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Strengthening Local Seed Systems Through Community Seed Banks For Sustainable Agricultural Development In Bara, District Khyber, Pakistan

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ABSTRACT

Community Seed Banks (CSBs) have emerged as an important strategy for strengthening local seed systems and promoting sustainable agricultural development in marginalized farming regions. The present study evaluated the role of CSBs in improving seed accessibility, crop productivity, crop diversity, climate resilience and household food security in Bara Tehsil, District Khyber, Khyber Pakhtunkhwa, Pakistan. A quantitative cross-sectional survey was conducted using stratified random sampling. A total of 230 farmers were selected and equally divided into CSB participant farmers (n = 115) and non-CSB farmers (n = 115). Primary data were collected through structured questionnaires, farmer interviews and field observations. Descriptive statistics, independent sample t-tests and multiple linear regression analysis were applied using SPSS. The socio-economic analysis indicated that 54.8% of respondents were smallholder farmers owning less than 1 hectare of land, while 37.4% were illiterate. Non-CSB farmers heavily depended on farmer-saved seed (69%), whereas CSB farmers diversified their seed sources through community seed banks (45%). Comparative yield analysis revealed significantly higher productivity among CSB farmers for wheat (2.82 ± 0.32 t/ha), summer OPV vegetables (6.40 ± 0.80 t/ha) and winter OPV vegetables (5.90 ± 0.70 t/ha) compared with non-CSB farmers, with highly significant differences ($p < 0.01$). Timely seed access improved from 59% among non-CSB farmers to 93% among CSB participants, while seed costs decreased by approximately 27%. Community seed

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banks also enhanced agrobiodiversity, climate resilience and increasing adoption of drought-resistant varieties. Household food security was substantially higher among CSB farmers (74%) compared with non-participants (43%). Regression analysis identified CSB participation as the strongest predictor of crop productivity (β = +0.65; $p < 0.01$), and the model explained 71% of total yield variation ($R^2 = 0.71$). The study concludes that CSBs significantly contribute to sustainable agriculture, biodiversity conservation and rural food security in conflict-affected regions of Pakistan.

Keywords: Community seed banks, sustainable agriculture, local seed systems, food security, crop diversity, climate resilience, Bara Tehsil, District Khyber.

Introduction

Agriculture remains the backbone of rural livelihoods in Pakistan and contributes significantly to food security, employment and economic stability (Shah et al., 2026). However, the sustainability of agricultural production is increasingly threatened by climate change, land degradation, declining genetic diversity and limited access to quality agricultural inputs, particularly seeds. Seed systems play a central role in agricultural productivity because seeds determine crop yield potential, resilience to environmental stress and adaptation to local ecological conditions (Aziz et al., 2025). In many developing countries, including Pakistan, informal seed systems dominate agricultural production, where farmers largely depend on farm-saved seed, local exchange and traditional knowledge for crop cultivation (FAO, 2021). Although these systems preserve indigenous genetic resources, they often suffer from poor seed quality, low productivity and weak institutional support.

In Khyber Pakhtunkhwa, especially in the newly merged tribal districts such as District Khyber, access to certified and improved seed remains limited due to geographic isolation, poor infrastructure, socio-economic instability and inadequate agricultural extension services. Consequently, farmers in Bara Tehsil primarily rely on traditional seed-saving practices and local seed markets, which frequently lack quality assurance and climate-resilient crop varieties. Such dependency has contributed to low agricultural productivity, food insecurity and vulnerability to climate-induced stresses including drought, erratic rainfall and pest outbreaks

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(CIMMYT, 2020). Moreover, the erosion of local crop diversity has become a major concern, threatening long-term agricultural sustainability and the conservation of indigenous germplasm.

