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Traditional community-led seed system for maintaining crop vigour, diversity and socio-cultural network in view of the changing climate: a case study from western Himalaya, India

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Abstract

This study describes the traditional seed system for maintaining crop vigour through seed selection, storage and exchange practices by the local farmers inhabiting the Shivalik-Bhabar tracts of western Himalaya in Una district of Himachal Pradesh state, India. The study area falls in sub-tropical zone where the arable land is heavily laden with cobbles and pebbles. Three villages, namely, Baliwal, Pubowal and Janani, were selected for documenting the traditional seed system. Chain referral method was used for identifying the Key Knowledge Holders and households (N=136) from the selected villages. Along with the documentation, a participatory experiment on traditional seed storage of indigenous and high-yielding varieties of wheat and maize was conducted during two cropping seasons, i.e. Rabi (Nov–Mar) and Kharif (Jun–Oct), respectively, to validate the traditional knowledge of local farmers. The results of the experiment showed that traditional treatments of seeds using dry neem (*Azadirachta indica*) leaves, safety match sticks and a combination of both acted as disinfectants during storage with slightly differing levels of effectiveness. It has been observed that the traditional seed system is playing a crucial role in maintaining the crop vigour and diversity and also strengthening the socio-cultural relationship among the local farming communities.

Keywords: Traditional seed treatment, Crop varieties, Participatory experiments, Cultural exchanges, Livelihoods

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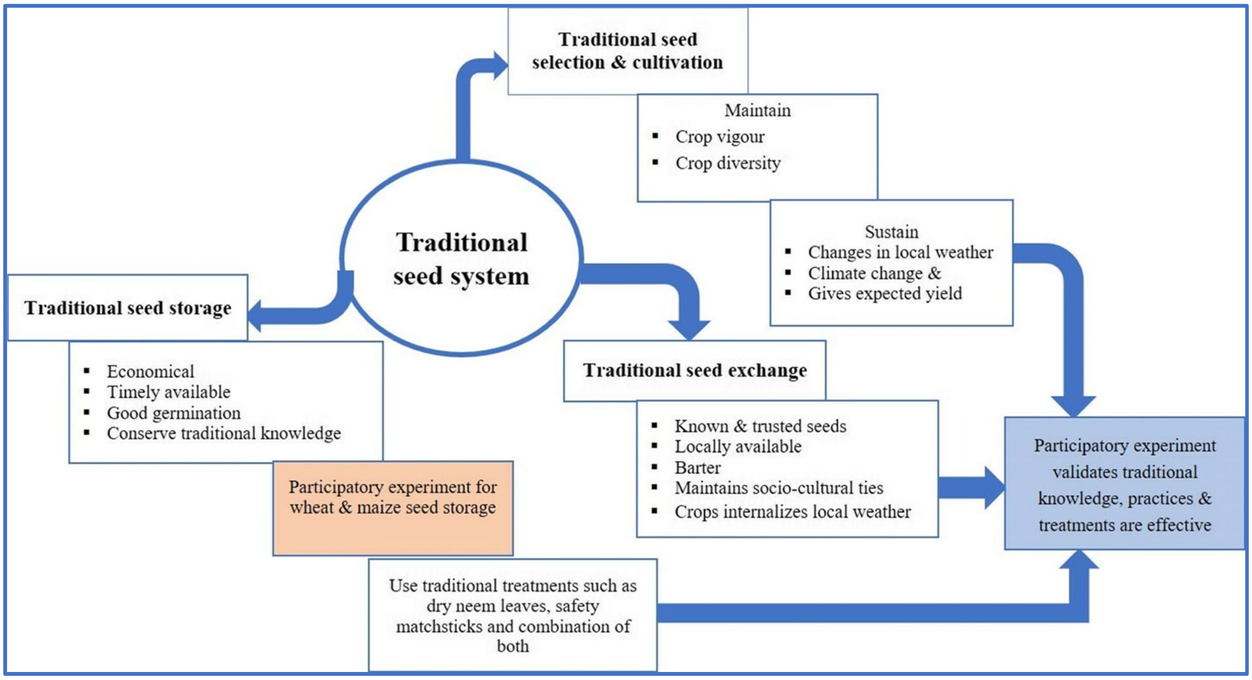
Graphical Abstract



Introduction

A traditional seed system governed by local farmers is crucial for sustainable food production, balance nutrition and maintaining genetic diversity under marginal environments (Altieri and Merrick 1987; Sperling et al. 1993; Almekinders et al. 1994; Jarvis et al. 2000; Poudel et al. 2015). Traditional seed system refers to the role of farmers in the management of local landraces which includes seed selection, production, storage and exchanges as gifts, bartered, and purchased from nearby markets (Jensen et al. 2013; Nabuuma et al. 2022). It supports the socio-cultural practices and strengthens the network of marginal farming communities (Montufar and Ayala 2019) as they rely on their ancestral knowledge systems and traditional storage techniques (Hlatshwayo et al. 2021). In addition, it keeps away the diffusion of ex situ seeds which disrupts the local socio-cultural values (Brush 1991, 1995). More importantly, the traditional seed system internalizes the minor environmental changes and weather changes, maintains soil health, controls the market price and ensures minimum production and income security (Asiedu-Darko 2014). The traditional agricultural system in Himalaya evolved through trial and error methods over the centuries (Bisht et al. 2006; Bisht et al. 2007). Amidst acculturation, the outer Himalaya is being increasingly exposed to the formal seed system and technology introduced by multinational seed companies (Shiva et al. 2012). The formal seed system denotes to genetically modified plant breeding and multiplication methodologies developed by public and private institutions which are distributed through regulations and certifications (Nabuuma et al. 2022). The market seeds undoubtedly increase the yield through the adoption of fossil-fuel-based inputs (Maikhuri et al. 1997) but at the same time erode the age-old community-based plant breeding practices (Li and Wu 1996; Almekinders and Louwaars 2002). Hence, documentation and preservation of traditional methods of seed selection, production, storage and exchange has become all the more important in the face of the constant erosion of many landraces and traditional crop cultivars (Maikhuri et al. 1997). Weakening of the traditional seed system has implications for seed sovereignty, conservation of in situ germplasm for future use and nutraceutical security of marginal farmers in the Indian Himalayan region (Vernooy et al. 2014). Moreover, by-products of the traditional crops serve as fodder for livestock, which is integral to subsistence farming in the Himalayan region (Maikhuri et al. 1996). Local people have developed many unique structures (made of wood, mud, canes, bamboos etc.) for safe storage of grains and seeds from rodents and pests/insects (Kiruba et al. 2006) which are relatively cheap, ecofriendly, climate resistant and impart high self-life (Mobolade et al. 2019). A number of studies (Curtis et al. 1997; Maikhuri et al. 1997; Wood and Lenne 1997; Bisht et al. 2007; Rice 2007; Bishaw and Turner 2008; Thomas et al. 2011a, 2011b: Mobolade et al. 2019; Maity et al. 2020; Pircher and Almekinders 2021) have highlighted the erosion of socio-economic and cultural knowledge interlinked to the traditional seed system. Some others (Mburu and Wale 2006; Agre et al. 2018; Lebot et al. 2018) have reported the role of traditional seed practices in the improvement of genetic diversity and gene flow. Similarly, the importance of traditional seed storage methods and treatments were evaluated by Govender et al. (2008), Mishra and Pandey (2014), Nabuuma et al. (2022) and Odjo et al. (2022). Studies so far described the people's perceptions and field observations, but lack in bringing forth scientific evidences on seed selection and storage. Hence, this study was undertaken to document farmers' knowledge related to seed selection, storage, exchange and also validation of their seed storage practices in maintaining the viability of seeds by conducting participatory field experiments with the farmers of the selected villages located in the foothills of western Himalaya, India.

