. Although leaf nipping is labour-intensive, it is a good source of income for the farmers. Thus, making fresh green leaves available throughout the year is a value-adding opportunity for increased profitability. Traditionally, many people dry the leaves to cook them later, but the taste is not the same as fresh leaves. As for grains, most farmers do not add value to their chickpea crop, selling the produce to the broker in the market soon after harvest. The money earned allows them to purchase the inputs for the next crop and also pay off any loans incurred for domestic use.

The situation at site 6 (Jafferabad) Baluchistan is similar to site 5 (Larkana) Sindh. Farmers do not know value addition. The farming system is credit-based, and there is a trend to sell the crop immediately after harvest to pay off loans. So farmers do not store their harvested crops and wait for value addition. The use of the tender leaves of chickpeas as a vegetable is also practised in the area.

Recommendations

The situational analysis prompted the need to undertake the following value-addition activities on selected project sites:

- Production of cold press groundnut oil using oil production and quality determination
- Post-harvest storage of pulses and groundnut, quality determination over storage
- Chickpea split production, splitting performance and quality of different varieties
- Chickpea flour production
- Puffed chickpea, puffing performance and quality of different varieties
- Producing pulse bread-partial substitution of wheat flour with pulse flour
- Canned chickpea green leaves vegetable production

11.3 Appendix 3: Report on Workshop to impart industry specifications to Pothwar region peanut growers

Understanding specifications and standards relating to the peanut industry was the focus of a workshop organised by the ACIAR-funded Pulses Project in Pakistan. Industry representatives, including an R&D professional from English Biscuit Manufacturers (EBM), presented this information, and farmers showed a commitment to comply with best practices to try to meet the specifications. Good quality peanuts are pure with a moisture content below 7% and free fatty acids (FFA) of less than 1%. They must be aflatoxin-free with minimum physical damage to grains during post-harvest handling.

The project team engaged the procurement manager of EBM (Mr Faheem Khan) during his visit to Chakwal. The company imports 1000 metric tons of peanuts annually from China. They are looking for a local source of cheap peanuts of the same standard as they import. Peanuts need to be processed before they are ready for the industry.

Nuts and Legume Co., a Lahore-based company, processes local peanuts for international brands. However, according to the CEO, Mr Muhammad Raza, the company faced many issues in processing local peanuts until it helped build the capacity of a local peanut farmer/trader (Malik Yar Muhammad) in Chakwal. However, he said more peanut growers were needed to meet the increasing demands of the industry.

Farmers have been growing peanuts as a cash crop in the Pothwar region for centuries. Eighty-nine per cent of the total peanut crop grown in Pakistan comes from this region. Pakistan produces 115,000 metric tons of peanuts annually, with an average yield of 800 kg/ha. Most of it is consumed as roasted nuts during winter. As Pakistan produces 77% of its total peanut demand and consumers are not highly conscious of quality, the producers know that whatever they produce will sell easily in local markets. However, the industry is particular about quality standards.

The ACIAR Pulses Project has been working with peanut growers since 2017 to enhance their productivity. Thirty-four tons of quality seed of improved varieties were made available to 263 growers, and the National Rural Support Program (NRSP), an NGO, facilitated farmer-led standardisation and demonstrations of peanut production technology. The farmers involved in these demonstrations achieved a 23% increase in overall peanut yield.

At this point, the project facilitated the farmers' learning about the cold press extraction, filtration, packaging, and branding of peanut oil to improve their profitability. However, the farmers were reluctant to process their produce – there was a need for a processor to operate in the peanut value chain.

The ACIAR Pulses Project provided an opportunity to tie up some loose ends in the peanut value chain by bringing producers, processors, and buyers from the industry together to learn more about each other’s requirements. The project team took the initiative by organising a workshop at a local hotel in Balkasar, district Chakwal. People from industry, processors, farmers, academia, and researchers from different research institutes participated in the workshop. The procurement manager from EBM, Mr Faheem Khan, talked about the industry's requirements, and his R&D manager spoke in more detail to farmers about the specifications and standards required by the industry. He said high FFA was due to the high oil content of local peanut varieties, causing rancidity and thus reducing their shelf life. It was an interactive session where farmers shared their experiences about post-harvest handling issues and market behaviour. Mr Muhammad Raza from the Nuts and Legume Co. said his company added steps in peanut processing due to the matters faced with local peanuts. He said a higher level of contamination, especially aflatoxins and inert material like husks, etc., was a significant issue. Mr Faheem said he was ready to buy local peanuts if meeting the specifications. The Nuts and

Legume Co. asked EBM representatives to share their specifications and showed interest in providing them with peanuts for their requirements. Project farmers showed interest in linking themselves with this value chain if the project facilitates capacity building in the post-harvest handling of peanuts.

