Charles Sturt University

Gulbali Institute
Agriculture Water Environment

Summary of Co-Inquiry Research Experiences with Salinity-Affected Jalalpur Farming Communities

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Research commissioned by the
Australian Centre for International Agricultural Research (ACIAR)

Cataloguing in Publication provided by the Gulbali Institute – Charles Sturt University, Albury, NSW 2640.

Faried, H. N., Ahsan, M. B., Baig, I. A., ul-Haq, T., Mohiuddin, I., Riaz, M. F., Sarfraz, B., Raza, N. (2024). Summary of Co-Inquiry Research Experiences with Salinity-Affected Jalalpur Farming Communities. Gulbali Institute, Charles Sturt University, Albury, NSW.

1 volume, Gulbali Institute Report No. 9

ISBN: 978-1-86-467461-3

Project	Adapting to Salinity in the Southern Basin (ASSIB)
Funding Research Program Project No.	Australian Centre for International Agriculture Research, Australia Land and Water Resources (LWR) LWR-2017-027
Project Team	Charles Sturt University (CSU) Commonwealth Scientific Industrial and Research Organisation (CSIRO) Ecoseal International Center for Biosaline Agriculture (ICBA) International Union for Conservation of Nature, Pakistan (IUCN) Mehran University of Engineering & Technology (MUET) MNS University of Agriculture, Multan (MNSUAM) Murdoch University Society of Facilitators and Trainers (SOFT) University of Canberra

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Executive Summary

Increasing salinity in water and soil is one of the challenges that irrigated agriculture is facing across the globe. These problems are experienced most acutely in the southern part of the Indus Basin, an area which also contributes predominantly to ensuring food security for the rapidly growing population of Pakistan. Over several decades, the Government of Pakistan has invested billions of rupees in projects designed to control the salinity issue; however, the desired results could not be achieved (Ali, 2023).

Through the current ACIAR-funded Adapting to Salinity in the Southern Basin (ASSIB) project, a new approach was adopted by the project partners. The focus of the new approach was to 'live with salinity' by adopting a systematic approach of Stakeholder Engagement for Research and Learning (SERL) (Heaney-Mustafa et al., 2023), involving a purposeful collaborative inquiry (researching and learning together). This co-inquiry enabled a range of stakeholders interested in managing, say, water, to encounter differing points of view, to maintain momentum when there is difference and uncertainty, and to design ways for improving the situation.

The project approach builds on an assumption that, for farmers to live productively with salinity, they need to explore changes in farming practices, which are best initiated and investigated through a process of co-inquiry drawing on local farmer knowledge and on-ground experience. Our project's co-inquiry involved an interdisciplinary research team from the Muhammad Nawaz Shareef University of Agriculture, Multan (MNSUAM), and a team from the Society of Facilitators and Trainers (SOFT) specialising in farmer-to-farmer facilitation and learning, to explore how farmers could adapt productively to the salinity conditions affecting their properties. The researchers interacted with the farmers in response to suitability of advice they provided on crop cultivation and to assess how the experiments were helping to improve livelihoods. This feedback and evaluation from farmers played a crucial role in shaping the research process and ensuring its relevance and effectiveness.

The Jalalpur area comprises mostly small and a few medium-sized farmer landholdings. Landlords operating larger landholdings are mostly absentee as the town lacks good quality civic amenities. Two villages near Jalalpur (Basti Kulab and Meerkot) were selected as "bright spots" using a set of criteria to assess their communities' potential to co-create salinity adaptation interventions. A key criterion was their potential to link in with and benefit from a network of researchers and agricultural service providers.

During the process of SERL, the combined team of experts, service providers and farmers have been able to prioritise 'interventions' that would enhance both sustainable management of resources and farming family livelihoods. Community desire to engage with external experts to collectively address challenges and develop sustainable solutions led them to be engaged in on-property experimentation. Several alternative experimental interventions were prioritised and supported through detailed soil and water sampling and analysis. These interventions included vegetable raising through nurseries, kitchen gardening, raising crops using multiple types of mulches, introduction of salinity tolerant grasses, improved orchard management, vertical vegetable cropping and developing new value-added products.

An encouraging and highly successful aspect to the experimentation was collaborative planning and execution of several outcomes-based on-farm trials involving women and nursery transplantation of vegetables (okra and onion) into fields and kitchen gardens. These trials had the added benefit of improving family access to nourishing foods and as an income supplement. The effectiveness of the approach became evident when other women community members in the area willingly adopted the improved vegetable production system. Similarly, the approach has also exerted positive behavioural changes not only in the rural community but also in the researchers themselves. These researchers delighted in witnessing the success of collaborative learning and effectiveness of farmer field experimentation processes with the support of experts and community mobilisers. Stories of change have documented these aspects very well (Allan et al., 2024).

The project partners have also started to explore how to sustain the project interventions. The teams worked with the communities to help them identify community-based volunteer farmers who would act as trainers / facilitators. The teams have also developed easy-to-understand, pictorial materials introducing recommended on-farm salinity management practices and conducted hands-on training events to further enhance capacity of farmer-to-farmer facilitators able to scale-out successful interventions.

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1. Introduction

Pakistan, highly vulnerable to climate change, is experiencing severe consequences that directly affect its natural resources. One significant issue is secondary salinisation, which is escalating at an alarming rate. The Indus River system, depositing approximately 1.25 tons of sediment per hectare annually, has led to soil and water salinity affecting nearly 6.8 million hectares. About 70% of tube wells pump saline-sodic water, exacerbating the salinity issue (Ali, 2023; Saiqa et al., 2022). The salinisation of water and soil poses a significant threat to the sustainability of irrigated agriculture and the livelihoods of farmers, particularly smallholders in the Indus basin. Consequently, the restoration and proper management of saline-prone soils are critical to meet the food, fibre, and feed demands of a growing population, especially given the current trend of shrinking cultivable land due to expansion by non-agricultural sectors.

Over many decades, Pakistan has invested heavily in various mega projects targeting land and water reclamation solutions. However, the outcomes have often been disappointing and unsustainable, largely due to inadequate facilities and insufficient post-project maintenance and operation, compounded by disruptions in salt balance (Qureshi et al., 2008; Ali, 2023). Therefore, it is crucial to involve farmers from the design through to the execution and maintenance phases, focusing on interventions that directly enhance community income and benefits, such as mulching and raised bed planting (Zaman and Ahmad, 2009; El-Beltagi et al., 2022). Additionally, the strategy should be better integrated with the dynamics of the existing social-ecological system, involving local farmers who possess a deeper understanding of local institutions and their functionalities. Consequently, a consolidated approach should be developed based on on-farm salinity management practices. This approach should be formulated in consultation with the farming community and subsequently disseminated widely (Ashraf et al., 2022).

To ensure effective engagement of farmers in our project's on-property salinity adaptation investigations, we created and used the Stakeholder Engagement for Research and Learning (SERL) approach (Heaney-Mustafa et al., 2023). SERL comprises three phases towards the development of an ongoing cycle of co-inquiry research: pre-research (so that researchers develop an understanding of local prior to their active engagement with farming communities), workshop (to facilitate problem identification, generate solution ideas, and refine them as research action plans), and implementation (integrating research action, evaluation and reflection, thus leading into a new cycle workshop and implementation). Transdisciplinary, systems-focused collaborative research and action is an increasingly acknowledged pathway for negotiating complex social-ecological issues (Ison, 2010: Alonso et al., 2019). The collaborative turn in many areas of governance and management recognises multiple knowledge and ways of knowing (see, for example, Deserti et al., 2021). Involving citizens in shaping managing and governing also enables them to question the aspects of power, risk, and accountability (Dormer, 2014). Purposeful collaborative inquiry (researching and learning together) enables a range of people interested in managing, say, water, to encounter differing points of view, to maintain momentum when there is difference and uncertainty, and to design ways for improving the situation (Steyaert & Jiggins, 2007). Co-inquiry can, for example, bring on-ground managers such as farmers and academic researchers together to share understandings and co-create innovations (see, e.g., Mackay et al., 2013). While co-inquiry can be powerful and effective, it often also encounters challenges that need to be navigated (e.g., Turner et al., 2020).

In this regard, the Australian Centre for International Agricultural Research (ACIAR) in cooperation with national and international organisations/ institutes developed a project titled "Adapting to Salinity in the South Indus Basin" (ASSIB) to investigate the adaptation options for farming communities living in salinity affected landscapes, and thus enhance their adaptive capacity. The ASSIB project encompasses three interconnected research domains. First, it aims to enhance a multi-scale understanding of salinity in the southern Indus Basin landscapes. Second, it involves collaborative inquiry into salinity adaptation strategies with affected communities. Third, it endeavours to demonstrate best practices for collaborative research that bolster community adaptive capacity. Broadly, the studies were carried out based on the co-designed co-inquiry concept of a staged process containing formative, participatory, and action research drawn on local farmer knowledge and on-ground experience including vegetable cultivation.

Sustainable involvement of the communities in these interventions / strategies also requires us to investigate efficient market access and free integration of supply chain actors. The salt-affected areas face challenges in accessing markets due to the perceived lower quality of their produce and lack of precise market linkages. Addressing these barriers is essential to ensure that the benefits of improved cultivation practices reach the farmers without undue leakages and contribute to their livelihood. By adopting collaborative efforts with the farming communities, the project sought to identify and promote sustainable practices adaptive to unique challenges posed by salinity and climate change, ultimately fostering resilience and livelihood sustainability in the region.

The overall objective of these co-experiments was to test various crop (field crops, vegetables, orchards) and on-farm management strategies (high density and vertical cultivation with mulch) and to explore value chain forward links (for okra, pomegranate and Moringa in particular) with communities managing salinity in salinity-affected areas of the Jalalpur Pirwala, South Punjab, Pakistan.

Jalalpur Pirwala (or Jalalpur for short) is a sub-division of Multan district situated around 90 kilometres south of Multan. It is an agricultural area near to the Chanab River in the east and Sutlej River to the west. Sitting at the tail of the canal system of Punjab, the area has been severely deprived of surface irrigation water, which means farmers in the area rely heavily on groundwater to enable agriculture intensification (a phase that was especially pronounced during the 1980s). Use of groundwater has led to secondary salinisation, especially as depleting groundwater levels mean farmers need to pump from deeper levels, where the groundwater becomes increasingly saline.

Jalalpur consists of nine union councils and a population of around 500,000 people, almost all of whom are rural dwellers. Four of Jalalpur's union councils have been badly impacted by salinity. Based on criteria developed to characterise the project's 'bright spots' during the project initial meetings, two village communities (Basti Kulab and Basti Meekot) were selected with whom co-inquiry investigations would be pursued as ASSIB project interventions.

Local farmers are well placed to understand how that system functions where they live and work and can thus contribute to the design of appropriate salinity adaptation interventions. Our project is thus part of a larger research agenda exploring how to build farmers' adaptive capacity, using the framing of co-inquiry.