Community Seed Banks (CSBs) have emerged globally as an effective strategy for strengthening local seed systems and promoting sustainable agriculture. These are farmer-managed institutions that conserve, multiply, store and distribute locally adapted seeds within rural communities. These systems enhance farmers' access to affordable and diverse seed varieties while simultaneously conserving traditional landraces and improving climate resilience (Vernooy et al., 2017). Previous studies have demonstrated that CSBs contribute significantly to crop productivity, seed security, biodiversity conservation and community empowerment in marginalized farming regions

(Shrestha et al., 2013). In addition, CSBs reduce farmers' dependence on external seed markets and enhance local participation in seed governance and agricultural decision-making processes. In Pakistan, the concept of community-based seed systems has gained increasing attention in recent years due to growing concerns regarding seed availability, food insecurity and climate vulnerability. Several development organizations and agricultural programs have promoted local seed conservation and participatory seed distribution in rural areas. Nevertheless, empirical research examining the effectiveness of community seed banks in conflict-affected and resource poor regions such as Bara remains limited. Understanding the socio-economic and agricultural impacts of CSBs is essential for designing evidence-based policies aimed at strengthening local seed sovereignty and sustainable rural development. Furthermore, there is a need to quantitatively evaluate how community seed banks influence crop productivity, seed accessibility, crop diversity and household food security under local farming conditions.

Therefore, the present study was conducted to assess the role of community seed banks in strengthening local seed systems and promoting sustainable agricultural development in Bara Tehsil, District Khyber, Pakistan. Specifically, the study aimed to compare CSB participant and non-participant farmers regarding crop productivity, seed access, food security and climate resilience. The study also investigated farmers' perceptions toward CSBs and identified the major constraints affecting their

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expansion and sustainability. The findings of this research are expected to provide valuable insights for policymakers, agricultural extension departments and development organizations working to improve rural livelihoods and sustainable agriculture in marginalized regions of Pakistan. Participation in Community Seed Banks (CSBs) has a significant positive effect on crop productivity, seed accessibility, crop diversity, household food security and sustainable agricultural development among farmers in Bara Tehsil.

Methodology Study Area

The study was conducted in Bara, District Khyber, Khyber Pakhtunkhwa, Pakistan, where two community seed banks (CSBs) were established to improve farmers' access to quality seed, enhance seed security, and strengthen local seed systems. The area is predominantly agricultural, with most farmers relying on small-scale farming for their livelihoods.

Community Engagement and Establishment of Seed Banks

The intervention began with consultative meetings involving Village Organization (VO) members to introduce the concept and objectives of community seed banks and promote community participation. A joint planning workshop with representatives from Village Organizations, Welthungerhilfe (WHH), and NIDA Pakistan was then conducted to identify suitable locations, infrastructure requirements, storage facilities, and seed types.

Following procurement and site preparation, two community seed banks were established in strategically selected Village Councils of Bara. Each seed bank was designed to serve farmers from approximately five surrounding Village Councils and Neighborhoods Councils.

Seed Procurement, Management, and Capacity Building

NIDA Pakistan stocked the seed banks with certified wheat seed and open-pollinated variety (OPV) vegetable seeds for both winter and summer seasons. Seeds were distributed according to seasonal requirements to ensure timely access to quality planting material.

To support sustainability, Seed Bank Maintenance Committees were formed, and formal agreements were signed among the committees, the Agriculture Extension

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Department, and NIDA Pakistan. The Agriculture Extension Department also provided training and awareness sessions on OPV seed promotion, seed storage and sustainable agricultural practices.

Study Design and Participants

The study employed a participatory intervention-based research design to assess the establishment and functioning of community seed banks. Participants included smallholder farmers from approximately ten Village Councils and Neighborhood Councils within the service areas of the seed banks. Data were collected to evaluate community participation, seed accessibility, institutional arrangements, and the contribution of community seed banks to local seed security and agricultural resilience.

Sampling Technique and Sample Size

A stratified random sampling technique was used to ensure representative participation from different farming communities within Bara Tehsil. Different union councils were purposively selected based on agricultural activity, existence of community-based seed initiatives and accessibility.

The total sample size consisted of 230 farmers, divided into two groups:

Farmer Category	Sample Size
CSB participant farmers	115
Non-CSB farmers	115
Total	**230**

The equal distribution of respondents allowed comparative statistical analysis between the two groups.

The sample size was determined using the sample size determination formula proposed by Yamane (1967) at a 95% confidence level and 5% margin of error:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

- n = required sample size
- N = total population of farmers in the selected area
- e = level of precision (0.05)

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Based on the estimated farming population of the selected union councils, the calculated sample size was approximately 230 respondents, which was considered adequate to provide reliable and statistically representative results. This sample size ensured sufficient power for comparative analyses between CSB participants and non-participants while minimizing sampling error.

