Charles Sturt University

Gulbali Institute
Agriculture Water Environment

Living with Salinity in the Southern Indus Basin through Saline Agriculture

Kamran Baksh Soomro, Akhtar Hussain Samoo, Ifrah Naseem Malik, Naveed Ali Soomro
(IUCN Pakistan)

Living with Salinity in the Southern Indus Basin through Saline Agriculture

Kamran Baksh Soomro, Akhtar Hussain Samoo, Ifrah Naseem Malik, Naveed Ali Soomro (IUCN Pakistan)

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.

Soomro, K. B., Samoo, A. H., Malik, I. N., Soomro, N. A. (2024). Living with Salinity in the Southern Indus Basin through Saline Agriculture. Gulbali Institute, Charles Sturt University, Albury, NSW.

1 volume, Gulbali Institute Report No. 14

ISBN: 978-1-86-467470-5

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

Disclaimer

Executive Summary

IUCN worked with communities affected by salinity in the Indus Delta as part of the Adapting to Salinity in Southern Indus Basin (ASSIB) project funded by the Australian Centre for International Agricultural Research (ACIAR). The goal of the project was to increase capacity of salinity-affected communities to develop strategies for increased resilience and livelihood sustainability. For the communities collaborating with IUCN, these strategies involved aquaculture (see Jarwar et al., 2024) and agriculture (covered in this report). Multiple co-inquiry interventions were established through the project's co-design process undertaken with a few chosen communities classified as bright spots. The agricultural interventions included field trials of various crops, kitchen gardening techniques for seasonal vegetables, vertical cultivation of ridge gourd and bitter gourd, organic mulching with dried banana leaves, and chili plantations on raised beds and ridges. All were enthusiastically accepted by the stakeholders. The development of women's skills in field experiments and their involvement in multi-vegetable kitchen gardening from sowing to harvest had a big influence and inspired other farmers to turn disused land into productive land. Each of the experiment had limitations mainly revolving around soil quality, irrigation water quality, method of sowing, and mode of irrigation.

The experiment on chili at Tippun Dublo was a bit difficult, but it was a good idea to experiment in Kharif 2022. The overall performance of the chili under two days of irrigation was quite satisfactory because frequent irrigation prevented salt buildup on the soil's surface and produced a good yield when compared to three days of irrigation. The experiment's results have given important new information to the national conversation on sustainable agricultural development. Data gathering was greatly influenced by the community's involvements with IUCN and SOFT, and Mr. Saleem Shah, a farmer at Tippun Dublo, participated physically in the process. Women farmers noticed that using mulch, which included dry banana leaves, produced good results and discovered that timely water availability is a major difficulty. Furthermore, mulching helped the field experiment save water and boost yield by reducing irrigation timing because the soil remained moist for two to three days. It was also noted that growing a variety of vegetables was a good way to find the area's potential harvest.

A novel concept for sustainable coastal development involves leveraging community-based participatory practices in agriculture and adapting to use of saline water. A community-driven multi-vegetable experiment has resulted from the blending of scientific competence and local understanding, as demonstrated by the ASSIB project's efforts in coastal Pakistan. Vertical cultivation of ridge-gourd and bitter-gourd with organic mulch produced good results in terms of fruit size and productivity. Because of the long sowing season and high temperatures, cotton and Salicornia did not provide very good results. On the other hand, wheat, brassica, and berseem yielded good results, and the community elected to keep growing these crops with improved management. The idea of agriculture, especially in a salty environment, establishes a paradigm shift for Sindh. With the globe debating the need for sustainable growth, this project's adaptable methodology highlights its distinctive and cutting-edge nature. Projects like ASSIB and its focus on co-inquiry can provide crucial insights for developing an ecology that supports the long-term sustainability of salt-tolerant crops in Sindh's coastal districts.

Contents

Introduction

Soil salinisation is one of the biggest risks to agriculture and food security (Tarolli et al., 2024), and decreases the productivity of numerous crops (Irshad et al., 2009). Salt intrusion is the main risk factor for crop decline and inappropriate hydrological and environmental circumstances that restrict regular crop growth (Jodder et al., 2016). Salinity is often higher during the dry season and lower during the rainy season (de la Peňa & Hughes, 2007). By adding various organic changes, saline soil can be reclaimed. This increases the soil's organic matter content and biological activity, which enhances crop productivity (Rashid et al., 2019). For soil to be productive, there must be enough organic matter present (Oldfield et al., 2018), yet soils impacted by salt typically have less than 1% organic matter, necessitating the addition of additional organic matter (Wood et al., 2018). When the soil's EC is higher than 4 dS.m-1, agricultural output under saline water application is similarly decreased (Rajpar et al., 2006). Vegetable crops are grown on 0.69 million hectares of land in Pakistan, with an annual production of 8.5 million tons. According to projections (Asif et al., 2016), the nation's vegetable consumption could reach over 25 million tons by 2030. The increasing demands on the world's finite water resources call for a critical rise in water productivity (Richey et al., 2015). In semi-arid regions, saline water must be used for irrigation to meet water demands (Wang et al., 2014). Therefore, it is necessary for farmers to investigate the possibility of using saline water for agricultural production in a moderate manner (Lekakis & Antonopoulos, 2015).

The Australian Centre for International Agricultural Research (ACIAR) funded the Adapting to Salinity in Southern Indus Basin (ASSIB) project to collaborate with salinity-affected communities in the Indus Delta to strengthen their capacity to develop strategies for increased resilience and livelihood sustainability in such circumstances. The project's approach to enhancing community resilience is based on community-based research co-inquiry. The results of this plan are presented in this report, which draws on the experiences and expertise of Sindh's coastal communities. The inhabitants of these villages worked with the ASSIB project team to explore saline agriculture as a source of income and resilience that would enable them to adjust to changing climate circumstances. The farming community at Tippun Dublo and IUCN, an ASSIB partner, worked together to conduct the co-inquiry over a two-year period. Since both parties had equal stakes in the research, the community was able to learn by doing actual adaptations to the changing conditions.

The use of co-inquiry principles has led to the emergence of an alternative community-based route, which is best illustrated by interventions in agriculture that incorporate both men and women. This kind of co-inquiry, which blends scientific and traditional knowledge, shows promise for improving the ecosystem and standard of living for Sindh's coastal populations. Although farming in saline environments is challenging, adopting a climate-resilient approach and introducing salt-tolerant plants could be a workable solution to the problem of food security. The co-inquiry approach is crucial because it tackles productivity challenges and provides viable options for sustainable lives that could yield noteworthy results and function as a model for sustainable revenue production with community involvement. Fruits and vegetables are thought to be essential for the rapidly growing populations in developing nations. Considering this, kitchen gardening has shown to be a valuable supplemental food source and can significantly contribute to the reduction of issues related to hunger and malnutrition (Galhena et al., 2013).

Since vegetables often have a higher financial value than field crops, it is crucial to know which types of plants can tolerate salinity. When managed properly and with appropriate precautions taken, saline agriculture can be a viable and profitable endeavour. Mulches have a positive effect on agronomic properties of crops and conserve moisture (Biswas et al., 2016). In the ASSIB initiative at Tippun Dublo, an experiment involving a limited number of vegetables was carried out during the Kharif and Rabi seasons. In the Kharif season, chili and bitter gourd are important vegetables. Chili has a considerable tolerance to salt and can be cultivated in saline conditions with an EC of less than 5 dS.m^{1} (Ahmadi & Souri, 2018). Like bitter melon, bitter gourd grows naturally in tropical regions of Asia and is widely distributed throughout China, Japan, Southeast Asia, and Africa (Hossain et al., 2006). It can withstand moderate amounts of salt (Lim, 1998) and is valued for its therapeutic and nutritional qualities (Dalamu et al., 2012).

Berseem, brassica, wheat, and barley are regarded as reasonably salt tolerant crops. While wheat is essential for maintaining food and nutritional security, its production is seriously threatened worldwide by rapidly increasing salinity. Salinity stress negatively affects the growth and development of wheat leading to diminished grain yield and quality (El Sabagh et al., 2021). Due to osmotic stress during early stages of exposure and ion toxicity during later phases of development, exposure to salt restricts the growth and production of wheat crops (Dissanayake et al., 2022). Wheat production is currently about 31.4 million tons annually from about 9.6 million hectares in Pakistan (Government of Pakistan, 2024), mostly from Punjab province, with Sindh province comprising 14% of the nation’s wheat production (Agriculture Policy Institute, 2023). Because wheat is not considered saline tolerant, it is not widely grown in Thatta. Though the trials are still ongoing, some salt-tolerant varieties have lately been introduced in Pakistan.