2. Methods

The ASSIB research team adopted a co-designed co-inquiry approach (SERL) with all 'bright spot' communities who engaged with the project and became part of the team. Such an approach was recognised as an effective way to pursue relevant investigations with these communities, keeping in view the diverse and increasing salinity threats (secondary salinisation), reducing surface water availability, small landholdings (<5 acres) involved, often single crop dependency (e.g. wheat), low crop yields, and the marginalised and impoverished character of the communities involved. The selection process for identifying 'bright spot' communities included those who showed evidence of successfully adapting to salinity-induced challenges, willingness of partner organisations to engage in collaborative research, logistical feasibility, evidence of community-driven adaptation efforts, and potential for engaging women and youth in research activities.

2.1. Research Area

The Jalalpur area (see Figure 1) comprises mostly small farm landholdings. Two villages near Jalalpur (Basti Kulab and Meerkot) were selected as 'bright spots' based on an assessment of their communities' potential to co-create salinity adaptation interventions. The aim was to encompass various contexts and adaptation strategies across the selected Jalalpur communities. Surface water supplies are unreliable, sometimes lacking, with minimal recharge contribution to groundwater, while also forcing farmers to often rely on the locally highly saline groundwater to irrigate their fields. A key aspect was their potential to link in with and benefit from a network of researchers and agricultural service providers. Only a few farmers were adopting recommended on-property salinity management practices.

The traditional knowledge of farming communities can be enhanced through engagement with outsiders to find better ways to address the soil and water salinity issues they are facing. Our project's co-inquiry involved an interdisciplinary research team from the Muhammad Nawaz Sharif University of Agriculture, Multan (MNSUAM). This team collaborated with a team from the Society of Facilitators and Trainers (SOFT), a non-government organisation specialising in facilitation to enable farmer-to-farmer learning, to establish co-inquiry research investigations with farmers to explore how they could adapt productively to the salinity conditions affecting their properties. We drew on a participatory research process SERL, which involved workshops where key issues faced by the communities were identified, leading to a set of co-designed research action plans to address them. Local agricultural government officials were also involved in the workshops to contribute to the design and implementation of these plans.

Basti Kulab & Meer Kot: Basic data
Coordinates:
Longitude: 71.21-22 ˚E
Latitude: 29.58-59 ˚N
Climate:
Arid, annual average rainfall: 54 mm.
Temperature range: 12-45.5 ˚C
Cropped Area: 4,650 acres.
Highly Saline: 800 acres
Irrigating Canal:
Alipur minor (6 monthly canal)
Salinity Levels:
Soil ECe* range: 6-38 dS m^{-1}
Groundwater ECiw** range: 3-8 dS m^{-1}
*ECe: saturated soil extracted water EC
**ECiw: irrigation water EC

2.2. Engaging Communities in the Experiments: SERL Research Process

The SERL methodology (Heaney-Mustafa et al., 2023) involves three main phases: pre-research, workshop, and action with evaluation and reflection. The pre-research phase is necessary to overcome imprecise problem identification by ensuring researchers develop an improved understanding of the context and challenges faced by farming communities. This included stakeholder analysis to identify relevant participants and gather preliminary data on the socio-economic and institutional contexts, as well as past agricultural practices. Pictorial data collection, such as asking participants to take photos depicting their lives, was also used to engage the community and inform workshop discussions.

The first SERL workshop was held with the Basti Kulab community on 26-27 July 2021. Its design consisted of two processes: a convergent process where information was shared and problems were identified, followed by a divergent process where ideas for research action were refined, assessed, and articulated with assigned responsibilities. The SERL workshop and farmer's meeting took place at the farm of a key resource person from Basti Kulab, who played a leading role in guiding the co-inquiry activities of the ASSIB project.

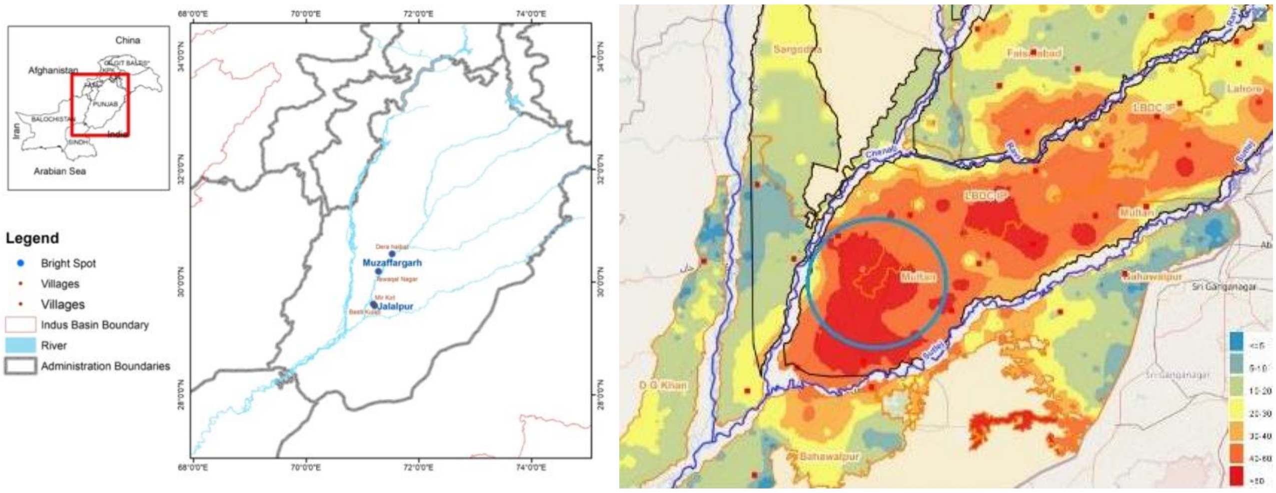

Figure 1. Maps showing (left) Location of South Punjab ASSIB bright spots and (right) Groundwater depth in the area

(Source: ASSIB using 2023 data provided by the Punjab Irrigation Department)

A gentleman from Meer Kot, who was also working as an operator of Laser Land Leveller, participated in both the SERL workshop and the capacity-building training on vegetable nursery raising. Impressed by the successful experiments conducted in Basti Kulab, he expressed his keen interest in engaging with ASSIB activities and eagerly embraced the co-inquiry process. Following an initial survey and adherence to the ASSIB site selection criteria, the ASSIB team commenced their work in Meer Kot. Therefore, a second SERL workshop was held with the Meerkot community, who had come to know about the activities at Basti Kulab. This workshop was held on 31 March and 1 April 2022. The series of workshops started at Meerkot extended until March 2024 due to the continuous interest and engagement of the community and one of the community member Haji Hanif volunteered himself to act as a 'farmer facilitator'.

Figure 2. SERL workshops showing women and men developing actions plans

These workshops (see Figure 2) were typically conducted over two days to allow for reflection and refinement of ideas. The research and action phase were implemented as a co-inquiry process involving farmers, researchers, and other stakeholders. Facilitators played a crucial role in facilitating this co-inquiry by regularly meeting with farmers to document progress, reactions, and learnings. These insights were shared with all stakeholders and used to guide subsequent workshops and actions. Overall, SERL provided a framework for collaborative problem-solving and knowledge co-construction, ensuring that all stakeholders were actively involved throughout the research process to achieve adaptive and sustainable changes in agricultural practices. Additionally, stories of change are collected and evaluated using a tailored version of the Most Significant Change (MSC) method (Allan et al., 2024). This participatory approach involves regular collection and assessment of narratives from project participants. The process includes participatory coaching, development of research questions, co-creation of narratives, ongoing review, and analysis of emergent themes. Technical data was collected by the research team to assess overall cropping seasons of implemented experiments.

The project's community engagement team, researchers and farmers worked collaboratively throughout the research process, from identifying research questions to analysing and interpreting results in terms of their implications as adaptive salinity management strategies (e.g. experimenting with crop varietal evaluation, mulching, raised beds, high density and/or vertical cultivation, kitchen gardening) for different field and horticultural crops.

2.3. Community-Led Experiments to Improve Productivity for Salinity Affected Properties

A range of experiments emerged through the SERL co-design process that farmers identified and 'owned' – these were conducted on the properties of farmers who had registered interest in such co-inquiry collaborations. Their range reflects the diversity of conditions and problems prioritised by participating farmers.

2.3.1. Community-Led Vegetable Cultivation Experiments

Increasing soil and water salinity along with higher temperature and evapotranspiration in the arid climate of Jalalpur, have been negatively affecting the vegetables (e.g., cauliflower, onion, cucurbits, etc) production. Therefore, the ASSIB team organised SERL workshops to discuss in the detail the issues followed by the possible solutions from farmers perspective. In this regard, composite soil and water samples were collected from the vegetable experiment site (0–12-inch depth) followed by a detailed analysis as per the recommended methods (Jackson, 2005). The soil was classified as saline-sodic (EC = 6.7 dS m^{-1}, pH = 8.21, SAR = 15.45, Na^+ = 68.3, Ca+Mg = 38.75 and Bicarbonate = 10.03 meq L^{-1}) and sandy loam texture. The water was declared unfit (EC = 3.7 dS m^{-1}, SAD = 6.33, Na^+ = 19 and bicarbonate = 7.58 meq L^{-1}).

Nursery Raising for Healthy Seedling Production

Seed germination and seedling stages are sensitive to salinity stress. Therefore, the ASSIB team in collaboration with co-researcher farmers established co-inquiry trainings events to share knowledge about healthy nursery production in plug trays by using peat moss (see Figure 3).

Figure 3. Healthy seeding production in plug trays filled with peat moss

The required material included quality water, peat moss, plug trays, seeds, and a shower. Peat moss provides a sterile, absorbent, and slightly acidic medium ideal for seed germination and root development. Media was prepared by adding water into peat moss and mixed appropriately by gradually adding the water until it was thoroughly moistened. Additionally, fungicide (e.g. Topsin M (Thiophenate Methyl) @ 2 g/l) was added to avoid an early attack of the pathogen on germinating seeds. The moistened growing media was added to seedling (plug) trays (540x280 mm) containing segmented plugs of different sizes to grow the seeds individually. The media was firmly pressed in trays followed by seed sowing and covering seeds with media (2-3 times of seed size). Lastly, plug trays were covered with black polythene to sustain temperature, and avoid evaporation and drying of media till germination. Furthermore, the farmers were guided to adopt regular watering of growing media, ensure appropriate nutrition (addition of 0.5, 1, and 1.5 g/litre NPK (20:20:20) during 2-3, 4-5 and 6-7 leave stage, respectively) provision of 6-8 hr light after emergence. Additionally, the seedlings were hardened (reducing watering 48 hrs before transplanting followed by irrigation before the transplantation process) to avoid transplanting shock. Therefore, the farmers were trained to produce a healthy nursery at the household level followed by transplanting into the field for appropriate growth and development.