Data Collection Methods

Primary data were collected through structured questionnaires, field observations and face-to-face interviews conducted during the cropping season. The questionnaire was designed in English and translated into Pashto and Urdu to facilitate farmer understanding.

The survey tool collected information on farmers' socio-economic characteristics, seed sources and management practices, crop productivity and farm performance. It also examined seed accessibility and costs, crop diversity and climate adaptation, household food security, farmers' perceptions regarding community seed banks and the constraints affecting agricultural sustainability.

Prior to data collection, a pilot survey involving 15 farmers was conducted to test the reliability and clarity of the questionnaire. Necessary modifications were made based on farmer feedback. **Variables of the Study**

Dependent Variables

- Crop yield (t/ha)
- Household food security status
- Crop diversity index

Independent Variables

- Participation in CSBs
- Farmyard Manure application
- Irrigation availability
- Farming experience
- Farm size
- Seed source type
- The study used crop yield (t/ha), household food security status and crop diversity index

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Measurement of Key Indicators Crop Productivity

Crop productivity was measured in tons per hectare (t/ha) for wheat, winter and summer OPV vegetable seed. Average yield values were calculated using farmer-reported production data and cultivated area.

Seed Accessibility

Seed accessibility was assessed based on:

- Timeliness of seed availability
- Distance to seed source
- Affordability of seed
- Dependence on external markets

Food Security Assessment

Household food security status was categorized into:

- Food secure
- Moderately food secure
- Food insecure

The classification was based on food availability, crop sufficiency, and frequency of food shortages during the year.

Statistical Analysis

Collected data were coded and entered into Statistical Package for Social Sciences (SPSS) version

26. Descriptive and inferential statistical methods were applied to analyze the data. The following statistical tools were used:

Statistical Tool	Purpose
Frequency and percentage	Socio-economic analysis
Mean ± Standard Deviation	Yield and perception analysis
Independent sample t-test	Comparison between CSB and non-CSB farmers
Multiple linear regression	Determinants of crop productivity
Likert scale analysis	Farmer perception assessment

all statistical tests was set at: $p \leq 0.05$

While highly significant relationships were considered at:

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$p \leq 0.01$

Regression Model Specification

To determine the effect of community seed bank participation on crop productivity, the following multiple linear regression model was applied:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \epsilon$$

Where:

Y	Crop yield (t/ha)
β_0	Constant/intercept
X1	CSB participation
X2	FYM
X3	Irrigation availability
X4	Farming experience
ϵ	Error term

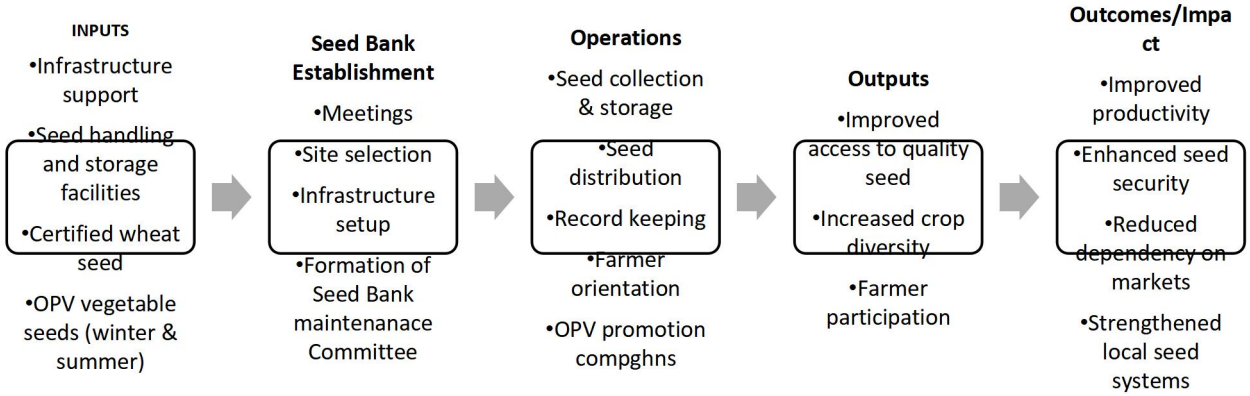


Fig. 1 Conceptual Framework of the Community Seed Bank System in Bara, District

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RESULTS AND DISCUSSION Study Design and Respondent Distribution

The study was conducted in Bara Tehsil of District Khyber to evaluate the contribution of Community Seed Banks (CSBs) toward strengthening local seed systems and promoting sustainable agricultural development. A total of 230 farmers were selected through stratified random sampling to ensure proper representation of different farming communities and agroecological zones. The respondents were equally divided into CSB participant and non-participant groups for comparative statistical analysis.