The present case study aimed to document the traditional practices related to the seed system, i.e. from seed collection till its storage. Secondly, to understand the socio-economical, ecological and cultural significance of the traditional seed system especially among the marginal farmers. Finally, to conduct participatory experiments to bring scientific evidences to traditional treatments used to wheat and maize seed storage systems.

Materials and methods

Study area

The eco-cultural zone, Una, is located in the outer Himalayan region in the North-Western state of Himachal Pradesh, India. The zone is composed of Shiwalik hills and Bhabar tracts; it is topographically undulating, gently sloping, loose boulder-pebbly along the northern edge of the vast Gangetic plain called the *Terai*. The Bhabar is made up of sediments washed down from the Himalayan mountain ranges and Shiwalik hills with streams disappearing into these coarse and loose sediments (Valdiya 1970; Valdiya 2003). The study area was selected through a comprehensive reconnaissance survey mainly because of the fact that the agricultural practices in this zone have been witnessing rapid acculturation and technological interventions for the last few decades. District Una is located at a latitude 31°21′ to 31° 50′ N and longitude 75° 55′ to 76°28′ E in Bhabhar tracts of Himachal Pradesh state and is bounded by the Kangra district in the north, Hamirpur and Bilaspur districts in the northeast, and Hoshiarpur and Rupnagar districts of the state of Punjab in the south-west, with a total geographical area of 1540 km^2. The forest area of Una can broadly be categorized as Khair-Sissoo Forest and Lower Shiwalik and Himalayan Subtropical Scrub (Champion and Seth 1968). According to a recent weather report from India Meteorology Department (IMD), the average minimum and maximum temperature vary from 4 °C in winter to 46 °C in summer. The area receives an average annual rainfall of about 1063 mm, of which about 70% fall during the monsoon season (June-September). According to the 2011 census, Una is host to nearly 0.11 million households with a total population of 0.52 million (male, 50.6% and female, 49.4%) with an average household size of 4.7 persons.

Three villages, namely, Baliwal, Pubowal and Janani from the Haroli block of Una district were selected for the detailed study (Fig. 1). The study villages belong to the *Bet* area (which means land near the River) of the *Doaba* region (land of two Rivers: Sutlej and Beas). The agricultural activities in the region are largely dependent on rainfall with maize (*Zea mays*) and wheat (*Triticum aestivum L.*) forming the major traditional crop rotation system during the Kharif and Rabi cropping seasons respectively. The region is known for its traditional seed system, especially seed selections, storage and exchanges among farming households/communities in the villages. Furthermore, nearly 65 % of the villagers belong to marginal and small landholding groups in the villages. With this background, the above-mentioned villages were selected for detailed documentation of the traditional knowledge linked to the seed system. The demographic details and other features of the villages are mentioned in Table 1.

Data documentation and analysis

All the key elements of participatory research described in the IIRR [International Institute of Rural Reconstruction] (1996), Huntington (2000), requirements laid down in the National Biological Diversity Act (2002) and Rules (2004) and Tengo et al. (2014) were followed for documentation of the socioeconomic profile and traditional knowledge efficiently. Keeping in view the described elements such as taking prior consent, explaining research objectives and activities to community members beforehand, maintaining transparency and neutrality and building trust between the research team and target community members were followed. Key Knowledge Holders (KKHs) from among the farming households (N=136) of different age groups (25–85 years) comprising 98 men and 38 women were identified through a chain referral method (Huntington 2000) for detailed discussion and interviews. Responses are analysed based on the different age groups [25–40 (31 respondents), 41–60 (75) and above 60 (30)], landholding size [marginal