Raised Bed Vegetable Cultivation under Mulch

Raised bed cultivation of the vegetables with improvised design was also carried out as one the production practice for better resilience against salinity. The cauliflower seeds (cv. CFL-1522 F1 by Syngenta) were sown as per detailed above during the 3rd week of September followed by transplanting during the 4th week of October. The nursery was transplanted at the experimental site (290 m^2, 24×12 m) with the plant (P×P) and row (R×R) spacing of 0.3 and 0.91 m, respectively (Figure 4A). The raised beds were developed a bit upright from the centre. Organic (3–4-inch rice straw) and black poly (4 gauge) mulch was applied in a way that it covered a 9-inch bed top and 6-7 inches inside of the irrigating furrow to avoid build-up of salinity within the crop rootzone, to reduce rhizosphere temperature fluctuations and evaporation (Fig. 3.1-A). The data for leave weight (wt.), shoot fresh wt., root fresh wt., potassium (K^+), sodium (Na^+), and calcium (Ca^{2+}) ions, Total Chl. and phenolic contents, superoxide dismutase (SOD), catalase (CAT), peroxidase (POX), 2,2-Diphenyl-1-picrylhydrazyl (DPPH), fruit wt., and yield attributes were collected followed by harvesting (4th week of February) and data analysis.

High-Density Cultivation under Mulch

High density cultivation experiment of the suitable vegetables was another outcome of the SERL workshops that was successfully conducted at the farmer field. The onion seeds (cv. Phulkara, open-pollinated) were sown during the 2nd week of October and transplanted during the 1st week of December. The raised bed was fully covered with organic (3–4-inch rice straw) and black poly (4 gauge) mulch including a 5-6 inch inside of irrigation furrow followed by transplanting with the plant (P×P) and row (R×R) spacing of 4 inches (0.091 m) (Figure 4B). Harvesting took place during the 4th week of April. Data for SOD and CAT activities, Na^+, K^+, phosphorus, total irrigation, fruit number and bulb yield were collected for further analysis.

Vertical Cultivation of Vegetables with Mulch

Hybrid seeds of sponge gourd (cv. Green Star F1 by Rachana Seed), ridge gourd (cv. Special F1), bitter gourd (cv. Sakuna 208 F1 by Chia Tai Seeds) and bottle gourd (cv. Akash F1 Millan Agro. seed) were purchased from a local market seed dealer. The soil was prepared as raised beds (8 ft) with organic mulch application (10-12-inch top bed and 7-8 inch inside row covering) followed by direct seed sowing into the beds during the 4th week of February with the plant (P×P) and row (R×R) spacing of 15 and 60 inches, respectively (Figure 4C). Black poly mulch was not used during the summer vegetable (gourd) cultivation due to higher summer temperatures. Crop harvesting started in May and continued until September. The data for SOD and CAT activities, Na^+, K^+, phosphorus, total irrigation, fruit No. and bulb yield was collected followed by harvesting (4th week of April) and data analysis. The sample and data were collected for Na^+, K^+, and Ca^{+2} ions, total irrigation, yield, and income followed by data analysis.

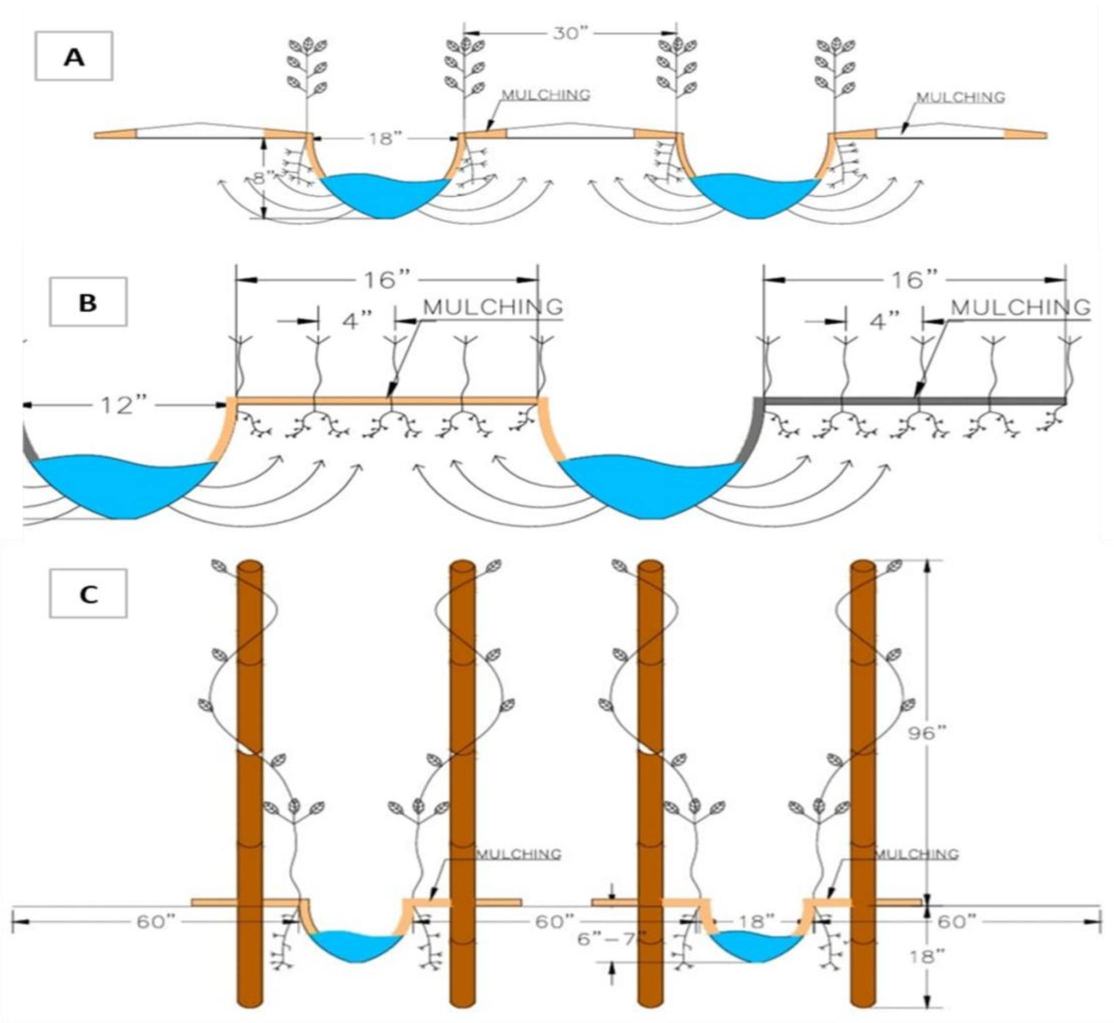

Figure 4. Crop layout and cropping geometry for mulching trials

2.3.2. Orchard Floor/Canopy Management and System Thinking Approach for Pomegranate Value Chain

Pomegranate is a commercial crop with higher salinity tolerance and less water requirements. Its cultivation has been increasing in the saline areas including by bright spot community farmers of the Jalalpur area. However, higher soil and water salinity along with poor crop production and protection management practices have negatively affected the crop. The farmers involved highlighted these issues and suggested possible solutions as part of the co-inquiry co-design process. The ASSIB team responded by arranging a visit with experts to one of the pomegranate orchards involved. Some mismanagement of the orchard was identified, including those leading to attack of various diseases like Bacterial Blight (Hadda) and Cercospora fungus (Chitri), pests (fruit fly, mites, thrips, termites), as well as extensive growth of off-shoots, suckers, and outbreaks of Parthenium weed. Reduced air circulation further aggravated the quality of fruit. Limited canal water and use of saline groundwater reduced pomegranate growth, productivity, and quality. A year-round crop calendar was thus developed by the ASSIB co-inquiry team.

An analysis of different segments of the pomegranate value chain was performed by adopting the value chain analysis and system thinking approach. This involves fostering synergy between different value chain actors to increase the benefits for each actor by minimising unequal distribution of margins between value chain actors. While focusing on the whole of chain approach, consumers' perceptions should be taken as a priority in determining what is valuable. Primary data were collected by different actors (4-5 each) of the value chain and 25 consumers using a semi-structured questionnaire designed for growers and consumers and interviews conducted with wholesalers/commission agents and retailers. Different open and close ended questions were used to explore challenges and opportunities across the value chain. Participants were free to choose responses to express their opinions verbally or in written form.

2.3.3. Value Chain Adding Strategies for Saline Commodities

A participatory value chain analysis and development strategy was created to engage the Jalalpur communities in line with and inspired by the co-design and co-inquiry research process. The Jalalpur communities came to realise that they had been wasting the leaves of the Moringa tree while selling flower buds to a pre-harvest contractor. Instead of letting the leaves waste on the ground, formal and informal discussions were carried out with farmers to raise awareness about the economic significance of Moringa leaf powder. During workshops, co-design methods led to adoption and motivation to initiate leaf powder production and to grow more Moringa trees to reap benefits from the local market as well as emerging ecommerce stores in metropolitan cities. The ASSIB team provided technical guidance and support throughout the process by engaging experts from industry, addressing challenges faced by farmers in production, such as fungal contamination, dust and improper drying techniques. Similarly, various value addition trainings to increase the shelf life of products (vegetable pickles, date jam and garlic paste).

2.3.4. Suitable Crop Selection on Saline Lands

Farmers were also concerned to have better crop variety selection for salinity affected areas. As an outcome of the SERL workshop, a salt-affected field was chosen at the farm of Haji Arif, Basti Kulab, Jalapur Pirwala. Soil samples were taken from the experimental area on a 5.0 x 5.0 m grid at two depths, 0-15 cm and 15-30 cm, before sowing the crop. The soil chemical analysis was done by standard methods (Richards, 1954). The ECe of the experimental area ranged from 5.0 to 13.0 dS m-1 and SAR from 8 to 12.0.

The soil was slightly alkaline with an average pHs of 8.10 ± 0.5. By keeping in view the soil analysis, a preferred layout was developed, and the crop was sown in the furrows of the furrow ridge system. The land was prepared, and the canola crop was sown on 18 November 2021 and harvested on 8 April 2022. However, the ideal sowing time of the canola crop is the 2nd week of September. The wheat crop was sown on ridges with the hypothesis that ridge sowing conserves water by minimising water runoff and optimising water penetration into the soil.

To explore crop production on saline lands, three farmers expressed interest to experiment with canola on their marginal lands. A plan was developed, and the first canola crop was sown on the farm of Haji Arif, at Meer Kot, Jalalpur during Rabi 2021-22. The seed of Canola Hybrid HC-022B, Hybrid-F1 was purchased from the company and planted on an area of one acre. The canola seed was broadcasted within the furrows followed by pushing in the tree branch on the surface of soil to improve contact between seed and soil.

To understand the performance of different cotton varieties in saline soils, five specific varieties – some known for their tolerance to salinity – were cultivated. This was undertaken with the aim of identifying cotton varieties that could perform best in saline conditions, thus offering farmers more resilient options for cultivation in such environments.

The experimental data on the number of grains per pod and grain yield in kg per hectare was recorded after harvesting the crop. The average number of grains per pod were recorded randomly by crushing the pods from the 10 plants and manually counting the grains in one pod. However, for the total grain yield, all the crop was threshed, and weight was taken through weighing scale.