The selected area represents a semi-arid agricultural zone where farmers primarily depend on rainfed farming systems with limited irrigation facilities. Wheat, winter and summer OPV vegetable seed were selected as focal crops because of their importance in local food security and rural livelihoods.

Socio-Economic Characteristics of Respondents

The demographic analysis revealed that agriculture in Bara is mainly dominated by middle-aged farmers. About 42.6% of respondents belonged to the 36–50 years age group, followed by 33.9% above 50 years of age. Younger farmers represented only 23.5% of the total respondents, indicating relatively lower youth involvement in farming activities.

Educational analysis demonstrated that 37.4% of respondents were illiterate, while only 30% had secondary or higher education. Limited literacy may reduce farmers' ability to adopt modern agricultural technologies and improved seed management practices. Similar trends have been observed in other rural regions of Khyber Pakhtunkhwa where low literacy levels negatively influence agricultural innovation.

Farm size analysis indicated that smallholder farming systems dominate the study area. More than half of the farmers (54.8%) possessed less than 1 hectare of land. Small farm size limits farmers' financial capacity to purchase certified seed and agricultural inputs, thereby increasing dependence on local and informal seed systems. These findings emphasize the importance of low-cost and community-based agricultural interventions such as CSBs in marginalized farming regions.

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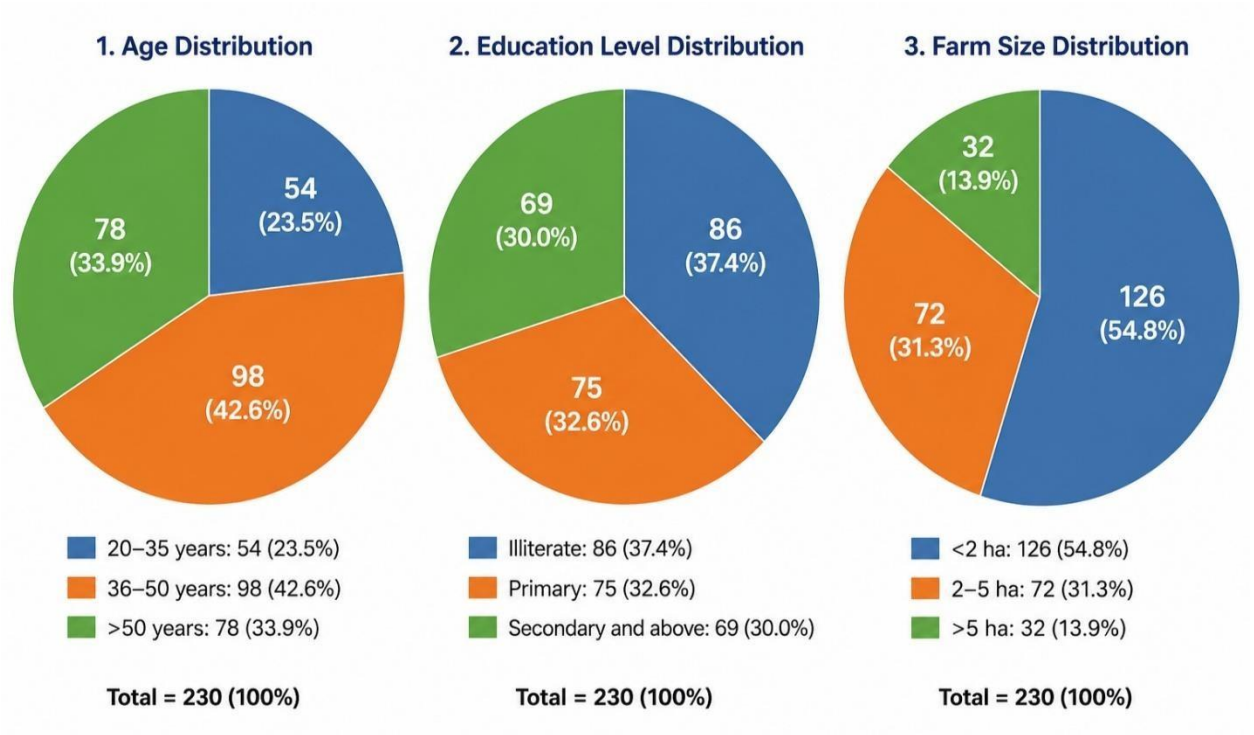
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Table 1. Demographic Characteristics of Farmers (n = 230)