Salinity has an impact on yield performance of various agronomically significant species in the Brassica genus, like wheat (Shahzad et al., 2022). Brassica can be cultivated using irrigation water of marginal quality if effective management techniques are used, but other factors, such as soil type and humidity, must be considered. The most common salt-tolerant cereal crop in the world is barley (*Hordeum vulgare*) (Munns and Tester, 2008). It can withstand up to 250 mM NaCl, or 40% seawater, but after that point, its chances of surviving rapidly decline (Hazzouri et al., 2018). In a similar vein, Berseem is a premium, quick-growing forage that is primarily chopped and fed as green forage. It grows best in a temperature that is somewhat cool, but not below 20 degrees Celsius. It possesses moderate tolerance to salinity and can be used for reclamation of saline land. Salicornia can also be grown for animal feed, and its cultivation is healthy for the environment. With 30% edible oil among its contents, Salicornia has enormous economic potential. Its seeds can yield more edible oil than those of soybeans (Lyra et al., 2022).

Methods

Five co-inquiry research action plans were identified through workshops using the Stakeholder Engagement for Research and Learning (SERL) process (Heaney-Mustafa et al., 2023) with Tippun Dublo community members who were focused on agriculture. The action plans were finalised after the workshops through cooperation with the Society of Facilitators and Trainers (SOFT) and IUCN. In some cases, the investigations evolved over consecutive seasons, enabling the co-inquiring community, researchers and other stakeholders to learn from evaluations of past trials, as befitting the SERL approach.

An experimental site in the village of Pir Allah Bux Shah in Tippun Dublo was chosen in conjunction with the family of Mr. Salim Shah. The site was a moderately to highly salinised area of around one acre. The water table was observed to be approximately eight feet deep, and the availability of canal was limited and could not meet the crop demand. The soil texture for complete profile depth was determined as silty clayey loam. It was found that the soil had relatively little organic matter—between 0.38 and 0.55%. The Tippun Dublo trial site was found to be extremely saline due to its higher EC value, which suggested a higher salt concentration in the soil. Nonetheless, the experimental soil had an alkaline pH of 8.2–8.6, which was within safe limits. A cultivator and disc harrow were used to completely till the land. During the field preparation process, 325 tons of farmyard manure (FYM) and 100 kg of single super phosphate (SSP) per acre were applied, as the combination of applying farmyard manure and single superphosphate (SSP) contribute the highest possible yield (Dawar et al., 2022). During the Kharif and Rabi seasons, several agricultural interventions were carried out, such as field studies and multi-vegetable kitchen gardening (2022-24). The farmer, Mr. Salim Shah, and his family participated in agricultural interventions. Growing vegetables was a little difficult at Tippun Dublo. To continue the co-inquiry trials, the technical team had to maintain a balance between conventional wisdom and scientific understanding. In general, the residents of Tippun Dublo's village Allah Bux understood the learning process and the technical aspects needed to effectively complete the experimental requirements.

We provide a description of each of the five co-inquiry interventions below.

1. Chili Experiment

Tippun Dublo conducted a green chili *(Capsicum frutescens)* experiment in Kharif 2022. To maximise seed germination, a total of 14,000 hybrid chili seeds were planted in plastic trays with peat moss. After four weeks in the nursery, the seedlings were placed on ridges at a depth of two meters and a distance apart of sixty centimetres. To enable comparison of results from this nursery seedling approach, 3,000 seeds were seeded straight onto a flatbed in the field.

Agronomic techniques, such as fertiliser application, were implemented under the guidance of an agriculture consultant. Fifteen days prior to the transplanting of saplings in the open field, twenty kilograms of ammonium sulphate and twenty kilograms of single super phosphate were applied and thoroughly mixed into the soil. Tippun Dublo used groundwater that had an EC of 5.0 dS/m and was saline. As a result, irrigation intervals, including T1 (two days) and T2 (three days), were taken into consideration as treatments. It was thought that the irrigation interval could decrease the accumulation of salts in the root zone. Using the volumetric approach, irrigation was applied until the crop reached physiological maturity. The irrigations were applied every two to three days at a depth of 5 cm. In May and June, the southern region of Sindh experiences warm weather relative to other parts of Pakistan. In 2022, during the Kharif season, there was a dramatic increase in temperature, reaching as high as 40^0C. This led to a 50% permanent wilting of plants and a mortality rate in chili plants. Following that, gap filling and transplanting were completed. In total, fourteen irrigations were applied to each plot, spaced two or three days apart. 3.25 m^3 of irrigation water were used in total on each plot.

The agricultural community group, both men and women, established nurseries, prepared the land with ridges, and used other best management techniques to produce chilies in a saline environment. Throughout the season, needs-based awareness and demonstration events were held at the experimental site. The monsoon arrived in Sindh in July 2022, bringing with it extremely heavy rains in Thatta, Badin, and Keti Bandar. Numerous plants were damaged when the trial site flooded. Despite the experiment's lack of success in this first trial, the community's spirits remained high because they were resolute and used the first cycle's lessons to launch the next cycle's co-inquiry. For the second cycle, the community prepared a nursery in March 2023, resulting in 90 percent germination in plastic trays. After four weeks the saplings were planted in the field, with the chili plants ending up giving positive results under a 2 and 3 day irrigation interval regime. The community's analysis of the chili experiment revealed that, when seeds were directly sown in a field, only 40% of them germinated. In contrast, 95% of the seeds germinated when they were planted in plastic using peatmoss, yielding positive results.

2. Bitter Gourd and Ridge Gourd Experiment

The same one-acre trial plot was used in Kharif 2022 for a trial undertaken in tandem with the above chili trial. Both bitter and ridge gourds are considered Kharif vegetables, however they can be cultivated all year round in Pakistan. These vegetables were once grown in Keti Bandar, but the groundwater quality declined because of sea water intrusion, and the continued use of traditional growing methods reduced the yield to 1,800-2,000 kg per acre in Tippun Dublo. A new technique for growing ridge gourds and bitter gourds was developed by taking climate change-related salinity difficulties into account. The hybrid seeds of bitter gourd and ridge gourd were sown at a rate of 4 kg/ha on ridges in July 2022. To improve germination, the seeds were soaked for three to four hours prior to being sown on a field. With a plant-to-plant spacing of 40-45 cm, the seeds were planted at a depth of 2-3 cm on both sides of the ridge. The surplus plants were trimmed out to preserve the necessary spacing between them after seed germination. A bamboo stick was a suitable support for better vertical creeping during the early stages of plant growth. The bitter and ridge gourd crop vines were then further raised vertically by installing bamboo stakes with fish net. By using this technique, the crop cycle was extended and losses from salt build-up on the soil's surface were avoided.

Soil salinity is influenced by irrigation schedule, and it has been found that regular irrigation application lowers the concentration of salts that accumulate in the soil (Soomro et al., 2021). The farming community was consulted when designing the irrigation treatment, which included T1 (4-day irrigation interval) and T2 (5-day irrigation interval). Irrigation with organic mulch under a saline climate may be beneficial. Horticultural crops are typically produced using organic mulches, such as banana leaves. It was recommended by the experts that if mulch over the seed bed was provided immediately it would decrease evaporation and decrease the movement of salt into the seed bed by capillarity. Diverse strategies exist to minimise water consumption in crop production. One such strategy is to mulch the soil to minimise evaporation of unproductive soil (Pi et al., 2017). Three weeks after transplanting, the material for the banana mulch was gathered from the closest location, chopped into small pieces for appropriate application, and spread out at a thickness of five centimetres. Dried banana leaves were then exposed to the sun for seven to fifteen days.

The Cucurbitaceae family has identified powdery mildew to be a highly prevalent pest. The disease manifests as white, powdery spots that form on the upper surface of leaves and cause them to wither. As advised by Jana (2014), 2 ml of pesticide Endosulfan (Thiodan) per litre of water was applied at the mature stage to reduce the likelihood of pest infestation and to stop fruit fly attacks, which happen after rains. In contrast, pests like aphids, mites, and beetles cause leaf curling and dropping, to manage the powdery mildew, the farming community sprayed 3 grams of carbendazim per litre, and 0.5 millilitres of imidacloprid per litre to reduce aphids.