At the end of the workshop, EBM, Nuts and Legume Co., farmers, and researchers exchanged contact details. Take-home messages from the workshop included:

- The project should develop the capacity of farmers in the post-harvest handling of peanuts
- Linking project farmers to the Nuts and Legume Co. for providing quality peanuts
- EBM meeting with Nuts and Legume Co. to visit their processing facility at Lahore
- After understanding the requirements of the industry, researchers should focus on developing low-oil-content varieties

Appendix 3.2

PRESS RELEASE

One-day Groundnut Stakeholders Linkages workshop at PMAS-AAUR

A one-day Groundnut Stakeholders Linkages workshop was organised on March 14, 2023, by the ACIAR Pulses Project team at the PMAS-Arid Agriculture University Rawalpindi. The objective of this workshop was to liaise and link the progressive growers of groundnut, the traders and processors with the industry to promote and utilise the local groundnut produce, maximise the profitability of the growers, and provide local peanuts to the industry for value addition and minimise its reliance on imported peanuts.

The workshop was initiated with a recitation from the Holy Qur'an. The welcome and opening remarks were delivered by Dr Ata ul Mohsin, project coordinator of the AAUR component. He extended a warm welcome to the participants and all stakeholders of the project, especially the growers and industry partners. He shared the workshop's objectives and urged participants to get maximum benefit from the day. Dr Shaid Riaz, team leader of the pulses program, NARC, Islamabad, apprised the participants about the efforts made by the project team at the national level to increase the profitability of groundnut growers under ACIAR Pulses Project 041. Dr Ghulam Shabbir, Associate Professor of the PBG Department, highlights the need for networking and linkages of groundnut stakeholders and SMEs. A representative of the growers, Mr Muhammad Arif, shared the project's efforts to upgrade the growers' awareness level and capacity to enhance their profitability.

Mr Faheem Khan, CEO of English Biscuits Manufacturers, Karachi, shared his views with growers and local traders about linking the growers’ network with industry, focusing on its potential and prerequisites. He shared the marketing and procurement procedure by the industry and offered to buy the growers' produce in the required form with a good return. Mr. Hasan Bilgrami, CEO of Biomasdar Pvt. Ltd., shared his ongoing initiatives in the value addition and processing of groundnuts and other crops through his presentation. Dr Ata ur Rehman, the project leader at Charles Sturt University, Australia, shared his ideas with participants through Zoom. He said he was very grateful to all stakeholders for their participation in the workshop and urged project teams to work hard to make the networking of stakeholders a reality.

Prof Dr Qamar uz Zaman, the Vice Chancellor of PMAS-Arid Agriculture University Rawalpindi, urged the participants and industry partners to strive for solid and viable linkages of groundnut stakeholders for higher profitability in a win-win situation. He apprised the participants of the international value chain system and the benefits to international growers and the industry from this collaboration. At the end of the workshop, Prof Dr Zahid Akram, Chairman of PBG Dept. PMAS-AAUR thanked the participants for sparing their time and thanked the organising team for an exciting and inspiring workshop.


"Groundnut Stakeholders' Linkages Workshop"

11.4 Appendix 4: Report on Visit of ACIAR-041 Project team to Village Seed Bank at PD Khan, Punjab Pakistan

Title	ACIAR Pulses Project CIM 2015/.041
Date	December 19, 2018
Start time from Islamabad	09:30 AM
Place visited	Village Chak Hameed, Pind Dadan Khan (PD Khan)
Contact person	Mr Muzammil, Area Manager (PD Khan), NRSP

Travellers

Dr Shahid Riaz	Mr Israr Hussain

Purpose

To visit the village seed bank at Chak Hameed, PD Khan developed under the NRSP in collaboration with CIMMYT.

The project team visited the Kisan Ittehad Group's wheat seed bank in Pind Dadan Khan, Punjab, as one of the ACIAR Pulses Project's objectives is to develop and evaluate site-specific, village-based seed production and dissemination systems to increase farmer access to improved varieties. The goal of the visit was to become familiar with the village seed bank's operations, overlapping with the interest of the collaborating pulses farmers in Attock and Chakwal districts in creating a pulses village seed bank.
CIMMYT (Pakistan) and NRSP established the wheat village seed banks. CIMMYT provided basic seeds of six wheat varieties, namely Pakistan 2013, Zincol, Borlag, Ujala, Ahsan, and Dharabi, to 25 farmers through NRSP. NRSP builds capacity for farmers through formal and informal training for crop establishment, management, harvesting, post-harvest management, and storage. CIMMYT provides seed graders.