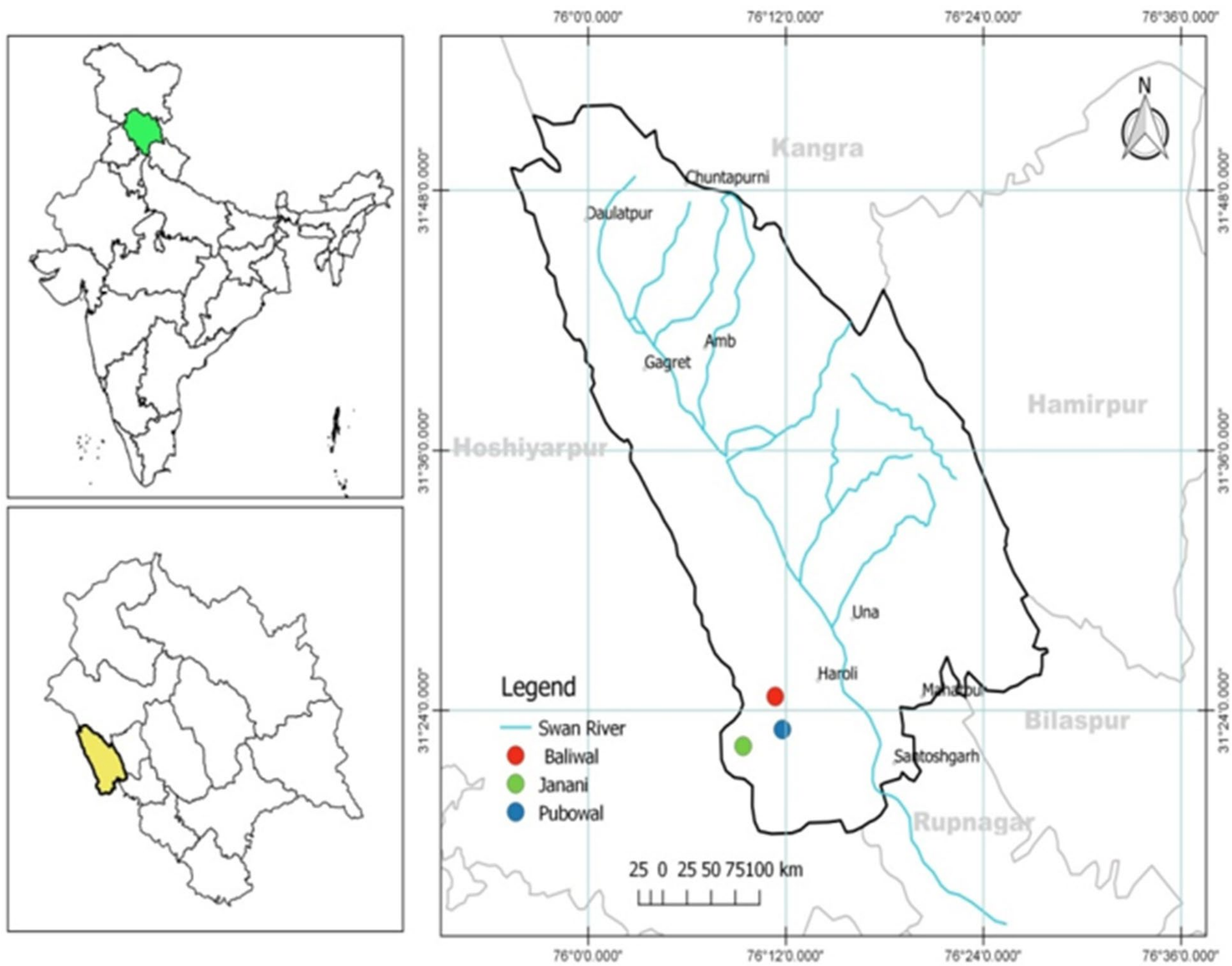


Fig. 1 Location of the study area, Una, Himachal Pradesh, India

(65), small (45) and medium (26)], and different social category [General (45), SC/ST (40) and OBC and others (51)]. Focussed Group Discussions (FGDs) and semi-directive interview methods were used to collect information from KKHs (Huntington 2000). Face-to-face interviews were conducted through open-ended, discovery-oriented, and semi-structured questionnaires and held free-flowing discussions with KKHs to understand and document a whole range of agronomic knowledge and practices pertaining to the maintenance of traditional landraces, crop diversity, crop production, seed selection, storage and exchanges. The semi-structured questionnaires were translated to local language (Hindi), pre-tested and made necessary adjustments prior to the actual interviews with KKHs. In addition to the semi-directive interviews and the FGDs, we have conducted a collaborative fieldwork with KKHs for validating the documented information. Relevant data from the various line agencies such as the Department of Agriculture, India Meteorology Department and Gram Panchayats (GPs) were collected using semi-structured questionnaires.

The field data was collected between November 2015 and June 2018. A total of eight field visits were made at different phases of crop cultivation such as growing, caring, harvesting, threshing, onsite seed selection, storing and exchanges during both Kahrif and Rabi seasons in the selected villages. During all the field visits, we have stayed in the study villages to understand a whole range of local practices pertaining to farming including the seed system also observe the changes in local weather patterns. Based on the existing literature (including web-based search and locally available records/archives) and with the help of KKHs, we have documented the socio-economic profile, cultural profile of the community and also a detailed account of their farming knowledge related to the traditional seed system in view of the historical context.

Table 1 Demographic and socio-economic details of the study villages in Una, Himachal Pradesh, India

Particulars/villages	Villages		
	Baliwal	Pubowal	Janani
Total households (hh)	310	457	45
Total population (nos.)	1502	2154	274
Male population (nos.)	783	1126	135
Female population (nos.)	719	1028	139
Sex ratio (% of male/female)	108.9	109.5	97.1
Literacy (%)	48.27	67.50	73.72
Altitude amsl (m)	510	490	430
Total crops (nos.)	28	38	25
Kharif crops (June–October) (nos.)	14	19	12
Rabi crops (November–April) (nos.)	14	17	12
Traditional crops (nos.)	14	16	12
Introduced crops (nos.)	14	22	13
Cereal crops (nos.)	2	2	2
Pulses and millets (nos.)	8	9	5
Vegetables (nos.)	13	18	12
Total livestock (nos.) (cattle and goats)[a]	920	398	181

Source: Census 2011, Revenue Records (ShajraNaasibMalkat) 2013-14 and field survey between 2015 and 2018

[a] As per livestock census, 2017

Description of seed storage experiment

According to our observations and information given by KKHs, seeds are stored in the earthen pots for several years using traditional treatments such as neem leaves (*Azadirachta indica*), wooden safety matchsticks and a combination of both. We have selected Janani and Baliwal villages for conducting participatory seed storage experiments as these two villages have mainly been practising traditional seed storage systems with relatively low acculturation. As wheat and maize were important crops, we have considered seeds of these two crops for conducting the experiments. Wheat crop was harvested during Mar–April 2016 and experiments started in May 2016. Similarly, maize was harvested in Oct–Nov 2016 and we carried out experiments in Nov 2016 using traditional treatments.