3. Multi-Layer Cropping Model for Kitchen Gardening

Kitchen gardening in saline environments has always been challenging, but drawing on technical approaches with community management could create positive outcomes. In 2022–2023, as part of the ASSIB project, multiple-vegetable kitchen gardening was conducted with women farmers in the Tippun Dublo bright spot community. These co-inquiry investigations involving kitchen gardening aided in the understanding of the types of problems faced by female farmers, such as the lack of fresh water and variable soil salinity, the lack of vegetable seeds at their level, and insufficient training and orientation in planting various vegetables and planting techniques. Because of the intense monsoon season in 2022–2023 in Tippun Dublo, the results of the initial experiment on chili crop were not noteworthy. On both sides of the experimental plot, a few rows of chili plants were not irreversibly wilted. The SOFT team met with the farming community and the IUCN at the end of October 2022 to introduce the multiple vegetable kitchen gardening technique that had been taken up elsewhere following training provided by Mustafa Nangraj from Sindh Agriculture Department (see Qureshi et al., 2024; Kumbhar et al., under review). Co-inquiry research interventions were developed with the community to plant many Rabi season crops on the same experimental plot that had flooded during the monsoon. Subsequently, the final layout plan was created to cultivate a variety of crops, such as tomato, cucumber, bitter gourd, garlic, mint, peas, and chili.

The mixed vegetables that were chosen to be grown in Tippun Dublo field have a threshold salinity of no more than 10 dS.m-1, and are thus somewhat tolerant of salt. Observing the potential of vegetables in a saline circumstance and including women farmers in kitchen gardening as a means of generating cash to support their families were the primary goals of this multiple vegetable kitchen gardening trial. Woman farmers received hands-on training in vegetable growing for the kitchen gardening project, including techniques like planting, sowing, applying pesticide, and mulching in a salinised area. In addition, the preparation of the seed bed was another task for the female farmers. Following that, the female farmers worked on irrigation scheduling and agronomic observations.

The farmers were asked to grow vegetables on their own, considering the project's scaling out plan. The IUCN provided about twelve vegetable seeds, much like the previous season. The community was urged to raise various crops using their own resources during the Rabi season in 2023. Accepted by the farming community, they planted vegetables like turnip, spinach, coriander, fenugreek, and ridge gourd. To enhance capacity among the women for kitchen gardening, training in recommended strategies for multiple vegetable kitchen gardening was provided to the women farmers. The primary goals of the training were to fortify the local community in support of innovative agricultural techniques on salt-tolerant types of multiple vegetable kitchen gardening and to improve farmers' knowledge and comprehension of kitchen gardening in saline soils. Together with the SOFT team and IUCN, the women farmers received training on how to prepare a local biopesticide throughout the session. Thirty-two people benefited from kitchen gardening with many vegetables being grown.

Furthermore, growing multiple vegetables in a single experimental plot through intercropping was a smart idea. The twenty-four furrow beds were prepped for intercropping and split into two sections: nine furrow beds were covered with mulch and the remaining nine were not. In Chili, peas, chili, and spinach were planted under Bed No. (5-6) under mulch and Bed (7-8) under non-mulch. Garlic was planted between bitter gourd at a distance of two feet under mulch in Bed No. (1-2) and in non-mulch under Bed (3-4-). Like this, Petha (Kadoo) was planted with chili and coriander in Beds 9–10 and 11–12, respectively, under mulch and without. Bottle gourd and chili with coriander were planted beneath mulch in Bed No. 13–14, and the same was done in Bed No. 15–16 without mulch. The bottle gourd was planted beneath mulch in Bed No. (17–18) and without mulch under Bed No. (19–20). It was paired with brinjal and pheno creek. Conversely, Bed Nos. 20–21 had cucumber and chili plants planted under mulch, whereas Bed Furrow Nos. 22–24 had the same plants put beneath non-mulch.

4. Wheat, Barley, Brassica and Berseem Cultivation

In Rabi 2022–2023, wheat, barley, brassica and berseem, cotton, and Salicornia were planted in Tippun Dublo under salinised conditions as part of a field experiment. Farmer Saleem Shah's experimental plot at Tippun Dublo was chosen after consulting with SOFT and IUCN. The plot was then divided into sixteen blocks, and a disc plough, cultivator, and ridger were used to plough the entire area thoroughly. The experimental plot took shape when 50 kg of NPK was added, each block was intended to be 45 by 50 feet in size and had 3 blocks of barley, 6 blocks of wheat, 3 blocks of brassica, and 4 blocks of berseem. 1 kg of brassica seeds including three varieties (Khanpur, Super Raya, and Sindh Raya) were planted over 0.5 acres. The crops received five irrigations at varying intervals. At Tippun Dublo, irrigation scheduling was a major problem because the Ochto canal had to be stopped for maintenance, which prevented the crops from received water on time and resulted in low yields.

5. Cotton and Salicornia Cultivation

At certain crucial stages, such as germination, flowering, and boll formation, cotton is somewhat vulnerable to salt stress, which reduces biomass and fibre production (Maryum et al., 2022). According to Zhang et al. (2021), irrigation with the right amount of salt in the water had minimal impact on cotton growth and might even control plant type, lower water consumption, boost cotton production, and improve water usage efficiency. Cotton is not a common crop in Thatta, although farmers do grow it on a modest scale.

A cotton crop experiment was carried out in Kharif 2023 in the village of Allah Bux Shah.Two Salicornia genotypes (500 grams each) obtained from ICBA were also planted in the experimental plot of 2,152 square feet (40x54) for each genotype. Cotton was planted in Kharif 2023 on 0.9 acres. The FH-901 variety was spaced 6 inches apart, while the row-to-row spacing was maintained at 2 feet. There were two sources of water available for cotton irrigation: groundwater and canal water from the Ochto River. The first time Salicornia was planted in Keti Bandar, ICBA supplied the seed for the project. Although it was a crop with potential for coastal and salinity regions and was produced effectively in the United Arab Emirates, it was not well recognised in Pakistan, particularly in Keti Bandar.

Salicornia cultivation was planned with input from the IUCN, SOFT, and specialists from MUET and ICBA. In Tippun Dublo's cultivated fields, 2 kg/m^2 of compost and 4 kg/m^2 were applied to the uncultivated area. In March 2023, the Salicornia seed was sown after consulting with SOFT and IUCN. As advised by ICBA, the seeds were dispersed in a row with a 50 cm spacing between rows and a 0.5 cm sowing depth. In the first part of March 2023, a tractor ploughed this land twice. Three manually levelled plots, each measuring forty feet in width and fifty feet in length, were created. The three plots were further divided into four beds. A total of twelve beds were constructed, with the intention of treating each one uniquely regarding the amount and technique of irrigation, the planting techniques, and the application of well-rotted farmyard manure (FYM). To mix and cool the FYM, the beds were further irrigated and hoed twice before seeding. Since Salicornia was a new intervention, the seed was sown immediately into the field without first undergoing a small-scale trial. Unfortunately, the Salicornia crop could not survive, and the germination rate was less than 1% due to the extremely warm weather in district Thatta during the sowing season. Upon visiting the trial site, the PCRWR team made some observations regarding the quality of the soil and water.

Data Collection

The government agriculture lab, which received water samples from the IUCN team, supplied the first data on water quality. The entire team, comprising SOFT, IUCN, the farming community and the technical team collected the experiment data using the farmers' daily records. The SOFT team was brought in to gather information on the quantity of irrigations, germination rate, and mortality percentages. Farmers collected data on vegetable irrigation, including the number of days and irrigation intervals. Date-wise records of farmers were kept. The following relationship was used to estimate the volume of irrigation water using the volumetric approach.