Variable	Category	Frequency	Percentage (%)
Age	20–35 years	54	23.5
	36–50 years	98	42.6
	>50 years	78	33.9
Education Level	Illiterate	86	37.4
	Primary	75	32.6
	Secondary and above	69	30.0
Farm Size	<2 ha	126	54.8
	2–5 ha	72	31.3
	>5 ha	32	13.9



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Fig. 2. Demographic and Farm Characteristics of Respondents Seed Source Distribution

The results demonstrate a clear shift in seed sourcing patterns due to the role of Community Seed Banks (CSBs) in Bara. Non-CSB farmers continued to rely heavily on farmer-saved seed (69%), reflecting strong dependence on informal seed systems. In contrast, CSB farmers showed a marked transition toward certified seed usage, with 45% of farmers obtaining certified wheat seed through the community seed bank system.

Market and local dealer dependence was lower among CSB farmers (18%) compared to non-CSB farmers (21%), indicating reduced reliance on external seed markets. Only a small proportion of CSB farmers (7%) used locally conserved or non-certified seed, as the program primarily focused on distributing certified wheat seed.

These results clearly indicate that community seed banks in Bara are not only preserving local seed systems but are also functioning as a formal distribution channel for certified seed, improving seed quality, productivity potential, and agricultural reliability

Table 2. Seed Sources Used by Farmers in Bara

Seed Source	CSB Farmers (%)	Non-CSB Farmers (%)
Own saved seed	30	69
Market/local dealers	18	21
Certified seed (including certified wheat seed supplied through CSB)	45	5
local/non-certified seed	7	5
Total	100	100

Impact of Community Seed Banks on Crop Productivity

The comparative analysis of crop productivity revealed statistically significant differences between CSB participant and non-participant farmers in Bara Tehsil. Farmers participating in Community Seed Banks (CSBs) showed higher productivity in both wheat and vegetable-based farming systems, mainly due to access to certified

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wheat seed and summer and winter open pollinated variety (OPV) vegetable seeds. Wheat yield among CSB farmers reached 2.82 t/ha compared with 2.15 t/ha among non-CSB farmers. In addition to wheat production, CSB farmers also demonstrated improved productivity in summer and winter OPV vegetable cultivation, which contributed to better household nutrition and income diversification.

The t-test results confirmed that differences between CSB and non-CSB farmers were statistically significant ($p < 0.01$), indicating a strong positive effect of community seed banks on agricultural productivity. The yield improvement is mainly attributed to improved seed quality, access to certified wheat seed, and the availability of locally adapted OPV vegetable varieties suited to Bara's agro-climatic conditions.

These findings support existing literature that community-based seed systems enhance productivity, diversification, and resilience in resource-limited farming environments. In semi-arid regions such as Bara, the integration of cereal and vegetable seed systems through CSBs plays a vital role in strengthening food security and livelihood sustainability.

Table 3. Comparison of Crop Yield Between CSB and Non-CSB Farmers

Crop	CSB Farmers (Mean ± SD) t/ha	Non-CSB Farmers (Mean ± SD) t/ha	t-value	p-value
Wheat (certified seed via CSB)	2.82 ± 0.32	2.15 ± 0.27	10.14	0.000**
Summer OPV Vegetables*	6.40 ± 0.80	4.10 ± 0.60	8.75	0.000**
Winter OPV Vegetables*	5.90 ± 0.70	3.85 ± 0.55	8.30	0.000**

* OPV = Open Pollinated Variety vegetables introduced through Community Seed Banks.

Seed Accessibility and Economic Efficiency

Community seed banks significantly improved seed accessibility among participating farmers by ensuring the timely distribution of certified wheat seed packages and

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OPV vegetable seed (summer and winter seasons). All CSB beneficiary farmers received seed through a structured distribution system, which ensured availability before sowing time and reduced dependence on informal seed markets.