Process of experiment

Following the practice of seed storage of the villagers and as per the advice of KKHs, a total of 24 earthen pots of equal volume (2.5 kg each) with lids, thin plastic sheets and matchboxes were placed at the experimental site. All 24 pots were filled with wheat (2 kg each), of which 12 pots were filled with a traditional wheat variety (*Desi*) and another 12 pots were filled with a hybrid variety

Fig. 2 **a** Weighing of wheat seeds and transferring to a pot. **b** Pots filled with wheat seeds and treatments. **c** Pots covered with polyethylene sheet and lid. **d** Sealing the pots airtight with mud paste by KKHs. **e** Pots placed for sun-drying. **f** Grouping the pots according to treatments. **g** Pots placed on the floor. **h**, **i** Pots placed on a shelf

(HYV 2967) (Fig. 2a). The pots were divided into four sets of six pots each. In the first set, sun-dried neem leaves (20 g/pot) were placed. In the second set, safety matchsticks (82 matchsticks per pot) were kept and third, a combination of both neem leaves (10 g/pot) and match sticks (41 matchsticks/pot) were placed (Fig. 2b). The fourth set was treated as control. The weight of neem leaves and the number of matchsticks were determined as per traditional knowledge followed by KKHs. The same method was followed to the maize seed storage experiment as well. Total 12 pots each were filled with traditional maize seeds and hybrid maize seeds (hi-shell variety), respectively. The names of the HYV varieties were confirmed by Agriculture Extension Office and seed distributors. Neem leaves and matchsticks kept in the pots were thoroughly mixed with seeds, then a thin plastic sheet was placed (Fig. 2c) on the mouth of the pot and sealed it airtight with mud paste that was mixed with wheat straw (Fig. 2d). All pots were arranged into six groups (Fig. 2e–f), and each group was kept in a separate house (6 individual houses) in the village to understand the impact of traditional treatments at various houses, which are managed by different farmers. Of the six groups, two groups were kept on the floor (Fig. 2g) and four groups were placed on the racks/shelves about 2.5 m above the ground (Fig. 2h, i). In case of the maize, four groups were kept on the floor and two groups on the shelves to observe the impact of traditional treatments at different places with relatively different microenvironmental conditions. The pots kept for the experiment were not disturbed until the sowing season. Wheat seeds were stored for 171 days and maize for 251 days. The number of days differs due to the differences between crop harvest and the next cropping seasons. For example, maize crop is harvested during October–November and the next sowing time is June the following year. Similarly, wheat crop is harvested in March–April and seeds are stored until November, the next sowing time. The pots were checked randomly during the storage period for any damage. At the time of opening, all the pots were again cross-checked to see any cracks/damage on the surface of the pots. To ensure the correctness of the experiment as per the traditional practices, all the experimental activities described above were carried out in the presence of both women and men KKHs

At the time of opening of the pots, KKHs were requested to describe the status of seed treatment, seed infection or damage by insects in local terminology. After keenly observing each pot, the KKHs explained like: *yeh matka saaf hai* (means this pot is clean, no infection), *isme keet lag gaya hai* (this pot is infected), *ise keet ne poora kha liya hai* (all seeds are fully eaten by insects), *kam khya* hai (less infected), *yeh theek hai* (no infection), *yeh atta ban gaya hai* (seeds have become powder), *yeh beej ke liye theek nahi hai* (not good for sowing), *yeh bovaee ke liye theek hai* (good for sowing), *yeh beej ugega* (this seed will germinate), *yeh beej nahi ugega* (this seed will not germinate) and so on. After ascertaining the degree of infection in the opened pots under different treatments, samples were brought to the lab for further analysis. Some of the seed samples were sent to an Entomologist in the Indian Council of Agricultural Research (ICAR) New Delhi for identifying the weevils. The degree of infection was analysed in the laboratory following the steps described in Bishaw et al. (2012). Samples were placed in a 50 ml measuring cylinder to count and weigh the infected and non-infected seeds for both traditional and hybrid varieties. Photographs of all the seeds from all the treatments (traditional v/s hybrid, infected v/s non-infected, treated v/s control, neem leaves v/s safety matchsticks) were taken for visual comparisons and interpretation to distinguish each other.

Results and discussion

Traditional seed system

In the traditional seed system, farmers give attention to the quality of grains, crop by-products, longevity and estimated yield. Moreover, they select seeds from the solo crop fields than mixed because of the chances of contamination and lower yield (Asiedu-Darko 2014). Primarily, farmers exchange seeds when the yield starts declining usually after 7–8 years of continuous cultivation. Before the exchange or purchase, farmers discuss with the crop owner about its yield, by-product and longevity etc., and decide to take it or not based on the discussion. If the crop owners are relatives or friends, they mutually agree to exchange seeds while returning the same quantity or 20% more soon after the crop harvest (Samberg et al. 2013). During the exchange or purchase of seeds, farmers collect an additional 25% than assumed due to storage losses and keeping wastages during sowing (Samberg et al. 2013). Generally, men or the head of the household plays a major role in exchanging the cereal crops within or outside the villages. Women are mainly involved in exchanging the seeds of vegetables and pulses within the village.

Seed selection and storage

Vegetables such as pumpkins (*Cucurbita maxima Duchesne*), cucumbers (*Cucumis sativus L.*), French beans (*Phaseolus vulgaris*), gourds, okra (*Abelmoschus esculentus*), brinjals (*Solanum melongena L.*) and tomatoes (*Lycopersicon esculentum Miller*) are the major crops, chosen on-site for seed purposes in the study area. On-site seed selection corresponds to identifying and plucking healthier, taller, bigger, plumper and heavier cobs, panicles, fruits and vegetables for seed purposes (Brush 1995). After selection, farmers leave the particular individuals on-field until they fully mature or ripen, more often till their roots and shoots get completely dried up. During the process, farmers protect these mother plants from wild animal crop raids, grazing livestock, poachers and pests. After plucking, the seeds are sun-dried for a few days and stored in wood, mud, metal or plastic containers using various traditional treatments to protect them from insects and pests (Pereira and Wohlgemuth 1982; Rahim 1998). It is observed that in-house storage promotes the traditional seed system and improves the genetic diversity of the local landraces (Brush 1986; Brush 1991; Pandey et al. 2011; Coomes et al. 2015).