Volume of water (m^3) = Length of furrow x width of furrow x depth of water
(Eq.1)

In conjunction with IUCN, the community together with the SOFT team conducted agronomic observations for all agricultural trials. Information on the agricultural experiment was examined, including plant height (cm), number of branches, number of fruit and fruit weight of three randomly chosen plants from each irrigation treatment. To evaluate the health of plants, including chilis cultivated with varying irrigation intervals, six randomly chosen plants from each treatment were examined for their fruit's diameter, weight, and length. Twelve plants in all were chosen and collected for agronomic observations, six from each treatment. The collected chili fruit were weighed. Like chili, the agronomic data for bitter gourd were collected with and without mulch. A Vernier caliper was used to measure the fruit's diameter, and a measuring tape was used to measure its length. By the end of November 2022, the agronomic observations were being recorded every two weeks. At Tippun Dublo, the mature bitter gourd and ridge gourd were periodically harvested from field plots with and without mulch, and their weight was measured using a weighing machine.

In Rabi 2022, Wheat, Barley, Brassica and Berseem were sown, the data including fertiliser dose, the amount of Irrigation, salinity impact on yield was jointly calculated by the SOFT and IUCN with the involvement of farmers at Tippun Dublo. Mr. Salim Shah, a farmer oversaw the irrigation application calendar and participated directly in data computation.

Results

1. Chili Experiment

The chili plot received twelve irrigations in total. Until the crop reached physiological maturity, irrigations were applied every two to three days at a depth of 5 cm. A total of 12.35 m^3 of water were applied for each treatment. Irrigation applications according to dates are shown in Figure 1.

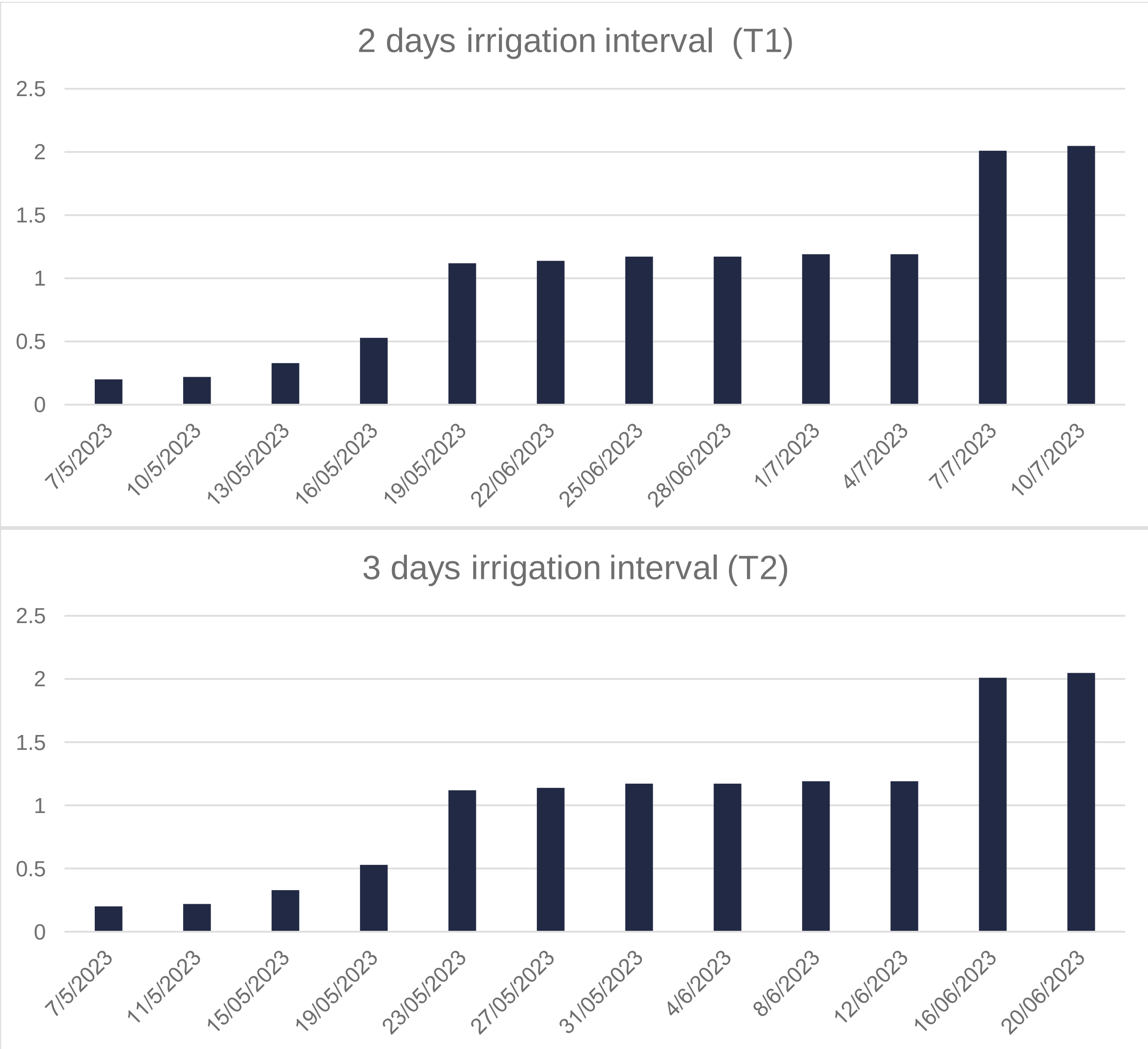

Figure 1. Total number of Irrigation applied to chili crop under treatment T1 and T2

Table 1 indicates that the average plant height and average fruit weight of chili under T1 irrigation treatment (2-day irrigation interval) were 28.72 cm and 1.4 gm respectively, significantly higher than those under T2 (3-day irrigation interval), which were 20.12 cm and 0.96 gm respectively. Based on the data shown in Table 1, estimates of chili yields have been calculated as actual yield data were not available due to the extreme monsoon event that occurred in July 2023. As only 9 chilis were picked, an estimate of potential yield is shown in Figure 2 (18 tons/ha for T1 compared with 15 tons/ ha under T2).

Table 1. Agronomic data of chili including Plant height, no of branches, number of fruit and average fruit weight under T1 and T2

	T1 (2 days irrigation interval)				T2 (3 days irrigation interval)			
Date of observation	Plant height (cm)	No. of branches	No. of fruit	Av. fruit weight (gm)	Plant height (cm)	No. of branches	No. of fruit	Av. fruit weight (gm)
28-05-22	11.15	3	08	0.9	09.15	2	05	0.6
13-06-22	19.37	5	15	1.2	12.37	3	11	0.9
28-06-22	28.45	7	22	1.6	21.45	5	17	0.8
10-07-22	37.13	8	35	1.5	28.13	6	27	1.1
18-07-22	47.51	10	47	1.8	29.51	8	34	1.4
Average	**28.72**	**6.6**	**25.4**	**1.4**	**20.12**	**4.8**	**18.8**	**0.96**

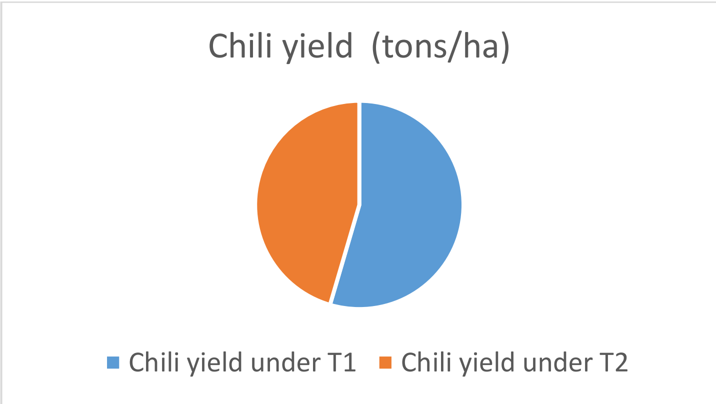

Figure 2. Estimated chili yields comparing the two irrigation interval treatments

Figure 3. Chili Transplantation at Tippun Dublo

2. Bitter Gourd and Ridge Gourd Experiment

The total number of irrigations including soaking dose applied to bitter-gourd crop since sowing up to the end of the crop season was 53. The total water applied under each treatment was 81.8m^3. Figure 4 shows fruit length and diameter of three randomly selected plants from each irrigation treatment. Overall, nine plants were selected for harvesting the bitter gourd fruits. The average length of fruit under T1 was measured 11.93cm followed by 10.65cm under T2. Fruit diameter under T1 was 2.37cm followed by 1.43cm under T2. Similarly, the average fruit length and diameter of ridge gourd under T1 were observed to be higher in comparison with T2 which was without mulch.