3. Results

In following sections, key findings of the experiments are presented showing significant impacts from our processes involving community engagement enabling community led experiments leading to improved benefit-cost ratios and income for the farmers involved.

3.1. Community-Led Vegetable Cultivation Experiments

Vegetable productivity in Jalalpur has been affected negatively by the soil and water salinity that further aggravated by the arid climate. However, application of mulching on a raised bed helped induce salt tolerance in cauliflower, onion, and gourd (bottle, sponge, bitter, and ridge gourd) vegetables. The cauliflower, onion, and gourd vegetables consumed 35%, 44%, and 27%, respectively, less irrigation water under organic mulch compared to non-mulch saline growing conditions (Figure. 5). Similarly, organic mulching enhanced 37%, 31%, and 26% yield of cauliflower, onion, and gourd vegetables, respectively compared to non-mulch saline growing conditions (Figure 5). Besides, organic mulching increased the potassium (K^+) uptake in the leaves of cauliflower (40%), onion (28%), and gourds (45%) while decreased the sodium (Na^+) absorption in the leaves of cauliflower (31%), onion (49%) and gourds (42%) compared to non-mulch saline growing conditions (Figure 6 A-F). Hence, the farmer achieved about 39%, 44%, and 26% higher income from cauliflower, onion, and gourd vegetables, respectively when grown under organic mulching relative to non-mulch saline growing conditions (Figure 7 A-C).

The crops grown in arid to semi-arid climates (e.g. Pakistan) require higher water delta that groundwater fulfills. Higher soil and water salinity negatively affected vegetable cultivation in the arid climate of Jalalpur. Based upon the positive impacts of mulching in crop production under an arid saline growing environment like Jalalpur, the ASSIB team planned and executed the mulching experiments through SERL in collaboration with co-researcher farmers. Mulching on a raised bed helped induce salt tolerance through water conservation (Figure 5 A-C) and reduced ionic accumulation (Figure 6 A-F) in the rootzone and growing plants, thereby higher yield (Figure 5 D-F) and income (Figure 7 A-C). Mulching induces salt tolerance (Caruso et al., 2019) by sustaining optimum soil temperature, reducing salt accumulation, and moisture loss (evaporation) from the rhizosphere, thereby helping sustain crop yield compared to non-mulch (Zhang et al., 2008; Dong et al., 2009; Aragüés et al., 2015; El-Beltagi et al., 2022). Moreover, organic mulching enhances soil fauna, nutrient cycling, and availability (El-Beltagi et al., 2022). Additionally, mulching decreases upward ionic (e.g. Na^{+1}, Cl^{-1}) movement and reduces salinity causing ions competition with nutrients. Hence, higher uptake of nutrients (e.g. K^{+1}) and crop growth (Abd El-Mageed et al., 2016). Similar results were observed in current studies where mulching decreased the irrigation requirement (Fig. 4.1A-C), increased K^{+1} uptake, and reduced the Na^{+1} build-up within the growing vegetables (Fig. 4.2A-F). It resulted in higher production (Fig. 4.1D-F) and farmers income (Fig. 4.3A-C) compared to non-mulch saline growing conditions. Positive mulching impacts are also found in various crops including broccoli (Jasim and Merhij, 2013), tomato (Saeed & Ahmad, 2009), squash (Abd El-Mageed et al., 2016), bitter gourd (Haque et al., 2023) and cauliflower (Okasha et al., 2022).

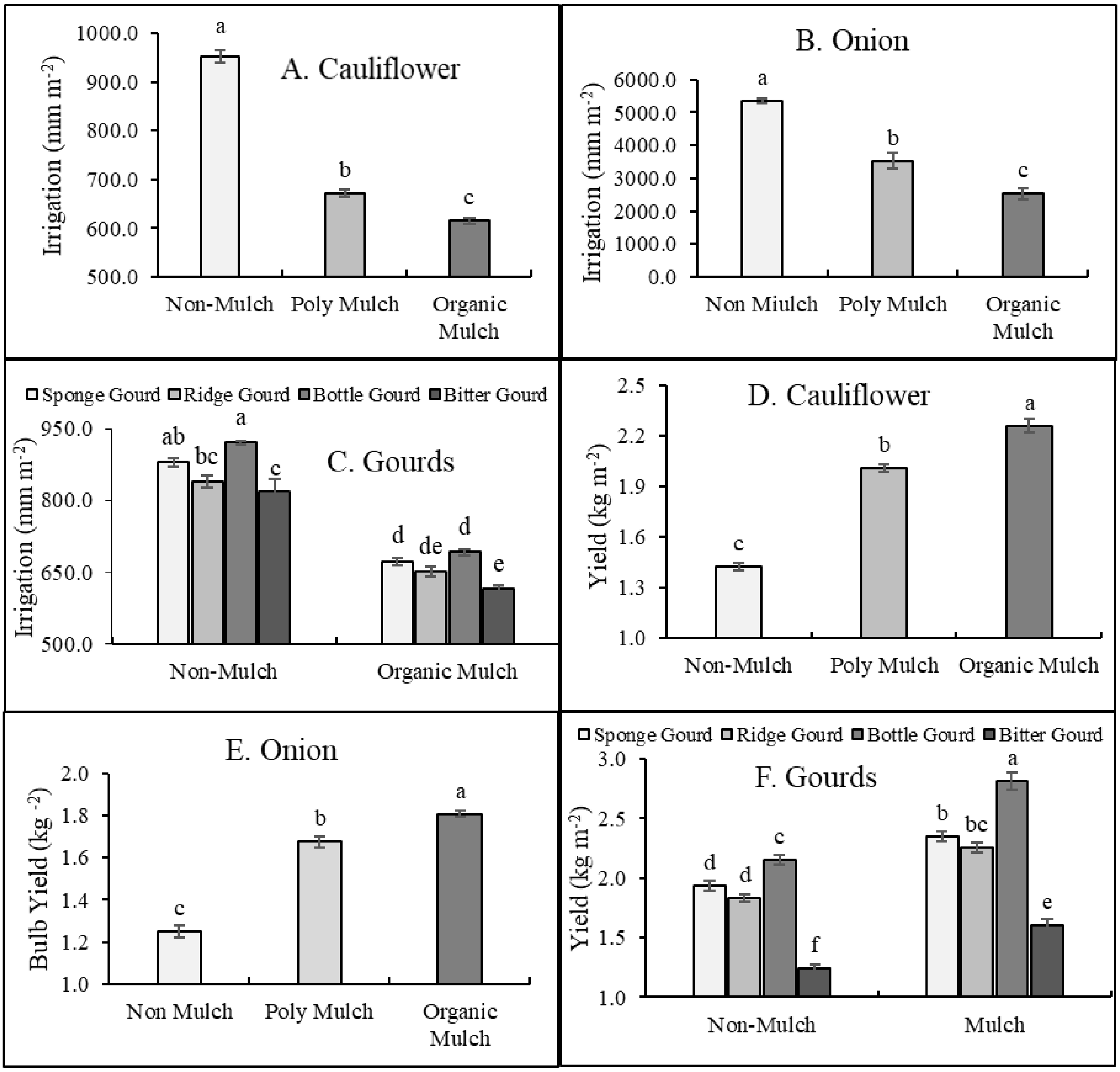

Figure 5. Impact of mulching on cauliflower, onion, and gourds' irrigation (A, B, C) and yield (D, E, F) under saline growing conditions

Each value in the above figures is a mean of 3 replicates.

HSD (Tuckey Test) for crop x treatment was significant at $p \leq 0.05 \pm$ S.E

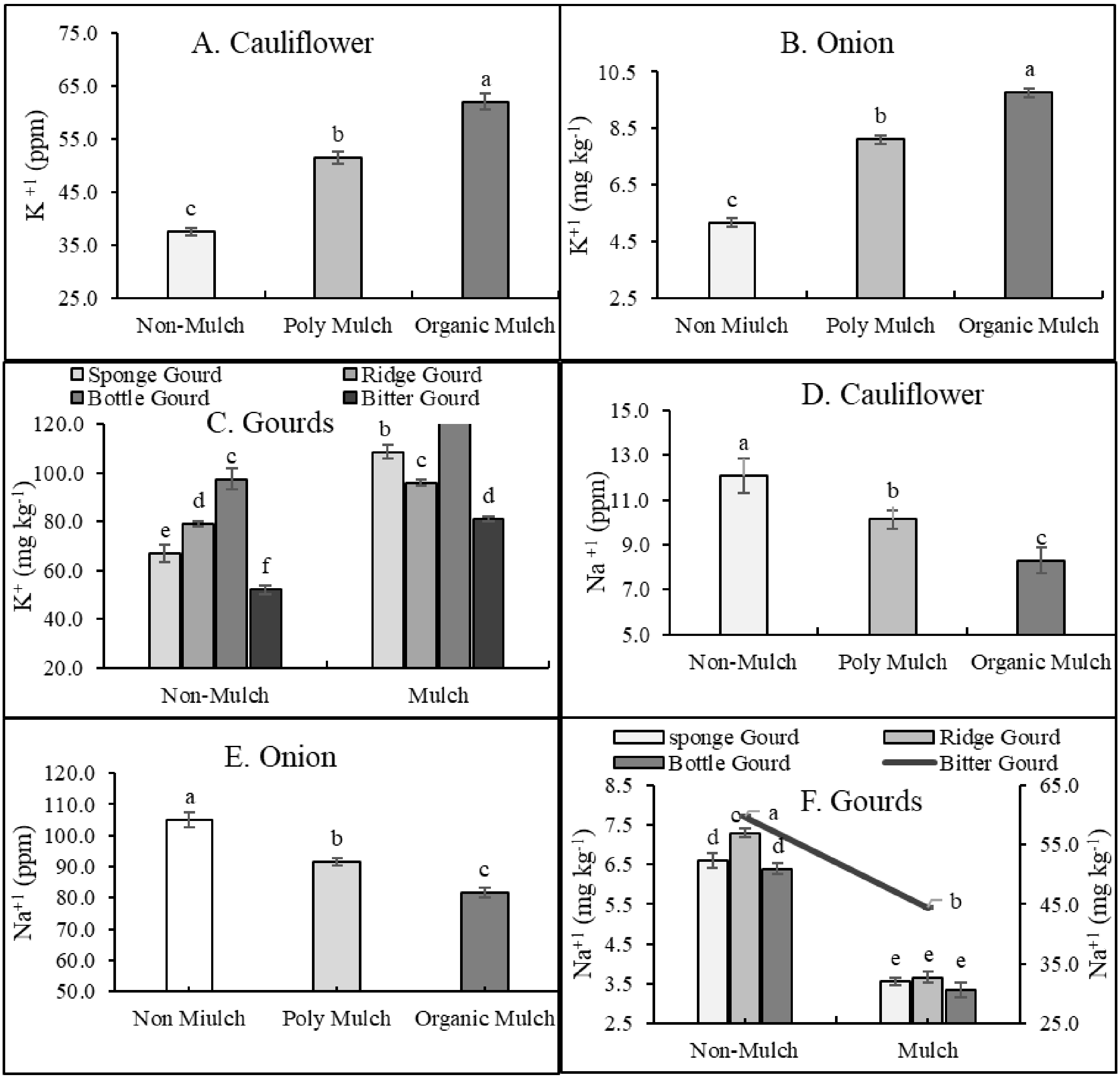

Figure 6. Impact of mulching on cauliflower, onion, and gourds' Potassium (K+) (A, B, C) and (Na+) (D, E, F) ions under saline growing conditions

Each value in the above figures is a mean of 3 replicates.