Maize

Farmers identify and select maize seeds that are >20% bigger, plump, bright and non-infected (Louette and Smale 2000: Modi 2004). They sun dry the cobs for a week time, generally hand-thresh the cobs to expel the kernels, again sun dry the kernels for 1–2 days (Bodholt and Diop 1987). The dried kernels are stored in earthen pots using traditional treatments such as neem leaves or matchsticks or a combination of both. It was observed that some farmers are using ash and sand as traditional treatments during the storage of seeds (Kiruba et al. 2006). After adding treatments pots are sealed airtight using a lid, plastic sheets and mud paste. Sealed pots are kept under the sun for 1-2 days for drying of a mud paste and then placed in safe places like on the shelf or on the floor inside the house (Gwinner et al. 1990).

Wheat

Farmers select healthy patches of crop/individual plants which are ready to an early harvest and have about 25% bigger panicle size for seed purposes. Such patches or individual plants are separately harvested, field dried, threshed and cleaned to prevent mixing. Low quality and broken seeds are removed during winnowing and cleaned manually (Golob et al. 2009). Cleaned seeds are sun/air dried for 2–3 days and then stored in earthen pots following the same method as described for maize seeds above (Gupta 2013).

Pulses

The major pulse crops grown in the study area are horsegram, bengalgram, pigeonpea, blackgram and greengram. To identify the best plant for seed purposes, farmers roam in and around the field and select the individuals which are 20–25% bigger, taller and ready for early harvest. They harvest selected plants separately and keep them aside for field drying, which avoids mixing with other crops. Farmers prefer hand-threshing of dried sheaves then do the winnowing to remove the low-quality and broken seeds. Separated good quality seeds are sun-dried for about two days or until the moisture levels reach to 13–14% (Lal and Verma 2007) and then store in unsealed earthen pots, iron/plastic containers or steel boxes mixed with neem leaves or ash or sand. The pots are either placed on a shelf or hung against the smoke in the kitchen. Stored seeds are regularly checked (~once in a month) for any infection. In case of infection, the container is emptied and cleaned, and the process of storing is repeated. It was noticed that a few farmers also spray kerosene in the area surrounding the container because they think it acts as a repellent.

Oil seeds

It was observed that farmers follow the same methods followed for pulses for collection and storage of oil seeds. However, the oilseeds are stored without using any traditional treatments because the chances of getting an infection is less in oil seeds. The major oilseeds grown in the study area are mustard (*Brassica nigra*), sesame (*Sesamum indicum*) and flax seeds (*Linum usitatissimum*).

Vegetables

Farmers select the best-grown robust plant for seed purposes. They take care of such plants, giving additional manure, water and proper support for optimum growth and also monitor regularly for any pest infection, wild animal raids and theft (Nakazibwe et al. 2019). Major vegetables growing in the area are bottle gourds (*Lagenaria vulgaris Seringe*), pumpkins, France beans, okra, Indian squash, cucumbers, tomatoes and brinjals. The fully ripen fruits are harvested and kept on the rooftop or in an open space for about 10–15 days for drying. After that, some farmers (30–35%) open the dried fruits to take out the best seeds and sun-dry them again for 3–4 days. Fully dried seeds are treated with ash then wrapped with a cotton cloth and hanged against smoke or stored in plastic containers or glass bottles. Seeds of cucumbers, tomatoes and brinjals are hung against smoke in the open kitchen (Mobolade et al. 2019). Most of the farmers keep whole dried fruit unbroken until the next sowing season. Breaks it just 3–4 days before sowing. Seeds of gourds, pumpkins, France beans, okras and squash are usually stored as unbroken.

Chilli/garlic/ginger/onion/potato

In the case of potatoes, farmers select some portion of the good produce from bulk harvest and keep them separate for the purpose of seeds. The selected portion are kept in ventilated wooden boxes or gunny bags and stored on a shelf or at safer places above the ground until the next cropping season. In the case of chillis, farmers select good quality chillis and sun-dry till it gets completely dry for about 7 days then clean them for removing the broken chillis and place them in gunny or polythene bags for storing at safer places above the ground. Similarly, good quality garlic and onions were selected from the final harvest, sun-dried and hung against smoke inside the house. The selected gingers and potatoes are stored inside the soil as it is, although some farmers take out and place them at safer, dry places in the house to avoid moisture contamination.

Sugarcane

The fresh, well-grown, taller, bigger, heavier and healthier plants are selected for Cane Setts. The cane sets with three-four buds are planted in the soil (Table 2 and Fig. 3a–p).

Majority of the farmers (60–70%) in the study area belong to marginal landholding and their primary concern is to produce food for their own consumption. Therefore, they allocate a major portion of their land (45–50%) to maize in the Kharif season and wheat (70–75%) in the Rabi season. The remaining land in Kharif is cultivated with vegetables and other cash crops. Crops like mustard, taramira (*Eruca sativa*) and other pulses as cultivated as intercrops in the Rabi season.

Findings of seed storage experiment

Field testing

Seed storage experiment indicates that traditional storage techniques using neem leaves, matchsticks and a combination of both have shown efficiency in controlling the pest infection during storage. Secondly, it shows that, traditional seeds are highly resistant to pest infections as compared to hybrid seeds. The studies conducted by Rahim (1998) on wheat, and Pereira and Wohlgemuth (1982) on maize confirm that neem leaves/kernels act as a disinfectant to control the growth of larvae during storage. Present experiments on local knowledge related to on-site seed selection, treatments and storage confirm the previous reports.

The pots placed on the shelves are more resistant to pest infections as compared to the pots kept on the floor during storage. The hybrid varieties of both wheat and maize placed on the floor and shelves are prone to pest and infected by *Sitophilus granaries* and *Sitophilus zeamais* Motsch, respectively (Fig. 4a–i)). Furthermore, it indicates that high-yielding varieties are not suitable for the region which comprises a heterogenous environment where local weather and rainfall is abnormal most of the time (Table 3). Therefore, farmers of the study area prefer local varieties for cultivation. Moreover, it suggests that the age-old traditional knowledge system related to seed selection and storage practices by local farmers remain relevant and valuable even today which needs to be protected and promoted.