Among CSB farmers, 93% reported timely receipt of seed packages, compared with 59% among non-CSB farmers who relied on local market purchases and farmer-saved seed. Timely seed provision is particularly important in rain-fed agriculture, where delayed sowing can significantly reduce crop establishment and final yield.

The CSB intervention also provided wheat seed at subsidized rates, including 12.5 kg packages at PKR 200 and 25 kg packages at PKR 400, making certified seed more affordable compared with market prices. Overall, CSB participation reduced seed costs by approximately 27%, with CSB farmers reporting an average cost of PKR 98/kg compared with PKR 134/kg among non-CSB farmers.

Dependence on external seed markets was also significantly reduced among CSB farmers, indicating improved local seed sovereignty and reduced vulnerability to price fluctuations and seasonal shortages. These findings demonstrate that community seed banks function as an effective institutional mechanism for ensuring timely seed delivery, lowering input costs, and strengthening smallholder resilience in Bara's rain-fed agricultural system.

Table 4. Seed Accessibility and Economic Efficiency

Indicator	CSB Farmers	Non-CSB Farmers	% Change
Timely seed receipt from CSB package (%)	93	59	+34%
Wheat seed cost (PKR/kg equivalent)	98	134	−27%
Dependence on market seed (%)	31	76	−45%

Household Food Security Status

Food security analysis showed that CSB farmers experienced substantially better household food security compared with non-CSB farmers. Approximately 74% of CSB households were categorized as food secure, whereas only 43% of non-CSB households achieved similar status. Food insecurity was much lower among CSB

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participants (7%) than among non-participants (21%). Improved food security among CSB farmers may be attributed to higher crop productivity, improved seed accessibility, and greater crop diversity. Diversified farming systems help ensure stable food availability and reduce vulnerability to crop failure.

The findings indicate that strengthening local seed systems through community seed banks can contribute significantly to poverty reduction and nutritional stability in rural communities.

Table 5. Household Food Security Among Respondents

Category	CSB Farmers (%)	Non-CSB Farmers (%)
Food secure	74	43
Moderately secure	19	36
Food insecure	7	21

Farmers' Perceptions Regarding Community Seed Banks

Farmers expressed highly positive perceptions regarding the role of community seed banks in agricultural development. Enhanced community cooperation received the highest mean score (4.8), followed by improved seed quality (4.7) and increased crop yield (4.6).

The high perception scores indicate strong farmer acceptance and trust in community-based seed systems. Improved cooperation among farmers may facilitate local seed exchange, collective problem-solving, and participatory agricultural decision-making. Such social cohesion is important for strengthening local institutions and ensuring long-term sustainability of CSBs.

Table 6. Farmers' Perceptions of CSB Benefits (Likert Scale 1–5)

Statement	Mean Score
Improved seed quality	4.7
Increased crop yield	4.6
Reduced production cost	4.4
Improved climate resilience	4.5

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Enhanced community cooperation	4.8

Regression Analysis of Yield Determinants

Multiple linear regression analysis identified CSB participation as the strongest predictor of crop productivity. The regression coefficient for CSB participation (+0.65) showed a highly significant positive relationship with yield improvement. Among other explanatory variables, organic nutrient management (Farmyard Manure application), irrigation availability, and farming experience also showed positive and statistically significant effects on crop productivity. The use of FYM reflects improved soil fertility management practices in low-input farming systems, which are particularly important in semi-arid regions such as Bara Tehsil.

The regression model explained 71% of the total variation in agricultural productivity, indicating strong explanatory power ($R^2 = 0.71$; Adjusted $R^2 = 0.69$). Overall, the findings suggest that community seed banks significantly enhance agricultural performance even when other agronomic factors are considered. Improved seed quality through CSBs, combined with organic soil fertility management and better irrigation access, substantially increases farm productivity under resource-constrained conditions.