HSD (Tuckey Test) for crop x treatment was significant at $p \leq 0.05 \pm$ S.E

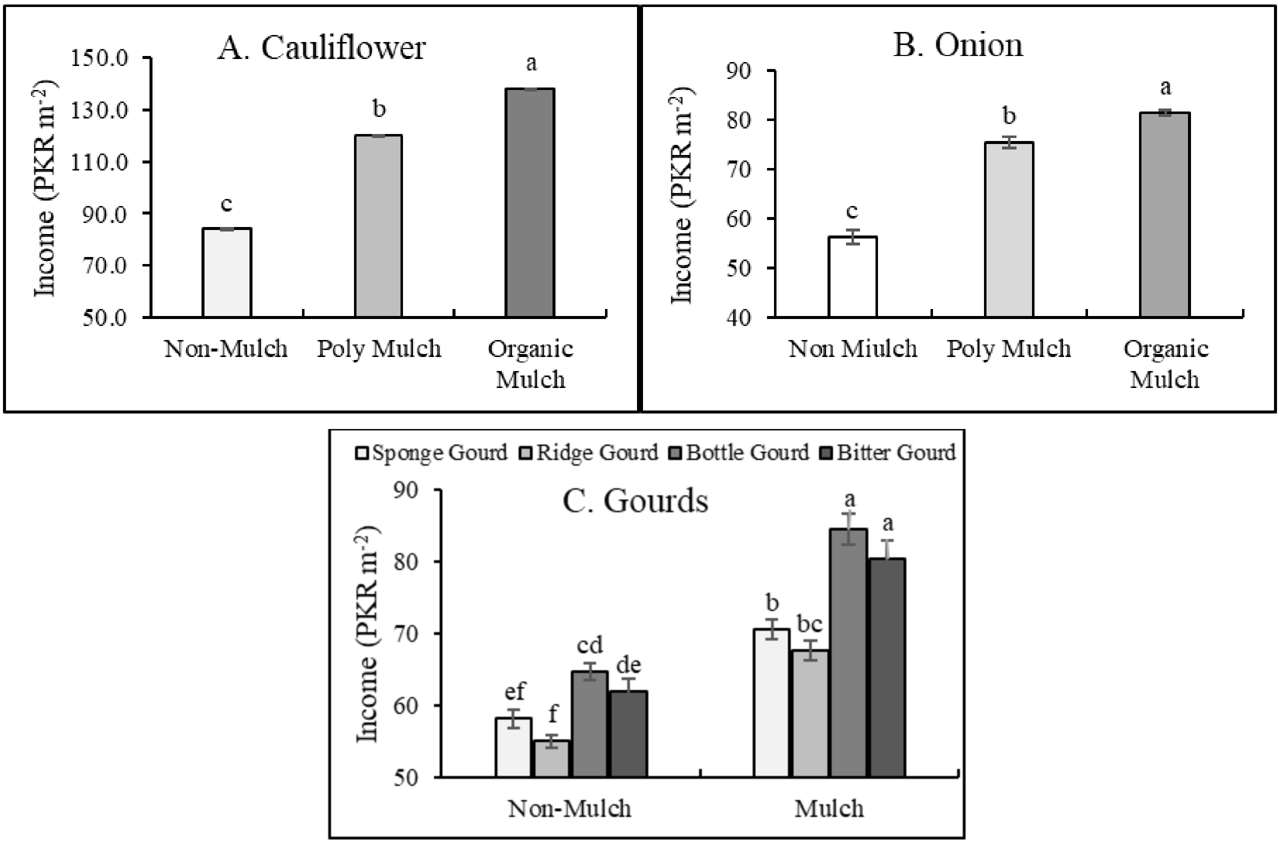

Figure 7. Impact of mulching on the income of cauliflower, onion, and gourd vegetables (A, B, C) under saline growing conditions

Each value in the above figures is a mean of 3 replicates.
HSD (Tuckey Test) for crop x treatment was significant at $p \leq 0.05 \pm$ S.E

Figure 8. Cauliflower (A), gourds (B), and onion (C) crops grown under mulch

3.2. Kitchen Gardening

The ASSIB project's collaboration with women led to transformative outcomes and demonstrated remarkable results through kitchen gardening of various winter and summer vegetables under mulch (Mohiuddin et al., under review). During 2021, only 12 farmers (5 women and 7 men-led farmers) engaged in kitchen gardening. Kitchen gardening ensured the availability of fresh quality vegetables at the household level followed by a reduction in kitchen gardening and malnutrition particularly in children and women. This activity proliferated and during 2023, 53 farmers (24 women and 29 men-led farmers) engaged themselves in kitchen gardening activities based on the preliminary encouraging results bright spot project farmers (Figure 9).

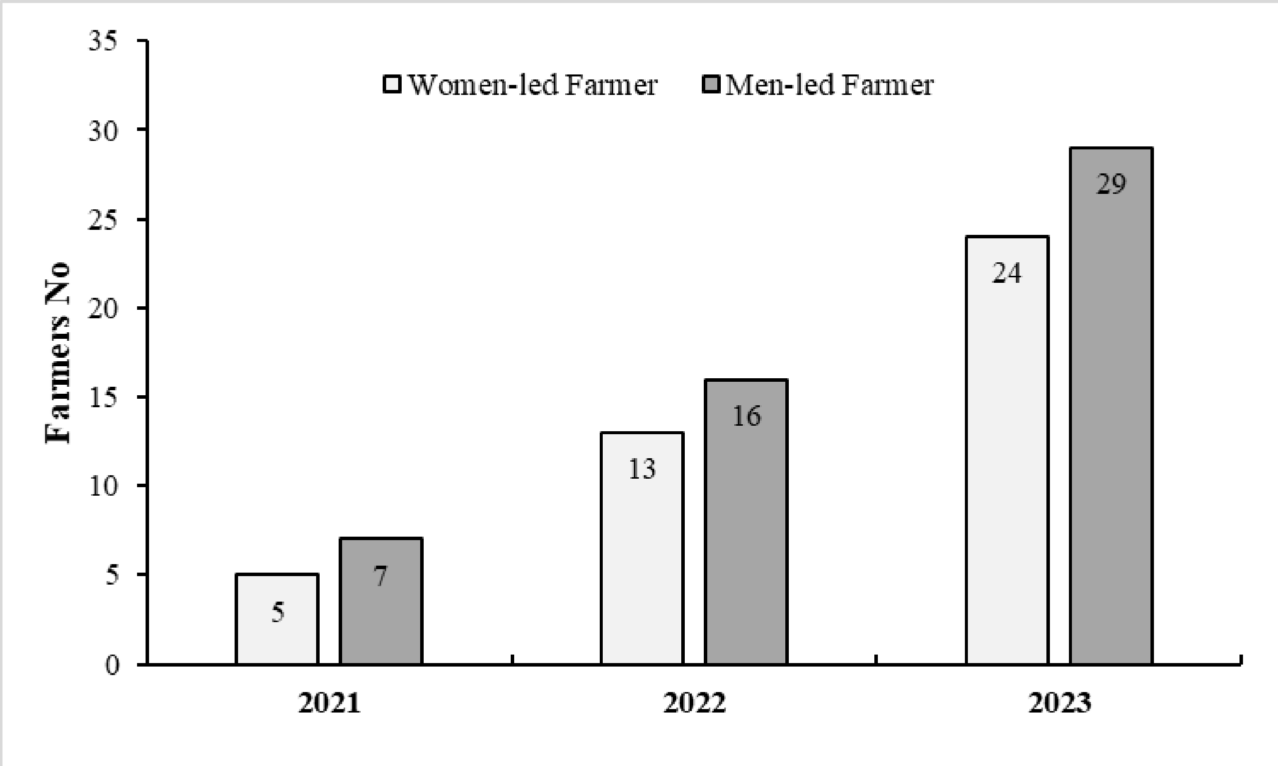

Figure 9. Kitchen gardening participants, 2021-2023

Figure 10. ASSIB project community engagement team with a farming family in their vegetable field

3.3. Orchard Management and System Thinking Approach for Value Chain Analysis

Farmers were facing quality issues in their produce resulting in low value in traditional markets due to less production of A-grade fruit. Value Chain team assessed the consumer preferences, and the MNSUAM horticulture team prepared a pomegranate calendar (See Table 1) and shared it with farmers. Additional extension services to achieve a-grade fruit were provided by Ghulam Mustafa (a PhD Student with MNSUAM working on pre- and post-harvest management of pomegranates).

The results of the systems analysis showed some positive relationships with different variables in the pomegranate value chain. Mulching was found to have a positive relationship with soil health, water management, and premium quality production. Conversely, water scarcity showed a negative relationship with the area under cultivation (Ahsan et al., in preparation). Extension services positively affected premium quality production, while communicable diseases had a negative impact on crop output and quality. Standardisation and strong value chain links positively influenced market access and consumer satisfaction. Ultimately, the study highlights the complex interplay of various factors within the pomegranate value chain, offering valuable insights for decision-makers (Ahsan et al., in preparation).

3.4. Value Chain Addition Strategies for Saline Commodities

Various marketing methods were employed by selling to wholesalers and retailers, with an emphasis on profitability and sustainability for leaves being wasted by communities. These efforts were aimed at establishing persistent value chain links for Moringa leaf powder. Despite encountering initial challenges, successful deliveries were made to wholesalers and retailers, including e-commerce stores in metropolitan areas. This endeavour not only created a sustainable market for moringa leaf powder but also provided an additional source of income for farming families.

This has motivated youth within these families to take a proactive approach by engaging in direct sales to consumers, yielding higher profit margins. Additionally, e-commerce retailers involved in the project have set some quality standards and donated seeds of two varieties in bulk known for tender leaves and fleshy fruits/ flower buds, facilitating cultivation at large scale in bright spot communities. The Value Chain team shared some success stories from the previous ACIAR projects, particularly on the direct marketing strategies employed, such as those used for ASLP Mango project. One significant achievement was the reduction of middlemen involvement, particularly when dealing with non-bulk production.

Communities involved in the project took the initiative to establish direct relationships with nearby retailers. This proactive approach resulted in the development of sustainable and persistent links for selling okra and other seasonal vegetables. As a result, the communities experienced improved cost-benefit ratios, primarily through reduced transportation costs (Ahsan et al., in preparation).