Lab testing

Maize seed samples brought to the laboratory were analysed for seed count, weight, the rate of infection and other comparative visual observations. The lab results show that the traditional seeds are robust/healthier, heavier and more efficient in resisting pest infection than hybrid seeds. The average counts of traditional maize seeds were 2929.53 kg^{-1} against hybrid maize seeds 4321.43 kg^{-1}. Secondly, the infection rate was significantly higher (60%) in hybrid seeds (171.17 kg^{-1}) than in traditional seeds (103.53 kg^{-1}). Thirdly, the seed pots placed on the shelf were found less infected (126.59 kg^{-1}) than the pot kept on the floor (158.88 kg^{-1}). Finally, it was found that the traditional treatments such as neem leaves (118.34 kg^{-1}) and matchsticks (131.10 kg^{-1}) proven as effective disinfectants compared to the control (147.12 kg^{-1}) (Table 4 and Fig. 5).

Table 2 Percentage of farmers securing seeds from different sources during the study period (2015–2019) in Una, Himachal Pradesh, India

Source of seeds	Baliwal		Pubowal		Janani	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Own production	62	80	40	70	75	85
Exchange within community	22	17	15	20	26	20
Exchange from nearby villages	10	15	10	10	20	10
Exchange with relatives from distant places	5	5	10	5	5	5
Nearby local market	20	15	25	15	15	10
Agricultural extension and research centres	35	15	55	25	20	10
Multinational seed company/seed suppliers	10	5	15	10	5	5

Source: Field survey between 2015 and 2018

Fig. 3 On-farm seed selection of crops **a** cucumber, **b** French bean, **c** ridge gourd, **d** round gourd, **e** ladies' fingers (okra), and **f** maize; **g** selecting cobs from harvest; **h** selecting cobs during threshing; **i** sun-drying of bottle gourd and pumpkin; **j** seeds stored in a glass bottle; **k** sun-drying of okra; **l** maize seeds treated with a combination of neem leaves + matchsticks and stored in a plastic container; **m** louki seeds stored for cultivation; **n** papaya seeds stored in a plastic bottle; **o** Bejju seeds stored for cultivation; and **p** wheat seeds stored airtight in an iron pot

Seed exchange and socio-cultural system

Farmers consider exchanging the seeds in various situations but largely it is done when seeds quality get degenerated. Farmers also exchange seeds if: seeds get infected during storage, seeds are used for food purposes due to a shortage of food grains, crop failure occurs due to drought, and seeds are sold for high prices (Niekerk and Wynberg 2017a, 2017b). Majority of the villagers (over 70 %) exchange the seeds within their community in their village or nearby villages. Moreover, almost 80 % of the farmers from Janani and Baliwal were preferring *jat* community for exchanging or purchasing the seeds, especially for wheat and maize as the *jat* community is known for practising the best farming in the area. The respondents belonging to the age group of 25–40 expressed mixed responses over traditional practices because of their increased exposure to formal seed networks. Most of the farmers in the age group of above 40 still give importance to local knowledge in cultivation, storage and exchange. Almost 85% of the men respondents are involved in the exchange or purchase of wheat and maize seeds within or outside the village. Most of the women representatives are involved in vegetable and pulses seeds exchanges only within their village and community and they also monitor stored seeds at home. The respondents from all the social category (Gen, SC/ST, OBC and others) who are aged above 40 are still following

Fig. 4 **a** Crosschecking the pots for damage before opening. **b** Opening the pots for testing. **c** Control pot infected by *Sitophilus granarius* weevil. **d** Hybrid wheat seed group infected (seeds looking like white powder, completely infected by *Sitophilus granaries* weevil, this was control pot). **e** Checking maize seeds for *Sitophilus zeamais* Motsch infection at the end of the experiment. **f** Observed infection in hybrid maize seeds treated with neem leaves + matchsticks and placed on the floor. **g** Observed no infection in traditional maize seeds treated with neem leaves + matchsticks and placed on shelf. **h** Found infection in hybrid maize seeds treated with only matchsticks and placed on a shelf. **i** Observed no infection in traditional maize seeds treated with only matchsticks and placed on shelf

Table 3 Farmers' perceptions on the outcome of the traditional seed storage experiment conducted for wheat and maize in Una, Himachal Pradesh

Crops	Traditional treatments	Traditional seeds		Hybrid seeds	
		Placed on the shelf	Placed on the floor	Placed on the shelf	Placed on the floor
Wheat	Neem leaves				+
	Matchsticks		+		+
	Neem leaves and matchsticks		+		+
	Control		+	+	+
Maize	Neem leaves				+
	Matchsticks	+		+	+
	Neem leaves and matchsticks			+	+
	Control		+	+	+

+ denotes infected seeds

Table 4 Outcome of a field experiment conducted for maize seed storage in Una, Himachal Pradesh, India

Particulars	Type of seed/treatment	Mean ± SD	Min.	Max.	Skewness	Kurtosis values
No. of seeds (kg^{-1})	Traditional seeds	2929.53± 30.346	2882	2987	0.574	−0.138
	Hybrid seeds	4321.43± 93.905	4201	4502	0.572	−0.470
No. of seeds infected (kg^{-1})	Traditional seeds	103.53 (3.5) ±105.297	19	339	1.715	1.879
	Hybrid seeds	171.17 (4.0) ±108.584	53	403	0.740	0.160
	Placed on the shelf	126.59±109.36	28	403	1.489	1.483
	Placed on the floor	158.88±115.96	19	339	0.235	−1.385
	Treated with neem leaves	118.34±112.86	38	339	2.045	3.267
	Treated with matchsticks	131.10±149.84	19	403	1.556	1.857
	Treated with neem leaves + Matchsticks	152.86±78.98	64	271	0.756	−0.983
	Control	147.12±116.22	37	297	0.317	-2.476

The values in parentheses represent percentage share (%)