Table 7. Multiple Linear Regression Analysis

Variable	Coefficient (β)	t-value	p-value
CSB participation	+0.65	6.24	0.000**
FYM (organic manure application)	+0.37	3.48	0.001**

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Irrigation availability	+0.43	4.36	0.000**
Farming experience	+0.20	2.28	0.024*
Model Statistics	**Value**		
R^2	0.71		
Adjusted R^2	0.69		

Constraints Limiting Expansion of Community Seed Banks

Despite the positive impacts of Community Seed Banks (CSBs), several operational and implementation-related constraints were identified during the study in Bara Tehsil, District Khyber. The most frequently reported issue was the limited quantity of seed provided per household (12 kg and 25 kg wheat seed packages), with 68% of respondents indicating that the allocated seed was insufficient to meet their cultivation requirements, particularly for larger landholdings. This suggests that demand for quality seed often exceeded the quantities available through the Community Seed Bank.

More than half of the respondents (52%) reported a low willingness to pay service or contribution fees, despite subsidized pricing and access to improved seed. This may reflect limited household cash resources and a long-standing dependence on externally supported agricultural inputs. Seasonal demand exceeding seed supply capacity (44%) and logistical challenges associated with large-scale seed distribution (38%) were also identified as significant barriers to expansion and wider outreach.

Additionally, 29% of respondents reported reluctance to return seed to the Community Seed Bank after harvest, which may hinder seed replenishment and weaken the revolving seed mechanism that underpins the sustainability of the system. Collectively, these findings indicate that the major challenges facing CSBs are increasingly related to demand management, farmer participation, and scalability rather than technical implementation. Addressing these constraints through optimized seed allocation, strengthened community engagement, and sustainable cost-sharing mechanisms will be essential for enhancing the long-term viability and expansion of Community Seed Banks in marginalized farming systems such as Bara Tehsil and other resource-constrained regions.

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Table 8. Major Constraints Reported by Farmers (Corrected Interpretation)

Constraint	Frequency (%)
Limited seed quantity per household (12 kg & 25 kg packages)	68
Low willingness to pay service/contribution fee	52
Seasonal demand exceeding supply capacity	44
Logistical challenges in large-scale distribution	38
Reluctance of farmers to return seed to the Community Seed Bank after harvest	29

DISCUSSION

The findings of the present study demonstrate that traditional seed systems continue to dominate agricultural practices in Bara Tehsil, District Khyber; however, these systems are characterized by low productivity, poor seed quality, limited genetic diversity, and high dependence on farmer saved seed. The majority of non-CSB farmers relied on informal seed sources, which often lack quality assurance and climate adaptability. Similar observations have been reported by the Food and Agriculture Organization (FAO, 2019), which emphasized that informal seed systems in developing countries frequently constrain agricultural productivity due to inadequate access to quality seed and weak institutional support.

The study revealed that Community Seed Banks (CSBs) significantly improved crop productivity, seed accessibility, biodiversity conservation, and household food security. Farmers participating in CSBs achieved substantially higher yields of wheat, maize, and sorghum compared with non CSB farmers. These findings are consistent with previous studies indicating that community-based seed systems enhance crop performance through the conservation and distribution of locally adapted and climate-resilient seed varieties (Vernooy et al., 2017). The availability of drought tolerant and disease-resistant landraces through CSBs likely contributed to improved productivity under the semi-arid conditions of Bara.

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Community seed banks also played an important role in strengthening agrobiodiversity and climate resilience. CSB farmers cultivated a greater number of crop varieties and conserved more indigenous landraces than non-participants. Conservation of local germplasm is essential for maintaining long-term agricultural sustainability and adaptation to climate variability (Shrestha et al., 2013). Increased crop diversity reduces production risks associated with drought, pests and environmental stress, particularly in marginalized and conflict-affected agricultural regions. Furthermore, the higher adoption of drought-resistant varieties among CSB farmers demonstrates the potential of community-managed seed systems in supporting climate-smart agriculture. The statistical analyses conducted in the study strongly support the effectiveness of CSBs in improving agricultural performance. Independent sample t-tests showed highly significant differences ($p < 0.01$) between CSB and non-CSB farmers for all major crops. Similarly, the multiple linear regression model identified CSB participation as the strongest predictor of crop productivity ($\beta = +0.65$, $p < 0.01$). The high coefficient of determination ($R^2 = 0.71$) indicates that community seed banks, together with improved agricultural inputs and management practices, explain a substantial proportion of yield variability in the study area. These findings are in agreement with previous research highlighting the positive relationship between local seed systems, farmer participation, and sustainable agricultural productivity (FAO, 2021).