3.5. Canola, Wheat and Cotton Production on Saline Lands

Germination and plant growth were higher in treatment where seed was sown in furrows under saline field conditions compared with flatbed sowing (Figure 11). It was found that the number of grains per pods were 40.7% higher in furrow sowing compared with flatbed sowing. Similarly, straw yield was higher in furrow sowing treatment compared with flatbed sowing under salinity. Figure 12 depicts variation in crop stand between furrow and flatbed sowing under saline conditions. The effect of the two sowing methods on the grain yield per ha of canola crop is presented in Figure 13. It is clear from the bar graph that the grain yield was higher with furrow sowing than with flatbed sowing. It was calculated that the furrow sowing registered 37.5 % higher grain yield compared with flatbed sowing method in a salinity affected plot. It was also found that the size of the grains was also more in case of furrow sowing due to better plant growth and low salinity in the furrows and better leaching of salts.

The soil textural class at the property of Haji Arif was sandy loam. The c ranged from 4.0 to 17.2 and SAR from 12 to 21.5. The farmer was satisfied with the canola crop production (see Figures 14 and 15) and is ready to grow it again in the next season over a larger area. Canola straws were used for mulching in the farming family's date palm orchard and vegetable plots.

We also need to mention that sometimes there were issues of the delayed sowing. Timely sowing is very much important. There were reports from the farm of Haji Ashaq that the inter cropping of canola in the pomegranate orchard results in yellowing of the leave of pomegranate which could be due to some allopathic effects of canola crop on pomegranate plants and need further confirm in future.

__Table 1. Pomegranate crop calendar for floor and canopy pre-harvest management practices__

Activities	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Irrigations (interval)	1 (30)	1 (20-30)	2-3 (10-15)	3-4 (7-10)	4 (6-8)	4 (6-8)	4 (6-8)	4 (6-8)	3 (8-10)	2 (12-15)	1 (30)	-
Urea gram (week)		500 g (2nd)	-	250 g (3rd)	-	250 g (2nd)	-	-	400 g (1st)	-	-	-
DAP gram (week)		500 (2nd)	-	250 (3rd)	-	-	-	-	500 (1st)	-	-	-
SOP gram (week)		350 (2nd)	-	350 (3rd)	-	-	-	-	300 (1st)	-	-	-
Foliar spray @ 250g/100l ($ZnSO_4$, $MgSO_4$, $MnSO_4$ & H_3BO_3)	-	-	2nd week	-	1st week	-	-	-	1st week (-Boric acid)	-	-	-
FYM (kg/plant)												50
Pruning	yes			yes		yes			yes			yes
Bactericides	yes			yes	yes	yes	yes					yes
Insecticides			Yes (Aphid)	Yes (Thrips)								
Fruit bagging (week)				4th	1st							
Fruit thinning (week)					1st							
Harvesting (week)	-	-	-	-	-	-	Aug 4 to Sep 3	-	--		-	

Figure 11. Land and ridges preparation canola sowing in a saline field and canola germination status at the farm of Haji Arif, Jalalpur

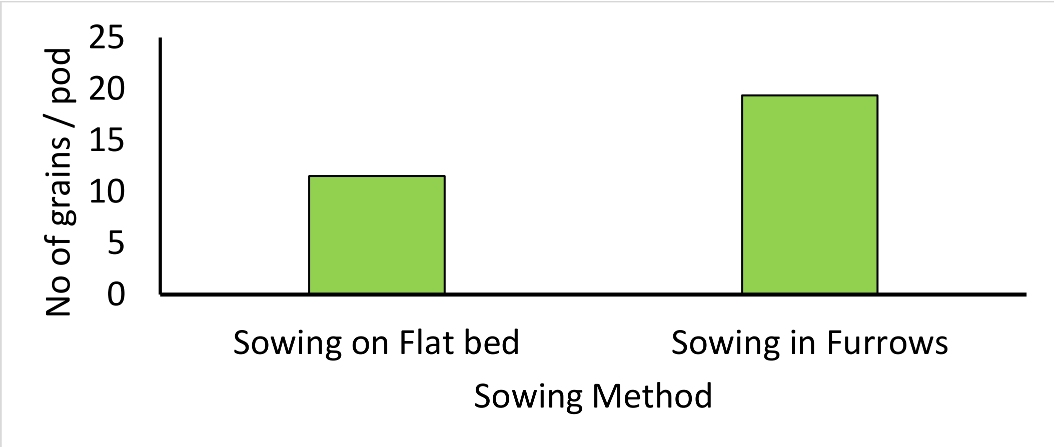

Figure 12. Average number of grains per pod under flat and furrow sowing of canola in a saline field (ECe: 9.5 dS /m)

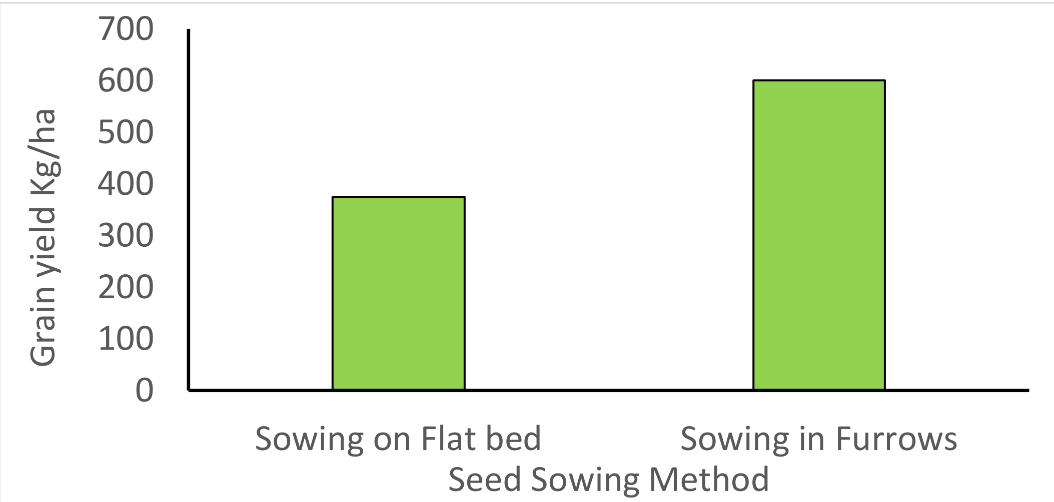

Figure 13. Grain yield per ha under flat and furrow sowing of canola in a saline field

Figure 14. Canola crop at the stage of flowering under flat bed and in furrows sowing

Figure 15. Harvested canola crop kept for drying in the field before threshing. Sample of grains

4. Discussion

The experiments after the SERL initiative have not only generated good scientific and technical knowledge but also contributed to capacity building of farmers to sustain interventions that have the potential to change livelihoods in the salinity affected landscape (see Figure 16). Results discussed above have well elaborated that the approach adopted in the ASSIB project has resulted in enhanced community engagement. The communities led the complicated procedures involved in technical experimentation. Next important social impact was capacity development of the community to take initiatives that can lead to better livelihoods and capacity to think collectively.

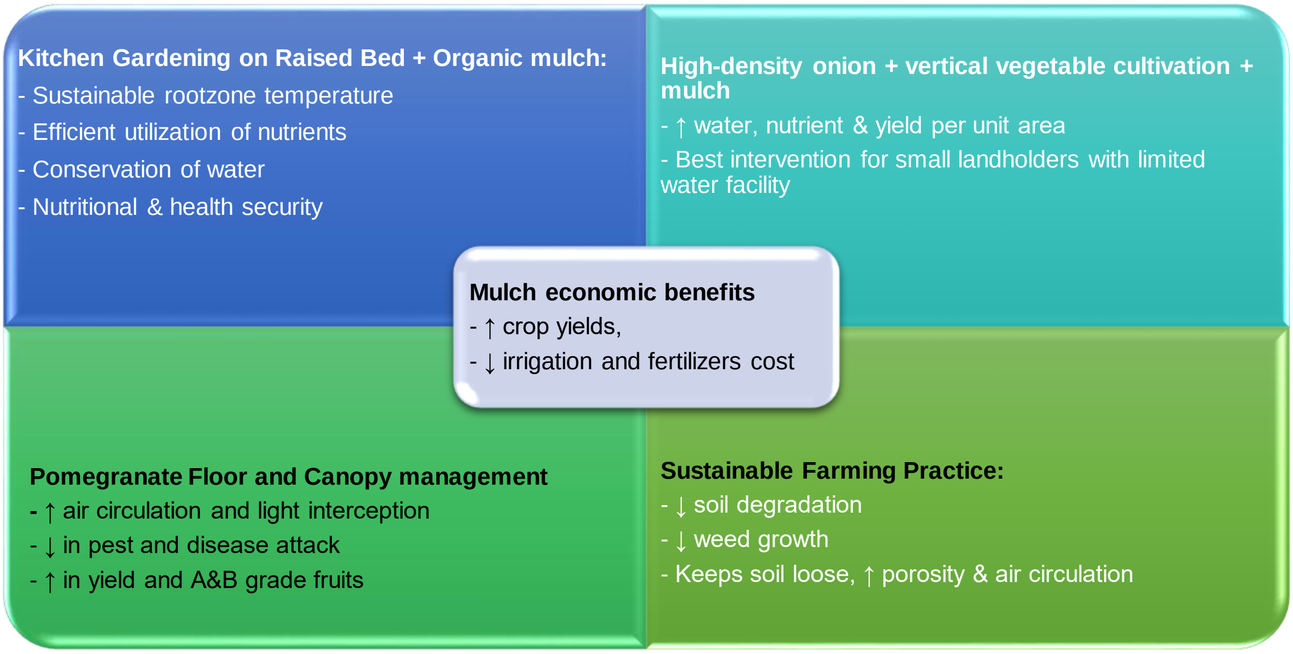

Figure 16. Summary of results and their benefits for the community and sustainability

Use of organic mulch has many environmental benefits including reducing air pollution and greenhouse gas emissions from using rice straw as mulch instead of burning it. Burning rice straw releases large amounts of particulate matter and greenhouse gases. Soil moisture is conserved as rice straw mulch reduces evaporation. This can be particularly beneficial in arid and semi-arid regions where water scarcity is a concern. Soil temperature regulation is another added advantage as mulch can moderate soil temperature, keeping the soil warmer in cold conditions and cooler during hot weather. This helps create a more stable environment for root development and microbial activity. It is also beneficial for enhanced soil fertility as it adds organic matter to the soil. This improves soil structure, increases nutrient availability, and enhances the soil's capacity to hold nutrients and water, reducing the need for synthetic fertilisers.

Moreover, this project focused on enhancing market links for the produce by strengthening market access and value addition strategies for farmers. Direct marketing, with a focus on quality and consumer-perceived value, has emerged as a sustainable solution for the bright spot communities. This approach allows for direct insights into consumer preferences through retailers, ensuring long-term viability and success.