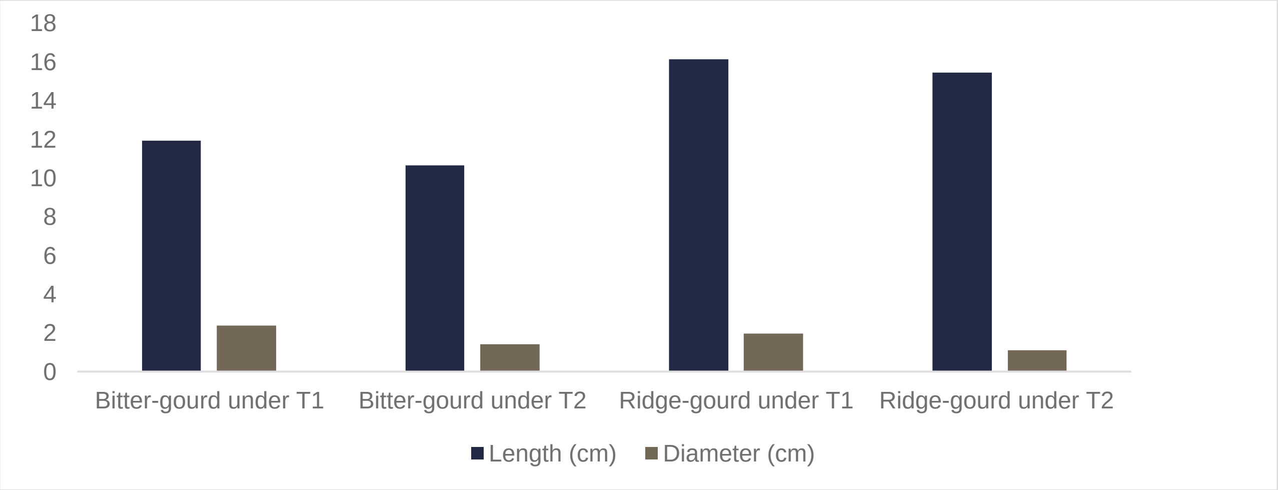

Figure 4. Average fruit length and diameter of bitter gourd under T1 and T2

The average weight of chosen bitter gourd fruits under T1 was 50.14 gm, whereas under T2, the average weight was 44.36 gm (Figure 5). The ridge-gourd with organic mulch had an average weight of 50.14 gm, and then 41.36 gm, following the same pattern as the bitter-gourd.

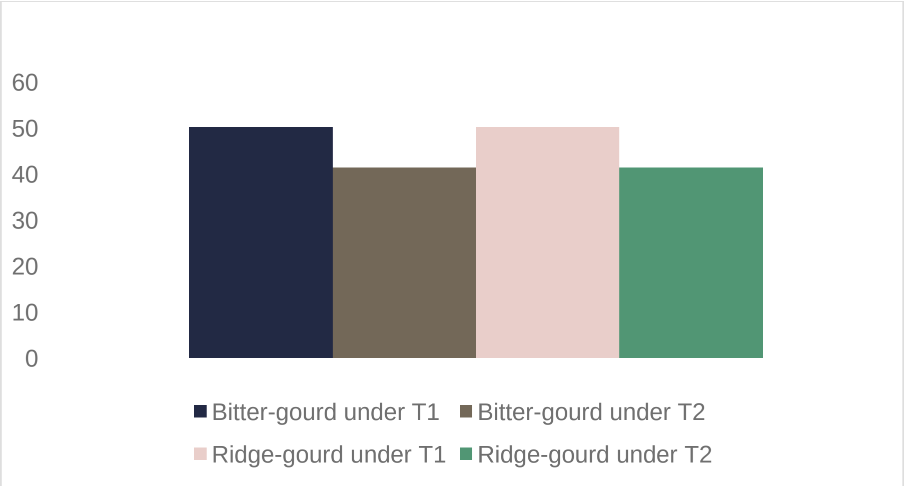

Figure 5. Average fruit weight of bitter gourd under T1 and T2

The harvesting of bitter-gourd and ridge gourd started in September 2022 and ended in November 2023. The total number harvested was 17, with total yields of bitter gourd obtained under T1 and T2 being 131 kg and 84 kg respectively. However, the average yield of ridge gourd under T1 and T2 was 160 kg/plot and 115 kg/plot. The bitter-gourd yield was further computed on hectare basis which came to 22 tons/ha and 17 tons/ha under T1 and T2 respectively. However, the average yield of ridge-gourd on hectare basis were 24 tons/ha and 19.5 tons. ha^{-1} (Figure 6).

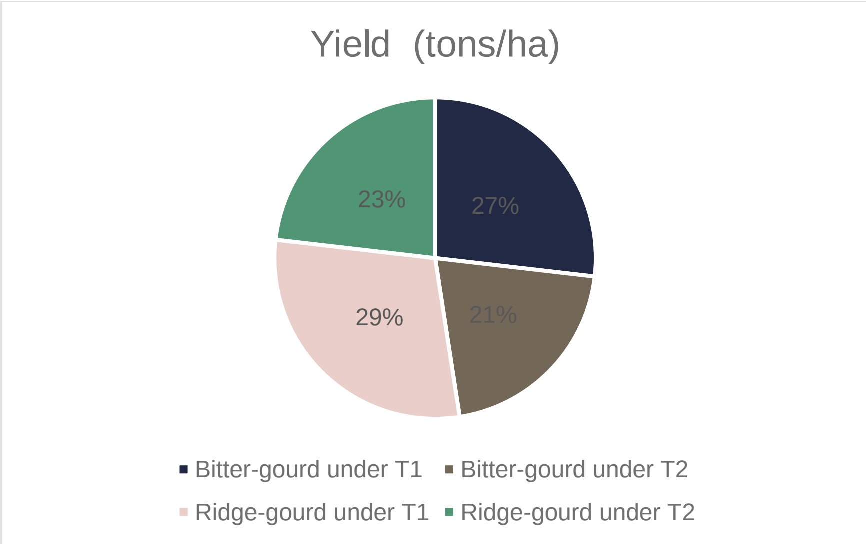

Figure 6. Average yield of bitter gourd and ridge gourd under T1 and T2

Figure 7. Vertical farming of ridge gourd and bitter gourd

3. Multi-layer Cropping Model for Kitchen Gardening

The introduction of a multilayer cropping model for kitchen gardening successfully enabled women farmers to learn cultivation process from sowing to harvesting, including how to protect their crop from pest and insect attack. The training on kitchen gardening was very useful to enhance the capacity of women farmers in the use of climate resilience agriculture to meet the food security challenges in a saline environment. The community mentioned that before the training provided by the SOFT team, they used to cultivate only a single crop and did not use bio pesticide. The community appreciated the role of bio pesticide and its effective use in kitchen gardening at their own resources. Intercropping of vegetables was found to be a good initiative. It was observed that the fruit health including plant height and yield of bottle gourd, chili and kadoo was much better under organic mulch than with no mulch.

Figure 8. Dry banana leaves used as mulch as part of the multi-layer cropping experiment

Figure 9. Kitchen garden training at Tippun Dublo

4. Wheat, Barley, Brassica and Berseem Cultivation

Figure 10. Wheat, brassica and berseem growing at Salim Shah's plot in Tippun Dublo

Figure 11 shows the total seed sown of berseem, wheat, brassica and barley at Tippun Dublo was 4, 16, 2 and 10 kg respectively. Wheat, brassica and berseem performed better than barley, which did not perform well under saline irrigation.