The Kisan Ittehad Group's wheat seed bank, established in 2016, has produced 600 bags of 50 Kg each. The bank also sells its seed to NRSP units in other districts of Punjab. Local farmers can purchase seeds at a price lower than the market price. The bank has a purchase committee comprising farmers who contributed to its establishment. The purchase committee visits the crop in March and April, selecting fields for seed purposes. The bank transports the harvested seed from the paddocks to the warehouse, selling it in October and November. Fifty farmers share the seed purchase for the bank, and if one farmer needs money urgently, the other farmer gives him money at a government support price at the time of harvest.

The seed bank also earns revenue by providing seed graders to other farmers on rent. Farmers shared their experiences with different wheat varieties and suggested the need for locally manufactured seed cum fertilizer drills for better crop establishment.
Later, the two groups of willing pulses farmers, one each from the Attock and Chakwal districts, were brought to the wheat village seed banks to gain hands-on experience in the seed bank operations. Consequently, these visits resulted in the formation of two Pulses Village Seed Banks. Each farmer group received two multi-crop seed cleaner graders from the project and offered training following a formal agreement with PMAS Arid Agricultural University to ensure continuity and expansion activities of the village seed banks after the end of the project term.

11.5 Appendix 5: Photos for Final Report CIM/2015/041

GCR farmers visiting chickpea varietal trial along with the project team at Mankera, Bhakkar

Scoring of chickpea varieties by farmers in a chickpea varietal trial at Karak

Situational Analysis for Improved Groundnut harvester

Meeting with NRSP for collaboration in dissemination of improved production technology of pulses

First meeting with Sayban at headoffice (Lahore) to engage for certified seed production

Meeting of project partners MNSUAM & AZRI, Bhakkar with Sayban Group of companies

Radio program to share project findings with local farmers (Larkana, Sindh)

Discussing outcomes of last chickpea season and planning for upcoming season in GCR (Larkana)

In an effort to link farmers to high end market-GCR farmer of Bhakkar displaying his farm produced-value added pulses during Pulses Mango Festival at centaurus mall, Islamabad

Chickpea-Peanut Festival at Centaurus Mall, Islamabad


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THE NEWS
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MULTAN: - Researcher Ms Penny from Australia cutting the ribbon to inaugurate plant centric meal competition at MNSUA.

Plant-centric food competition at MNSUAM

Visit of Australian farmers to Bhakkar

Farmer Field Day at Chakwal

Farmer field Day at Bhakkar

Training on identification and rouging of off type plants from chickpea field

Learning the seed certification process through FSC & RD

Glimps from farmer field day conducted at KARAK for chickpea growers

Situational analysis with SRSO farmers at Larkana, Sindh

Event to handover seed grader to village seed bank (Kot Sarang)

Training of farmers for seed grader operation by the manufacturer

Meeting with Director Agricultural Research, KPK

Seminar on World Pulses Day at Larkana

	
Workshop on digital value chains for pulses farmers	**Groundnut stakeholders linkages workshop at PMASAAUR**

	
FGD with female households of pulses farming families of SRSO at Dhokri, Sindh	**Talking to Mr. Mehboob Mastoi from FSC & RD at seminar for exposure of farmers to new chickpea varietis at Sohbatpur, Baluchistan**
	

<table>
<tr><td>Project team assessing on farm groundnut issues at farmers' field day</td><td>Seminar at site 5 for improved chickpea production technology</td></tr>
<tr><td></td><td>
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<tr><td>FFD at Karak</td><td>FFD at Sohbatpur, Baluchistan</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Expansion activity with SRSO farmers, Sindh</td><td>Demonstration of low-cost efficient irrigation system for chickpea at Mankera, Bhakkar</td></tr>
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<tr><td colspan="2">Workshop to link groundnut growers to industry</td></tr>
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Participation in ACIAR Pulses Value Chain Project Event at Karak, KPK

Situational Analysis for Farm Level Pulses Value addition

Participation in ACIAR Pulses Value Chain Project Event at Bhakkar

Demonstration of multicrop seed/fertiliser drill at site 3

Demonstration of improved groundnut digger inverter

Showcasing work under ACIAR Projects at Agriculture Expo, Lahore, Punjab

Workshop on chickpea value chain demonstration at Lawa by ACIAR Pulses Value Chain project

Workshop on organic chickpea production at Bhakkar

Understanding the impact of reseach on life of female households of pulses farming families