Experiments evaluating various crops under saline conditions, including wheat on ridges and varietal comparisons of cotton and canola for salinity tolerance were conducted, prioritising the adaptive varieties for saline conditions. In crop raising experiments we compared flat bed and furrow sowing methods for Canola Hybrid HC-022B, Hybrid-F1 seeds in a one-acre field. Furrow sowing resulted in a 40.7% increase in grains per pod and a 37.5% higher grain yield compared to flat-bed sowing. This method also produced larger grains due to better plant growth and lower soil salinity in the furrows, allowing for improved leaching of salts. Furrow sowing shows promise as an effective technique for increasing canola and wheat yield in salinity-affected areas. Through this integrated approach, we are optimistic that further spread-out of these interventions will increase crop resilience but also enhance profitability and sustainability for farmers in salt-affected areas.

5. Conclusion

The adoption of a community engagement and farmer-led approach has led to desired outcomes being achieved for the bright spot communities involved (see Figure 17). The trials of experiential learnings ended up in numerous successful implementations of salinity adaptive practices such as mulching and ridge cultivation, developing market links. These trials were a collective outcome of farmer ownership together with increased level of trust between farmers, researchers and other stakeholders. This integrated approach has been fundamental in driving these initiatives, fostering a sense of collective responsibility and success among farmers. The dissemination of success stories and farmer-to-farmer learning has resulted in adoption of interventions by surrounding communities.

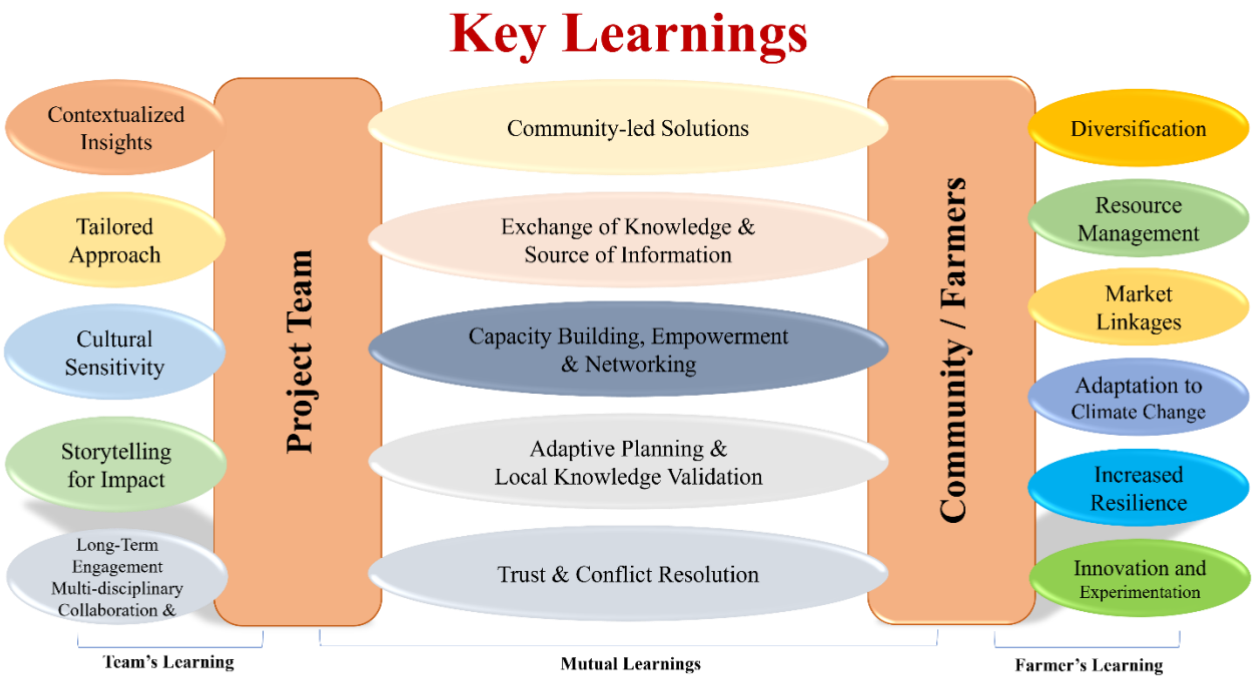

Figure 17. Key learnings for farmers and project team from the co-inquiry process

Our co-inquiry journey with the bright spot communities involved practical interventions using indigenous knowledge and resources that were tested using a systematic interactive process, enabling farmers to start planning their futures through efficient resource management, better access to information, use of collective wisdom, and active participation of women and youth. It also enhanced their adaptive capacity, enabling them to respond with resilience to the extreme weather events. Additionally, farmer led experiments to harvest better yield of vegetables and crops under saline conditions led to the improved livelihood and better resilience against salinity. Through this integrated approach, we are also optimistic that further spread-out of these interventions will increase, helping to paint a 'big picture' reflecting the impact of the project learnings on a wider scale.

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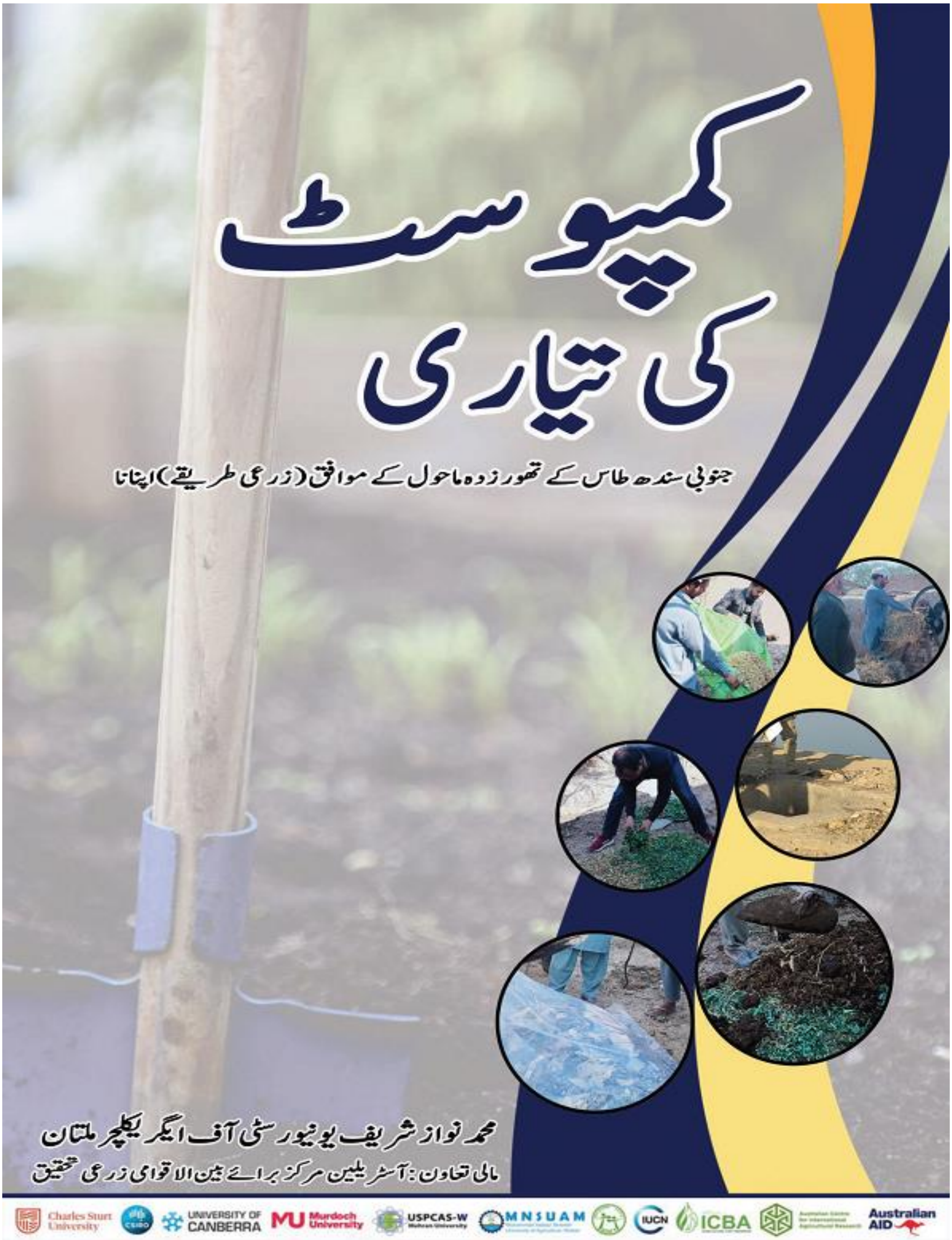
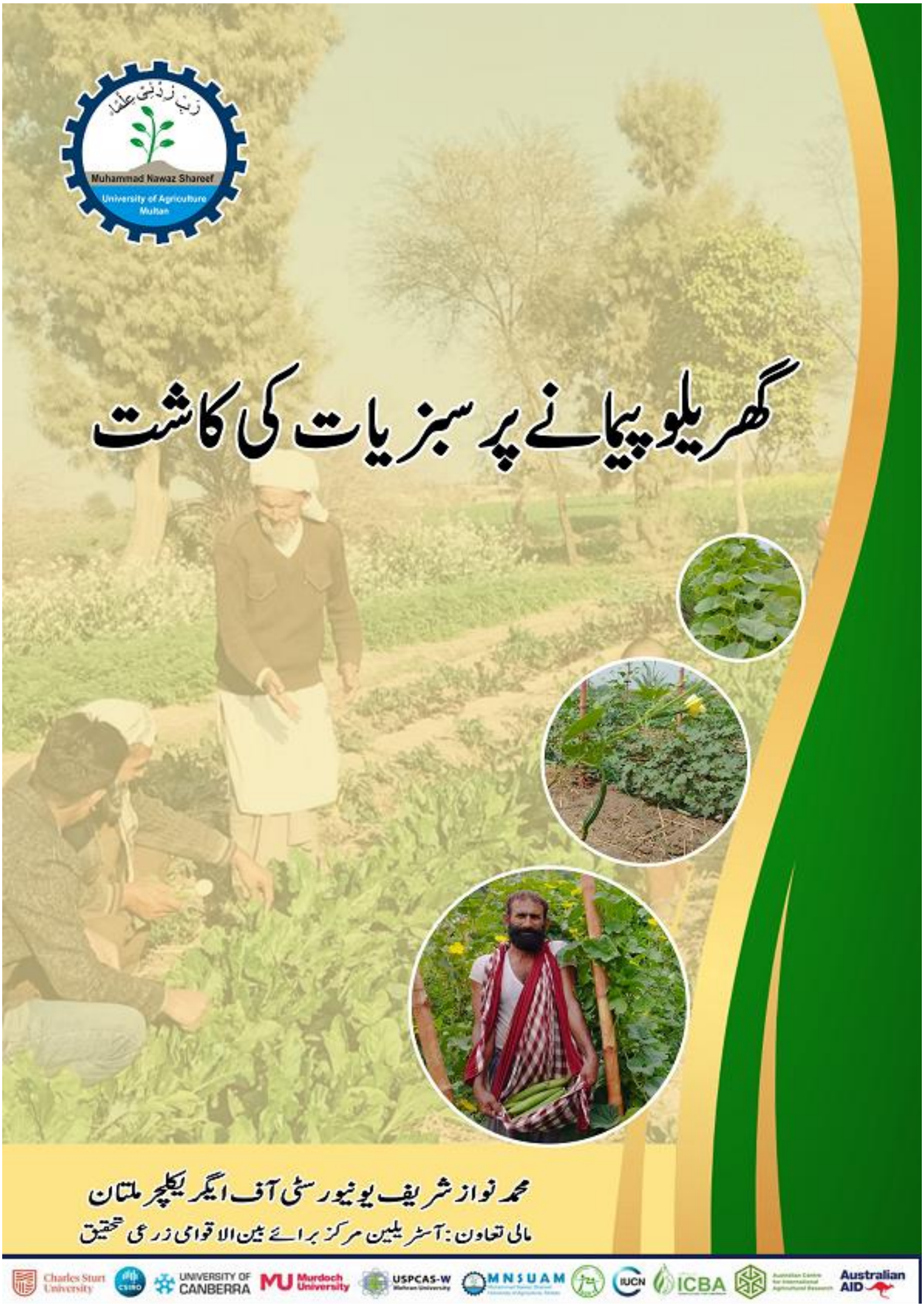
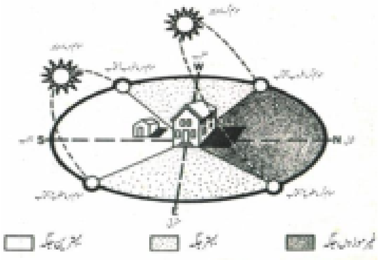
Appendix: Material Developed for Use by Farmer Facilitators