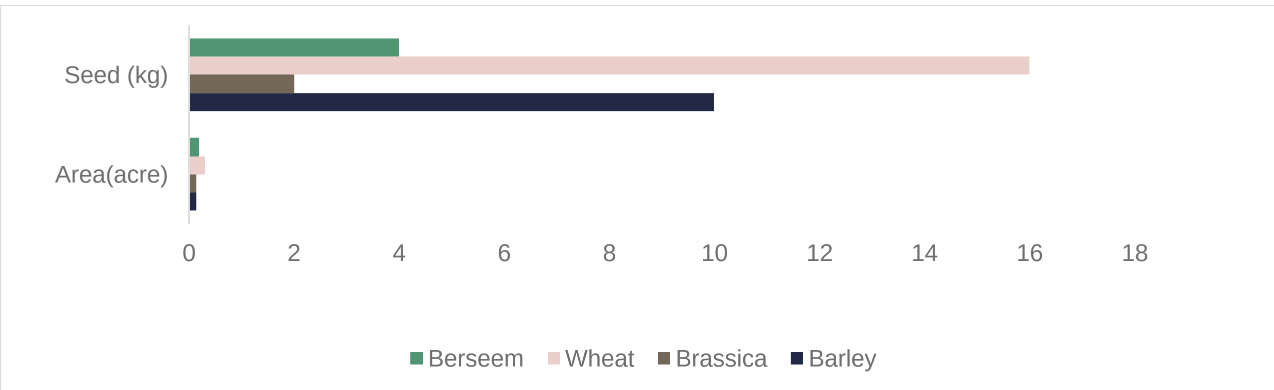

Figure 11. Seeds sown in experimental area at Tippun Dublo by acre

Overall, the germination percentage of all above crops was not good with only a few plots offering positive outcomes. Table 2 shows that the average yield of wheat was 13 maunds per acre (c. 1,200 kg per hectare) with a net profit of Rs. 19,100, the average yield of brassica was 19 maunds per care (c. 1,750 kg per hectare) with a net profit of Rs 73,700, and the average yield of berseem was 354 maunds per care (32,650 kg per hectare) with a net profit of Rs 60,700. Overall berseem performed well at Tippun Dublo with high agricultural productivity as berseem is more salt tolerant than the other Rabi crops grown there. Even though the yield of all crops grown in the plot was low, the farmer was happy that his once uncultivable land was now able to produce multiple crops, making him confident to grow more crops in the future.

Table 2. Yield and productivity of wheat, brassica and berseem
(1 maund = 37.32 kg; 1 acre = 0.405 hectares)

Crop	Yield (maunds per acre)	Price per maund (PKR)	Gross income	Total gross income	Cost per acre	Net income
Wheat	13	4,000	52,000 + 7,800 (straw)	61,100	42,000	19,100
Brassica	19	6,000	114,000	114,000	40,300	73,700
Berseem	354	250	88,500	8,500	27,800	60,700

5. Cotton and Salicornia Cultivation

Cotton cultivation was a big challenge for the farmer Mr. Salim Shah at Tippun Dublo but he was passionate about growing cotton, so he gave it a go with the support of SOFT and IUCN team. Unfortunately, the germination rate of cotton was only 10% in the first trial of 2023 because the seeds were sown later than recommended in the experimental area and the farmer was not able to obtain a salt tolerant variety of cotton seed.

Figure 12. Cotton Plot at Tippun Dublo in Kharif 2023

In a second trial during the April 2024 season, a hybrid cotton seed was sown in ridges, and the germination rate was much improved at 65%. The farmer, Salima Shah, attributed the improved result as a learning from the previous trial. They had identified the most suitable position on the slope of the ridge for where the seeds should be planted. A small amount of water applied every two days also gave a better establishment than larger amounts of water applied weekly, and the use of mulch was beneficial. The average yield of cotton at Tippun Dublo was found to be 380 kg per acre, which is 30% lower than in other parts of Sindh. However, the result still shows the potential to grow cotton in these salinity-affected coastal areas of Pakistan.

Figure 13. Cotton Plot at Tippun Dublo in Kharif 2024. What a difference!

The trial of Salicornia using seeds supplied by the International Center for Biosaline Agriculture (ICBA) was not successful at Tippun Dublo. Not a single plant of the Salicornia germinated despite the land being completely hoed. Other factors like irrigation and use of FYM were different in terms of quantity, quality and methods from bed to bed, which may have contributed to the failure of Salicornia. As the Salicornia seed is small, it may have been better to establish them as seedlings in a nursery first prior to being put into the ground.

Figure 14. Salicornia trial at Tippun Dublo as per ICBA recommendations

Discussion

The agricultural experiments at Tippun Dublo were challenging. In Kharif 2022, the experiment on chili was a good initiative. The overall performance of chili under two days irrigation interval was quite satisfactory as the frequent irrigation application helped prevent salts accumulating on the soil surface and good yields were achieved in comparison with three days irrigation interval. The results from this frequent irrigation scheduling regime for chili and use of organic mulch in general has contributed valuable insights to the ongoing discourse on sustainable agriculture development for saline affected areas across Pakistan. The fruit size and length of ridge gourd and bitter gourd increased under saline soil at Tippun Dublo. This was attributable to higher vegetative growth in summer, which was able to support higher fruit plant. These observations are in line with Jellani et al. (2016) who reported that lower yields of bitter gourd might be because of the impact of weather patterns on pollinator activity and higher temperatures during growth periods, which improved early production of flowers leading to early harvesting. The ridge gourd and bitter gourd yield increased under vertical farming and the use of organic mulch. The highest increase in vegetative growth might be due to the availability of soil moisture and temperature at optimum level (Pattanaik et al., 2003). The lowest value of vegetative growth without mulch might be because of moisture stress in the soil through surface irrigation and competition of weeds for nutrients (Agrawal & Agrawal, 2005).

Vegetable production under kitchen gardening provides the household with direct access to important nutrients (Shaheb et al., 2014). At Tippun Dublo, the kitchen gardening approach of growing multiple vegetables was a good initiative. A few vegetables like coriander, chili and bottle gourd gave good initial germination on raised beds. The findings revealed that seed germination percentage under saline irrigation plays a crucial role as it influences post-transplant growth in the field. However, the growth rate is significantly altered by the level of salinity in the water applied (Chachar et al., 2023)

Community participation with IUCN and SOFT significant improved data collection and Mr. Saleem Shah, a farmer at Tippun Dublo, was physically involved. Multiple vegetable cropping was a productive experiment at Tippun Dublo site which was moderately saline, and women farmers observed that the use of mulch including dry banana leaves gave positive results. They found that the availability of water when needed is a big challenge, so mulching supported the field experiment to reduce irrigation intervals as the soil was moist for two to three days. They thus saved their water and increased their productivity. Growing multiple types of vegetables also helped identify the potential of the crop for that area. While not all vegetables performed well, it was found that bottle-gourd, bitter-gourd and coriander had the potential to germinate and perform well in the saline environment.

Conclusion

Adapting to salinity through community co-inquiry into agricultural options is a revolutionary idea for sustainable coastal development. The agricultural experiments undertaken by the coastal community of Pakistan under the ASSIB project encountered several formidable challenges that cast a shadow on its sustainability. However, the resilience of the community and the invaluable lessons derived from these challenges have not only strengthened their capacity but also propelled them into the realm of entrepreneurs. The experiments involving chili, bitter gourd and ridge gourd underscores the significance of drawing on traditional knowledge, specifically in identifying locations with consistent seed availability, and integrating that knowledge with technical and extension support.

The adoption of the ASSIB approach through collaborative inquiry and joint decision-making has emerged as a cornerstone in sustaining vegetable farming in coastal areas of Sindh. This transformative journey has uplifted the community and breathed new life into their entrepreneurial spirit, providing them with a sustainable option for livelihood generation and food security. In essence, the uplift of climate resilience agriculture hinges on the synergy fostered through collaborative efforts among stakeholders, government bodies, and industry players, creating an opportunity to cultivate and convert saline land into productive.

Multiple interventions regarding agriculture were carried out at Tippun Dublo including on farm vegetable cultivation, kitchen gardening and crop cultivation. The merger of scientific expertise and local knowledge led to a community-driven multiple vegetable kitchen gardening experiment. In terms of fruit size and yield, vertical cultivation of ridge gourd and bitter gourd with organic mulch produced good results. Mulching improved the crop cycle and helped to preserve soil moisture, all of which contributed to an overall boost in yield.

Salicornia and the first trial of cotton did not produce noteworthy results because of high temperatures, long sowing period, time of sowing, and/or seed quality in the case of the first cotton trial. However, the second trial of cotton yielded better results, perhaps due to improved seed quality, time of sowing, better use of irrigation, and application of mulch. It might be challenging to find certified Salicornia seed in Pakistan, especially for imported seed that is typically not tested under the same agricultural conditions. Therefore, it was noted that to prevent low yield, particularly in saline locations, the quality of seed should be checked by a registered body such as the Seed Certification Department.