Fig. 5 **a** Examining the infection ratio of maize seeds in the laboratory. **b** Infected hybrid maize seed separated for further assessment. **c** Infected traditional maize seeds separated for further assessment. **d** Comparison of both traditional and hybrid maize seeds placed on the shelf and floor at the time of storage

the ancestral local knowledge in farm management and other socio-cultural developments in the villages. Use of locally produced seeds, including those grown on their own field, gifted by relatives and friends is the primary practice in the region, particularly for traditional landraces due to less trust in high-yield varieties (Carpenter 2005; Thomas et al. 2011a, 2011b) (Fig. 6). High-yielding seeds are purchased from the nearby market and Agriculture Extension Department located in Haroli. Farmers from Pubowal village have started with a formal seed system in recent decades perhaps because of their proximity and connectivity to the

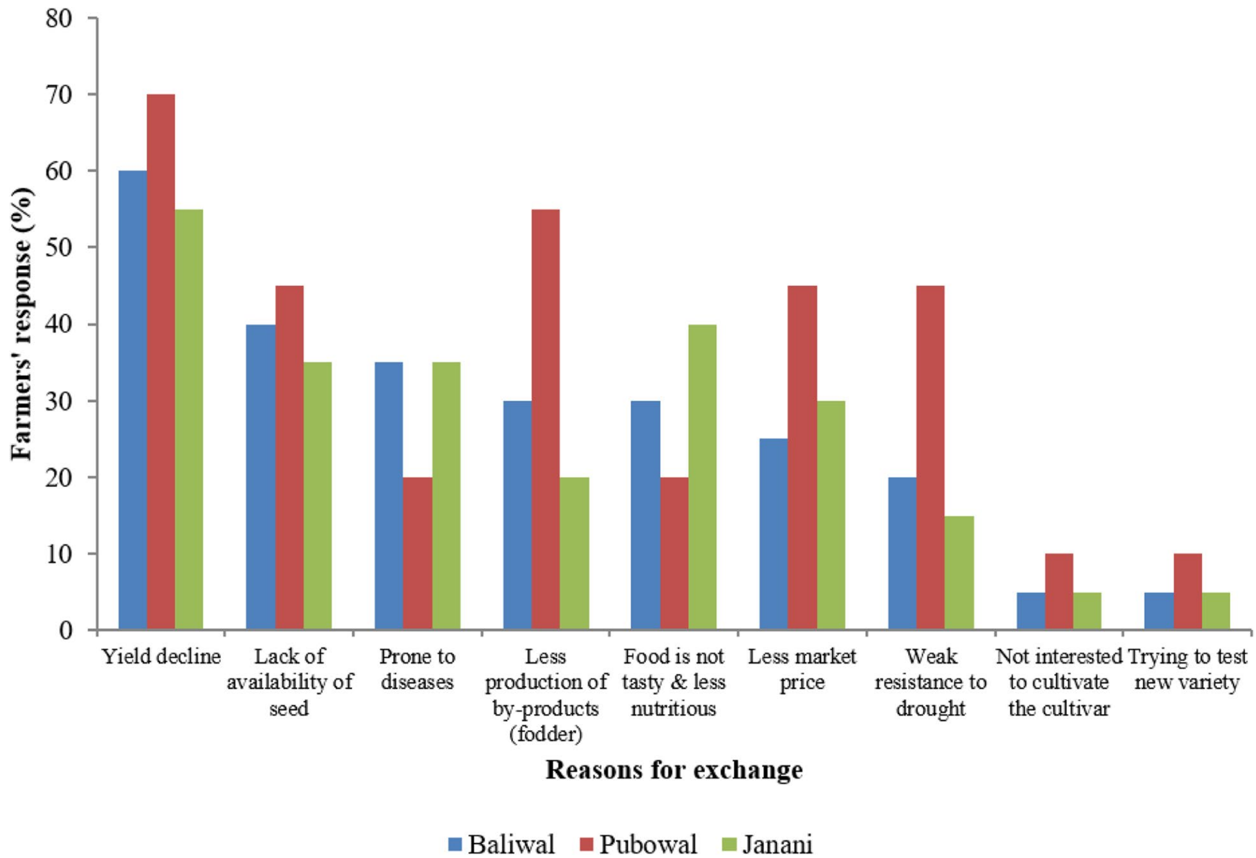


Fig. 6 Farmers' perception about seed exchange in Una, Himachal Pradesh

towns and also some part of the area brought under tank irrigation, which they feel is suitable to ex situ seeds. Moreover, changes in socio-economic conditions and deviations from traditional cultural activities have been weakening the traditional seed exchange system in the Pubowal more than other villages in the region.

Discussion

The present study revealed that 70–80% of seeds in Rabi and 50–60% of seeds in Kharif seasons, circulated through the traditional system in the region. Introduction of the formal seed system was found ineffective due to less trust, no significant production of by-products and it is weakly adapted to a heterogenous environment of the study area that remains harsh most of the time during the year. The study area is frequently subjected to uncertain weather and precipitation regimes, on which the cropping practices heavily depend. In addition, undulating terrain, farming land laden with pebble cobbles and smaller land holding makes communities more vulnerable. Institutional interventions did not succeed in such locations (Pandey et al. 2011). Currently, the traditional communities are less exposed to advanced mechanization in farming, capacity and knowledge development training and other digital benefits. Several respondents expressed that they are unable to take the advantage of Government benefits like subsidies and grants due to their meagre landholding size. Moreover, a formal seed system has been introduced in recent decades and may take a longer time for its adaptation in the region. Also, it is expensive, locally unavailable, and needs long-distance travel for purchase of required inputs like seeds, fertilizers and machineries. Most of the villagers were unaware of the sources of inputs and their actual costs. All these further discourage the change in agricultural practices from traditional to formal systems. People are quite satisfied with their usual traditional practices because these are treated as 'hands on practice', known, cost-effective, timely available and people and environment friendly. During the interviews, both marginal and small farmers expressed that, they are unable to adapt to advanced techniques available in the farming sector due to their small land holding size (1-2 ha) that too located as patches in different places. Since most of the people's diet is adapted to local food production, it further influences growing of traditional food crops following their old practices. Around 65% of the respondents from different landholding groups and social categories have expressed that they are growing crops for their own consumption and using by-products such as fodder for livestock. Therefore, traditional practices dominate in the area. Presently, overall, 12–16 traditional varieties are being cultivated in the region of which horsegram, chickpea and greengram are disappearing fast due to low production, less income, change in diet and cultivation becoming laborious. In addition, farmers have cited harsh environmental conditions, out migration, socio-economic changes and crop raids by wild animals &stray cattle especially during Rabi season as some other reasons for the erosion of these locally grown varieties (Agre et al. 2017). Moreover, 45% of farmers quoted that rapid acculturation and technological interventions are also contributing to the extinction of said traditional varieties in the area.