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Despite the positive impacts of Community Seed Banks several challenges constrain their expansion and long-term sustainability, including limited farmer awareness, insufficient technical knowledge on quality seed production and management and financial constraints. If these barriers are not effectively addressed the sustainability and scalability of CSBs may be compromised. Therefore, stronger collaboration among agricultural extension services, research institutions, non-governmental organizations and local communities is essential to enhance farmer capacity building and access to quality seed production practices.

Community Seed Banks contribute significantly to sustainable food systems by improving farmers' access to locally adapted and quality seed, enhancing crop productivity and conserving agricultural biodiversity. By promoting the use and exchange of diverse crop varieties, CSBs strengthen household food security, increase resilience to climate variability and reduce dependence on external seed markets. Furthermore, they support sustainable agricultural practices by preserving local genetic resources and ensuring the continuous availability of planting materials for future generations. Integrating Community Seed Banks into agricultural and rural development policies can therefore strengthen local seed sovereignty, enhance food system sustainability, improve climate resilience, and promote inclusive rural development in resource-constrained areas such as Bara Tehsil, District Khyber, Pakistan.

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dedicated efforts in project execution, field coordination, community mobilization, data collection, and overall management of intervention activities. The commitment and professionalism of the NIDA Pakistan team were instrumental in achieving the objectives of the intervention and this research study.

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Novelty Statement

This study focuses on Bara Tehsil, District Khyber, a semi-arid, resource constrained and conflict-affected region of Pakistan where formal seed systems are weak and farmers largely depend on traditional practices. In such a context, agricultural services are often inconsistent, making community-based solutions more critical for sustaining productivity. Community Seed Banks (CSBs) remain under-researched in Pakistan, particularly at the local level, despite their potential role in improving seed access, crop diversification and climate resilience. This research fills this gap by providing empirical comparative evidence between CSB and non-CSB farmers, focusing on a mixed seed system involving certified wheat seed and seasonal OPV vegetable seeds, thereby highlighting the effectiveness of decentralized seed systems in enhancing sustainable agriculture in marginalized regions.

Declarations, Ethics Approval and Consent to Participate

Prior informed oral consent was obtained from all participants before conducting interviews, discussions, and data collection activities. The study was carried out in accordance with ethical principles and standards for agricultural and social science research, ensuring voluntary participation, confidentiality, anonymity and respect for respondents' rights throughout the research process.

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Availability of Data and Materials

The datasets generated or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this research article.

Authors' Contributions

All authors contributed substantially to the conception and design of the study, field data collection, data analysis, interpretation of results and manuscript preparation. All authors critically reviewed, revised and approved the final version of the manuscript and agreed to its submission for publication.

REFERENCES

Food and Agriculture Organization (FAO). (2019). *Farmer seed systems and sustainable agriculture*. Rome: FAO.

Food and Agriculture Organization (FAO). (2021). *The state of food and agriculture 2021: Making agrifood systems more resilient to shocks and stresses*. Rome: FAO.

International Maize and Wheat Improvement Center (CIMMYT). (2020). *Predominance of informal seed systems in Khyber Pakhtunkhwa, Pakistan: A wake-up call for improvement*.

CIMMYT, Mexico.

Shah, Z., Shah, G. M., Gul, A., Ullah, A., Haq, A., Ullah, I., ... & Rahim, F. (2026). Phototherapeutic and ethnobotanical relevance of weed flora: A quantitative assessment from the cultivated fields of District Bajaur, Pakistan. *Ethnobotany Research and Applications*, *33*, 1-20.

Shrestha, P., Sthapit, B., Lamers, H., & Rao, V. R. (2013). Community seed banks in Nepal: Past, present, future. *Proceedings of the National Workshop on Community Seed Banks*, 12–25.

Ullah, A., Shah, Z., Jan, Z., Khan, F., Rome, B., Hafeez, S., & Arif, M. (2025). Effect of Foliar Application of Zinc and Boron on Growth, Yield and Quality Seed Production of Onion

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/a

(Allium cepa L.) cv. Swat-1. *American Journal of Pure and Applied Biosciences*, *7*(5), 192-201.

Vernooy, R., Shrestha, P., & Sthapit, B. (2017). *Community seed banks: Origins, evolution and prospects*. Routledge, London.

Yamane, T. (1967). *Statistics: An introductory analysis* (2nd ed.). New York, NY: Harper and Row.