Because cotton, berseem, brassica, and wheat had good results, the community was resolved to use these crops going forward with effective management. The agriculture concept, particularly in a saline environment, sets a revolutionary pattern for Sindh. With the world struggling with the necessity of sustainable growth, this project's flexible methodology showcases its unique and avant-garde character. Important insights for creating an ecosystem that supports the long-term viability of salt-tolerant crops in Sindh's coastal areas can be gained from projects that use the ASSIB approach of co-inquiry.

References

Ahmadi, M., & Souri, M.K. (2018). Growth and mineral content of coriander (*Coriandrum sativum* L.) plants under mild salinity with different salts. *Acta Physiologiae Plantarum, 40*(11), 194. https://doi.org/10.1007/s11738-018-2773-x

Agrawal, N., & Agrawal S. (2005). Effect of drip irrigation and mulches on the growth and yield of banana cv. Dwaraf Cavendish. *Indian Journal of Horticulture, 62*(3), 238-240.

Agriculture Policy Institute. (2023). *Wheat Policy Analysis for 2023-24 Crop.* Islamabad, Pakistan: Agriculture Policy Institute, Ministry of National Food Security and Research, Government of Pakistan.

Asif, M., Akram, M., & Ali, A. (2016). Multi-locational trials to compare the relative water use and vegetable crops productivity by drip irrigation and conventional furrow irrigation systems in district Toba Tek Singh, Pakistan. *Science Letters, 4*(1), 60-65.

Biswas, S.K., Akanda, A.R., Rahman, M.S., & Hossain, M.A. (2016). Effect of drip irrigation and mulching on yield, water-use efficiency and economics of tomato. *Plant, Soil and Environment, 61*(3), 97-102. https://doi.org/10.17221/804/2014-PSE

Chachar, M., Hakro, R.A., Ahmed, S., Murtaza, G., Jillani, P.S.A.N.S., & Baloch, H. (2023). Innovative approaches to enhancing food security: Saline water kitchen gardening. *Global Research in Environment and Sustainability, 1*(9), 23-29.

Dalamu, Behera, T.K., Gaikwad, A.B., Saxena, S., Bharadwaj, C., & Munshi, A.D. (2012). Morphological and molecular analyses define the genetic diversity of Asian bitter gourd (*Momordica charantia* L.). *Australian Journal of Crop Science, 6*(2), 261-267.

Dawar, K., Khalil, Z., Mian, I. A., Khan, B., Ali, S., Rahi, A. A., . . . Datta, R. (2022). Effects of Farmyard Manure and Different Phosphorus Inorganic Fertilizer Application Rates on Wheat Cultivation in Phosphorus-Deficient Soil. *Sustainability, 14*(15), 9030. https://doi.org/10.3390/su14159030

de la Peňa, R., & Hughes, J. (2007). Improving vegetable productivity in a variable and changing climate. *Journal of SAT Agricultural Research, 4*(1), 1-22.

Dissanayake, B.M., Staudinger, C., Munns, R., Taylor, N.L., & Millar, A.H. (2022). Distinct salinity-induced changes in wheat metabolic machinery in different root tissue types. *Journal of Proteomics, 256*, 104502. https://doi.org/10.1016/j.jprot.2022.104502

EL Sabagh, A., Islam, M.S., Skalicky, M., Ali Raza, M., Singh, K., Anwar Hossain, M., . . . Arshad, A. (2021). Salinity Stress in Wheat (*Triticum aestivum* L.) in the Changing Climate: Adaptation and Management Strategies. *Frontiers in Agronomy, 3,* 661932. https://doi.org/10.3389/fagro.2021.661932

Galhena, D.H., Freed, R., & Maredia, K.M. (2013). Home gardens: a promising approach to enhance household food security and wellbeing. *Agriculture and Food Security, 2*(1), 8. https://doi.org/10.1186/2048-7010-2-8

Government of Pakistan, (2024), *Pakistan Economic Survey 2023-24*, Finance Division, Government of Pakistan, Islamabad, Pakistan. https://www.finance.gov.pk/survey_2024.html

Hazzouri, K.M., Khraiwesh, B., Amiri, K.M.A., Pauli, D., Blake, T., Shahid, M., . . . Masmoudi, K. (2018). Mapping of HKT1;5 gene in barley using GWAS approach and its implication in salt tolerance mechanism. *Frontiers in Plant Science, 9*, 156. https://doi.org/10.3389/fpls.2018.00156

Heaney-Mustafa, S., Channa, M. Y., Baloch, T., Channa, M. A., Kumbhar, B., Mohiuddin, I. Riaz, M. F., Rubab, A., Samoo, A. H., Zahid, S. M. A., & Zaman, B. (2023). *Stakeholder engagement for research and learning (SERL): Theoretical underpinnings and guidelines for facilitators (Gulbali Institute Report No. 3).* Albury, NSW: Gulbali Institute, Charles Sturt University. https://www.csu.edu.au/research/gulbali/about-us/publications

Hossain, D., Karim, M.A., Pramanik, M.H.R., & Rahman, A.S. (2006). Effect of Gibberellic Acid (GA_3) on flowering and fruit development of bitter gourd (*Momordica charantia* L.). *International Journal of Botany, 2*(3), 329-332. https://doi.org/10.3923/ijb.2006.329.332

Irshad, M., Eneji, A.E., Khattak, R.A., & Khan, A. (2009). Influence of nitrogen and saline water on the growth and partitioning of mineral content in maize. *Journal of Plant Nutrition, 32*(3), 458-469. https://doi.org/10.1080/01904160802660768

Jana, H. (2014). Bitter gourd growers pesticides use pattern in controlling insect-pests and diseases in Nadia district of West Bengal. *Agriculture Update, 9*(3):320-326.

Jarwar, A., Samoo, A.H., Malik, I.N., Soomro, N.A. (2024). *Living with Salinity in the Southern Indus Basin through Aquaculture (Gulbali Report No. 13).* Albury, NSW: Gulbali Institute, Charles Sturt University https://www.csu.edu.au/research/gulbali/about-us/publications/

Jellani, G., Atif, M.J., Ullah, H., Khan, T.N., & Saleem, N. (2016). Seedling age impact on growth and yield of bitter gourd. *Science, Technology and Development, 35*(2), 94-97.

Jodder, R., Asadul Haque, M., Kumar, T., Jahiruddin, M., Zulfikar Rahman, M., & Clarke, D. (2016). Climate change effects and adaptation measures for crop production in southwest coast of Bangladesh. *Research in Agriculture, Livestock and Fisheries, 3*(3), 369-378. https://doi.org/10.3329/ralf.v3i3.30727

Kumbhar, B., Heaney-Mustafa, S., Mitchell, M., Qureshi, A.L., Baloch, T.S., & Ullah, A. (under review). Building and scaling out knowledge: Women as researchers in raising multi-vegetable gardens in Malwah, Sindh, Pakistan.

Lekakis, E.H., & Antonopoulos, V.Z. (2015). Modeling the effects of different irrigation water salinity on soil water movement, uptake and multicomponent solute transport. *Journal of Hydrology, 530*, 431-446. https://doi.org/10.1016/j.jhydrol.2015.09.070

Lim, T. (1998). Loofahs, gourds, melons and snake beans. In K.W. Hyde (Ed.), *The New Rural Industries: A Handbook for Farmers and Investors* (pp. 212-218). Canberra: Rural Industries Research and Development Corporation.

Lyra, D.-A., Raman, A., Hozayen, A., Zaaboul, R., Abou-Zaid, F.O., El-Naggar, A., . . . Ammar, K. (2022). Evaluation of *Salicornia bigelovii* germplasm for food use in Egypt and the United Arab Emirates based on agronomic traits and nutritional composition. *Plants, 11*(19), 2653. https://doi.org/10.3390/plants11192653

Maryum, Z., Luqman, T., Nadeem, S., Khan, S.M.U.D., Wang, B., Ditta, A., & Khan, M.K.R. (2022). An overview of salinity stress, mechanism of salinity tolerance and strategies for its management in cotton. *Frontiers in Plant Science, 13*, 907037. https://doi.org/10.3389/fpls.2022.907937

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology, 59*, 651–681. https://doi.org/10.1146/annurev.arplant.59.032607.092911

Oldfield, E.E., Wood, S.A., & Bradford, M.A. (2018). Direct effects of soil organic matter on productivity mirror those observed with organic amendments. *Plant and Soil, 423*(1), 363-373. https://doi.org/10.1007/s11104-017-3513-5

Pattanaik, S.K., Sahu, N.N., Pradhan, P.C., & Mohanty, M.K. (2003). Response of banana to drip irrigation under different irrigation designs. *Journal of Agricultural Engineering, 40*(3), 29-34.