Field analysis reveals that nearly 40–50% of local farmers are following on-farm seed selection for vegetables and maize (Jarvis et al. 2000; Asiedu-Darko 2014) which our collaborative field visits with participants confirmed. It was observed that women farmers and senior citizens of the households play an important role in on-farm seed selection and storage systems. The study conducted by Brush (1995) related to on-farm seed selection suggests that traditional farming practices and seed selection on-farm from the middle of the crop field can multiply in-situ conservation along with socio-cultural values of the communities in the region. Almekinders et al. (1994) found that local seed system complements to the formal seed system in scaling up. Moreover, the traditional seed system plays a vital role in the conservation and maintenance of local landraces, social ties with the communities, cultural promotions and regional importance (Sperling et al. 1993; Li and Wu 1996; Poudel et al. 2015; Altieri and Merrick 1987). Our observations, in this regard, show that the entire Haroli block is known for effective practices of traditional knowledge particularly in farming. Furthermore, it was found that a large number of farmers are exchanging the seeds within a 10km radius from their respective villages; Kuthar, Kongrat, Laluwal and Haroli are some villages coming within their limits. They consider exchanging the seeds when yield starts declining and stored seeds get infected. Farmers exchange the seeds in the region because this system helps to preserve the phenological integrity, genetic stability and morphological characteristics of local landraces (Bisht et al. 2006; Niekerk and Wynberg 2017a, 2017b). A scientific understanding in this direction will help improve the nutrient level, disease resistance and gene characteristics of landraces. Jensen et al. (2013) observed that there is a positive linkage between the seed exchange system and gene flow. Similarly, Bajracharya et al. (2012) also reported that traditional seed management skills improve the genetic diversity of crops. Similar to the previous reports (Mobolade et al. 2019; Montufar and Ayala 2019; Pircher and Almekinders 2021; Odjo et al. 2022), our field findings highlight that there is a strong socio-cultural linkage among the seed exchangers in the community and among villages that are helping to protect and preserve the traditional landraces in the region.

Field experiments revealed that traditional treatments like neem leaves, safety matchsticks and a combination of neem leaves and safety matchsticks are effective in controlling the seed infection during storage. These treatments are developed based on trial and errors. The application of these traditional treatments effectively controls the growth of larvae of *Sitophilus granaries* in wheat and *Sitophilus zeamais* Motsch in maize during storage (Pereira and Wohlgemuth 1982; Rahim 1998). We could notice these practices and storage structures in most of the houses in the study region. The respondents including both men and women aged above 40 are generally involved with the storage of seeds in their respective homes. It was observed that they feel very confident about these practices particularly for traditional varieties which are grown in their fields as compared to hybrid varieties (Moreno et al. 2006; Kiruba et al. 2006; Montufar and Ayala 2019; Hlatshwayo et al. 2021). Further, field experiments confirm that seeds stored above ground showed lower moisture contamination and were less vulnerable to insect attacks. Insect resistance by traditional seeds placed on a shelf was significantly higher than that of the formal seeds introduced from outside and the ones placed on the ground. Furthermore, the study found that the seeds stored in traditional houses (relatively kutchha) are much safer than the seeds placed in modern houses which have cemented floors and roofs, perhaps due to relatively higher moisture inside the modern houses. We could also notice that the pots with increased thickness and good quality resist moisture absorbance. The low-quality pots were found to absorb moisture from the air. Apart from that, abnormal local weather conditions negatively affect the stored seeds. In addition, erratic rainfall also influences the local conditions to increase the moisture content in the air. It was observed that the traditional seeds relatively internalize these changes as compared to hybrid varieties. Therefore, the traditional knowledge of farmers is effective in terms of seed selection, storage and exchange along with the promotion of socio-cultural values in the region. Thus, traditional knowledge needs to be protected and promoted for future use (Almekinders et al. 1994: Brush 1995; Mobolade et al. 2019; Odjo et al. 2022).

Conclusion

Traditional community-led seed system has the potential in conserving local landraces and maintaining the neutraceutical security of local people. This is one of the important studies that document neglected traditional knowledge of local people and adds scientific evidences to their practices through conducting participatory field experiments. The study fills the wider research gap especially in terms of validating traditional practices through scientific experiments. Moreover, it supports for protection and promotion of the traditional seed system which is a real voice of vulnerable farming communities i.e., marginal and small landholders. The study highlights the importance of the traditional seed system for food production, securing livelihoods and adaptation to climate change and in situ conservation of traditional crop diversity. Therefore, it certainly contributes to achieving Sustainable Development Goals (SDGs) particularly to address SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), SDG 12 (Ensure sustainable consumption and production patterns) and SDG 13 (Take urgent action to combat climate change and its impacts). As described by several studies, the Bhabhar tract of Himalayan region is witnessing several changes in its landscape which include erosion of traditional knowledge, technological interventions, acculturations and climate change. Therefore, the present findings would help to support policy decisions for the conservation of this age-old, valuable traditional knowledge.

Key findings of this study on traditional knowledge related to on-farm seed selection, collection, production, storage and exchanges would be useful for developing suitable adaptation strategies to climate change. These traditional seed practices in the region, not only strengthen the social ties among the local people and promote cultural systems through the celebration of farm fairs and festivals during pre and post harvesting seasons, but also maintain crop vigour and diversity. Integration of traditional seed system with formal seed system, especially for developing suitable local breeds, and use of environment-friendly insecticides and pesticides as described in the study would help to conserve the traditional landraces at a very low cost and also protect human and soil health in the face of changing climate.

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Code availability
Not applicable.

Authors' contributions
The author(s) read and approved the final manuscript.

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Availability of data and materials
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Declarations

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