Muhammad Nawaz Shareef
University of Agriculture Multan
گھریلو پیمانے پر سبزیات کی کاشت
محمد نواز شریف یونیورسٹی آف ایگریکلچر ملتان
مالی تعاون: آسٹریلین مرکز برائے بین الاقوامی زرعی تحقیق
Charles Sturt University
CSIRO
UNIVERSITY OF CANBERRA
Murdoch University
USPCAS-W
MNSUAM
IUCN
ICBA
Australian AID

گھریلو پیمانے پر سبزیات کی کاشت

گھر کے افراد کا گھریلو سطح پر کم اخراجات سے سبزیات کاشت کرنا اور استعمال کرنا کچن گارڈننگ کہلاتا ہے۔ اوسطاً ایک گھرانہ کی سبزیوں کی ضرورت کو پورا کرنے کیلئے 3-5 مرلہ جگہ درکار ہوتی ہے۔ عموماً گھریلو پیمانہ پر نہ تو مناسب حالات میسر ہوتے ہیں اور نہ پیداواری صلاحیت کے مطابق ان کا حصول اور آمدن مد نظر رکھی جاتی ہے۔ اسکا مقصد گھریلو پیمانہ پر آلودگی سے پاک تازہ سبزیات پیدا کرنا، گھریلو بجٹ اور میڈیکل بل میں کمی کرنا ہوتا ہے۔ عموماً سبزیات کا انتخاب خاندان کے افراد اور دیکھ بھال کیلئے درکار وقت، کھلی ہوا اور ہموار زمین، پودوں کی بڑھوتری کیلئے 6-8 گھنٹے تک سورج کی روشنی کی دستیابی، آبپاشی کیلئے پانی کی وافر مقدار اور نکاسی آب کے مناسب انتظام کی بنیاد پر کیا جاتا ہے۔



تصویر نمبر 1: موسم سرما و گرما میں سورج کی چال اور جگہ کا انتخاب

چھت پر گملوں میں سبزیات کی کاشت: اگر گھر میں زمین موجود نہ ہو تو مختلف طرح کے گملوں (مٹی کے گملے، پلاسٹک کے ٹب اور ٹوکریاں، لکڑی کے کریٹ، پلاسٹک اور کھاد والے تھیلے، پلاسٹک اور لوہے کے ڈرم، پرانے ٹائر وغیرہ) میں بھی سبزیاں کاشت کی جا سکتی ہیں۔ شہروں میں سبزیات کی گملوں میں کاشت زمینی کاشت کی طرح فروغ پا رہی ہے۔

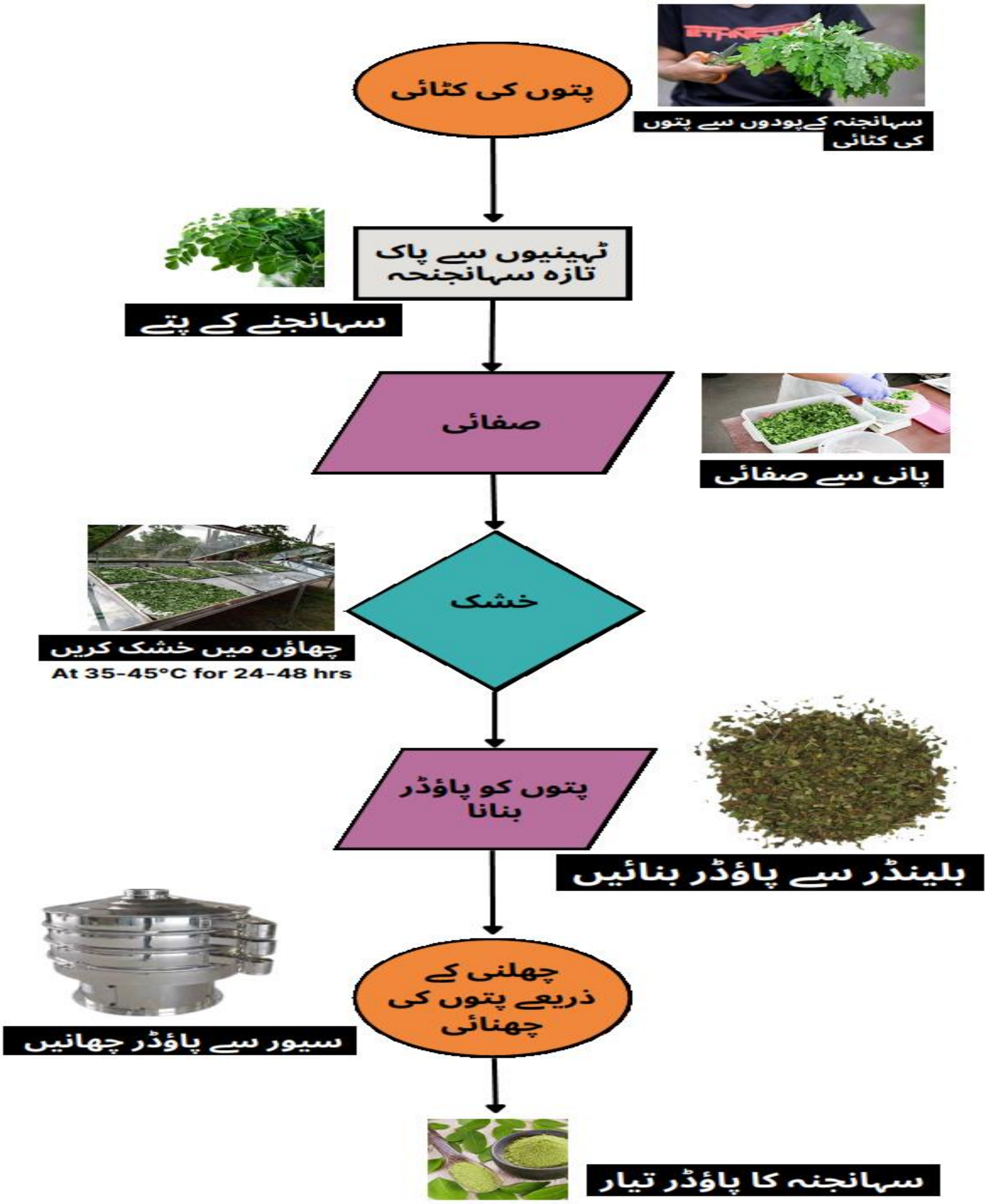
پنیری سے اگائی جانے والی سبزیات: موسم سرما میں پھول گوبھی، بند گوبھی، سلاد اور پیاز جبکہ موسم گرما میں ٹماٹر، بینگن، مرچ اور شملہ مرچ کی بیج لگا کر 30-40 دن کی پنیری تیار کی جاتی ہے۔ گھریلو پیمانے پر سبزیوں کی پنیری تیار کرنے کیلئے بیج پلاسٹک کی ٹرے، 128-200 سوراخوں والی پگ ٹرے یا پھر کیاریوں پر لگائے جا سکتے ہیں۔ اس کے لیئے ایک حصہ ریت، تین حصے گوبر یا پتوں کی گلی سڑی کھاد اور تین حصے کھیت کی مٹی چھان کر آمیزہ تیار کر لیں۔ اس مٹی کو ٹرے میں ڈال دیں یا کیاریاں بنا کر 2 انچ کے فاصلے پر لائنیں لگا کر تقریباً 0.5 انچ کے فاصلے پر 0.5-2 انچ گہرائی میں بیج لگا دیں۔ تیار شدہ آمیزے یا ریت کی باریک تہہ سے بیج ڈھانپ دیں۔ بیج کے اگنے تک فوارے سے پانی دیتے رہیں۔ اگر درجہ حرارت کم ہو تو شفاف پلاسٹک شیٹ سے ڈھانپ دیں جب بیج اگ آئیں تو روزانہ پانی دیتے رہیں۔ جب پودوں کے 4-6 پتے نکل آئیں تو پنیری کو تیار کی ہوئی جگہ پر گرمیوں میں شام کے وقت جبکہ سردیوں میں دوپہر کے وقت منتقل کر دیں۔

زمین کی تیاری: پہلی بار زمین کو تقریباً 1 فٹ گہرائی تک الٹ پلٹ کریں اور بھر بھرا کر لیں۔ 2-4 دن زمین کو دھوپ اور ہوا لگنے دیں۔ سبزی لگانے کے وقت کھاد ڈال کر سبزیوں کی قسم کے مطابق ہموار زمین، وٹیں یا پٹڑیاں بنا کر کاشت کر دیں۔

آبپاشی، گوڈی اور جڑی بوٹیوں کی تلفی: سبزیوں کے بیج کاشت کرنے یا پنیری کو منتقل کرنے کے فوراً بعد پانی لگائیں۔ مزید موسم، سبزیوں کی ضرورت اور محکمانہ سفارشات کے مطابق پانی لگاتے رہیں۔ گوڈی کا عمل مسلسل جاری رکھیں تاکہ جڑی بوٹیاں تلف ہوں اور پودوں کو یکساں دھوپ، خوراک اور پانی حاصل ہوتے ہیں۔ عموماً سبزیوں کی جتنی گوڈی کریں گے اتنی ہی پیداوار زیادہ ہو گی۔

سہانجنہ کے پتوں سے پاؤڈر کی تیاری

فلو چارٹ کے عناصر



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