Pi, X., Zhang, T., Sun, B., Cui, Q., Guo, Y., Gao, M., Feng, H., & Hopkins, D.W. (2017). Effects of mulching for water conservation on soil carbon, nitrogen and biological properties. *Frontiers of Agricultural Science and Engineering, 4*(2), 146-154. https://doi.org/10.15302/J-FASE-2017136

Qureshi, A. L., Memon, K. S., Zaidi, A. Z., Ullah, A., Kumbhar, B. & Zaman, B. (2024). *Summary of Co-Inquiry Research Experiences with Salinity-Affected Farming Communities along the Malwah Distributary (Gulbali Report No. 10).* Gulbali Institute, Charles Sturt University, Albury, NSW. https://www.csu.edu.au/research/gulbali/about-us/publications/

Rajpar, I., Khanif, Y., Soomro, F., & Suthar, J. (2006). Effect of NaCl salinity on the growth and yield of Inqlab wheat (*Triticum aestivum* L.) Variety. *American Journal of Plant Physiology, 1*(1), 34-40.

Rashid, M.F., Aziz, T., Maqsood, M.A., & Farooq, M. (2019). Soil phosphorus fractions and their transformation in normal and salt affected soils as affected by organic amendments. *Pakistan Journal of Agricultural Sciences, 56*(2), 301-312. https://doi.org/10.21162/PAKJAS/19.8083

Richey, A.S., Thomas, B.F., Lo, M.-H., Reager, J.T., Famiglietti, J.S., Voss, K., . . . Rodell, M. (2015). Quantifying renewable groundwater stress with GRACE. *Water Resources Research, 51*(7), 5217-5238. https://doi.org/10.1002/2015WR017349

Shaheb, M.R., Nazrul, M.I., & Sarker A. (2014). Improvement of livelihood, food and nutrition security through homestead vegetables production and fruit tree management in Bangladesh. *Journal of the Bangladesh Agricultural University, 12*(2), 377-387.

Shahzad, B., Rehman, A., Tanveer, M., Wang, L., Park, S.K., & Ali, A. (2022). Salt stress in *brassica*: Effects, tolerance mechanisms, and management. *Journal of Plant Growth Regulation, 41*, 781-795. https://doi.org/10.1007/s00344-021-10338-x

Soomro, K.B., Alaghmand, S., Shaikh, M.M., Andriyas, S., & Talei, A. (2021). Response of salts in saline soil using different irrigation scheduling in semi-arid zone of Pakistan. *Pakistan Journal of Scientific and Industrial Research Series A: Physical Sciences, 64*(2), 110-118. https://doi.org/10.52763/PJSIR.PHYS.SCI.64.2.2021.110.118

Tarolli, P., Luo, J., Park, E., Barcaccia, G., & Masin, R. (2024). Soil salinization in agriculture: Mitigation and adaptation strategies combining nature-based solutions and bioengineering. *iScience, 27*(2), 108830. https://doi.org/10.1016/j.isci.2024.108830

Wang, Z., Jin, M., Šimůnek, J., & van Genuchten, M.T. (2014). Evaluation of mulched drip irrigation for cotton in arid Northwest China. *Irrigation Science, 32*(1), 15-27. https://doi.org/10.1007/s00271-013-0409-x

Wood, S.A., Tirfessa, D., & Baudron, F. (2018). Soil organic matter underlies crop nutritional quality and productivity in smallholder agriculture. *Agriculture, Ecosystems and Environment, 266*, 100-108. https://doi.org/10.1016/j.agee.2018.07.025

Zhang, J., Zhang, P., Huo, X., Gao, Y., Chen, Y., Song, Z., . . . Zhang, J. (2021). Comparative phenotypic and transcriptomic analysis reveals key responses of upland cotton to salinity stress during postgermination. *Frontiers in Plant Science, 12*, 639104. https://doi.org/10.3389/fpls.2021.639104

Appendix 1. Soil and Water Quality Report for Tippun Dublo Agricultural Sites

OFFICE OF THE
DISTRICT SOIL & WATER TESTING LABORATORY
THATTA @ MAKLI

No. Sr. Sci (S&WTL)Tech. 52 / 2022 **Dated:** 21-02-2022

Soil and water Analysis of (LOCATOIN NO: 01)
HAJI AYOOB RANO

Soil sample	Depth (cm)	EC (dS/m)	pH	MC (%)	O.M	Textural Class
Block 1	0-15	10.37	8.2	42.2	0.41	Silty Loam
	15-30	6.67	8.5	41.2	0.29	Silty Loam
Block 2	0-15	4.29	8.5	41.7	0.35	Silty Loam
	15-30	1.63	8.7	40.4	0.42	Silty Loam
Block 3	0-15	4.53	8.5	43.0	0.43	Silty Clay Loam
	15-30	2.38	8.2	46.1	0.28	Silty Loam

S.No	Water Sample	pH	EC (dS/m	TSS	Remarks
1	Ground water (Bore 1)	7.3	6.03	4221	Fit for irrigation
2	Ground water (Bore 2)	7.2	2.39	1530	Highly alkaline not fit for irrigation
3	Ground water (Bore 3)	7.3	2.09	1338	Highly alkaline not fit for irrigation

TSS CLASSIFICATION/LIMITS IN PPM

Soil and water Analysis of (LOCATION NO: 2)
PIR ALLAH BUX

Soil sample.	Depth (cm)	EC (dS/m)	pH	MC (%)	O.M	Textural Class
Block 1	0-15	8.12	8.3	18.7	0.55	Silty Clay Loam
	15-30	5.88	8.3	5.9	0.48	Silty Clay Loam
Block 2	0-15	12.45	8.5	31.9	0.36	Silty Clay Loam
	15-30	4.25	8.6	7.0	0.35	Silty Loam
Block 3	0-15	33.72	8.7	5.9	0.41	Silty Clay Loam
	15-30	26.41	9.1	10.1	0.35	Silty Clay Loam

S.No	Water Sample	pH	EC (dS/m	TSS	Remarks
1	Canal/River water	7.2	3.73	2387	Highly alkaline not fit for irrigation
2	Ground water (Bore 1)	7.0	3.64	2330	Highly alkaline not fit for irrigation

TSS CLASSIFICATION/LIMITS IN PPM

Soil and water Analysis of (LOCATOIN NO: 03)
MUHAMMED ALI BHARJ

Soil sample	Depth (cm)	EC (dS/m)	pH	MC (%)	O.M	Textural Class
Block 1	0-15	17.41	8.2	44.1	0.29	Silty Loam
	15-30	7.73	8.5	45.7	0.48	Silty Loam
Block 2	0-15	4.68	8.5	46.9	0.41	Clay Loam
	15-30	2.89	8.7	47.0	0.39	Silty Loam
Block 3	0-15	9.64	8.5	48.7	0.46	Silty Clay Loam
	15-30	9.45	8.2	41.6	0.33	Silty Loam

S.No	Water Sample	pH	EC (dS/m)	TSS	Remarks
1	Canal/River water	7.3	1.45	928	Fit for irrigation

TSS CLASSIFICATION/LIMITS IN PPM

Gulbali Institute
Agriculture, Water and Environment

Charles Sturt University
Boorooma Street
Locked Bag 588
Wagga Wagga NSW 2678

1800 275 278 (free call within Australia)
+61 1800 275 278 (callers outside Australia)

gulbali@csu.edu.au

gulbaliinstitute gulbali_inst

gulbaliinstitute charlessturtuni

Charles Sturt University
Gulbali Institute
Agriculture Water Environment

IUCN

INTERNATIONAL UNION FOR CONSERVATION OF NATURE
Karachi Programme Office
House No. F-17/B/2
Clifton, Block-7
Karachi 75600, Pakistan
Tel +92 (21) 35861540/41/42
Fax +92 (21) 35861448
cro.pk@iucn.org
www.iucn.org/pakistan