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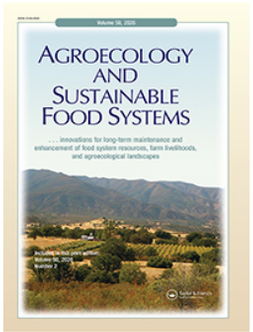

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The importance of traditional seeds in agroecology transitions: a case study from Himachal Pradesh in India

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ABSTRACT

This paper is based on a qualitative case study of an initiative by the state of Himachal Pradesh in North India to transition all its farmers to natural farming, an agroecological approach. The paper explores the importance of traditional seeds in the context of a transition to natural farming where cash crops and hybrid seeds had been previously promoted. The study was conducted in thirty-five villages across five districts in Himachal Pradesh. Farmers were interviewed to explore the transition processes and assess their experiences of how traditional seeds and hybrid seeds respond to natural farming practices. The research indicates that many farmers view hybrid seeds as lacking climate resilience, necessitating the use of agrochemicals, and being culturally and practically unsuitable. Employing natural farming practices with hybrid crops resulted in increased workloads and lower yields in cereals. Additionally, the research explores how state mechanisms facilitated access to traditional seeds and identifies areas that require further effort to revitalize farmer seed systems. We argue that supporting traditional seed systems is a key enabling factor for agroecology: it is crucial to maintaining food security, improving health and nutrition, and building resilience to climate change.

KEYWORDS

Indigenous seeds; agroecology; natural farming; hybrid seeds; food sovereignty

SUSTAINABLE DEVELOPMENT GOALS

SDG 2, SDG 12, SDG 11, SDG 15

Introduction

This paper examines the importance of traditional seed varieties (TVs) for small and marginal farmers in Himachal Pradesh. In addition, the research asks how the state mechanisms facilitated access to traditional seeds and supported farmer seed systems during the transition to natural farming. In 2018, Himachal Pradesh began an ambitious plan to transition all their farmers from conventional chemical farming to natural farming. Natural farming is defined as "the direction and process of transition towards a more local, resilient, and adaptive agroecology based farming" (NCNF 2021). It is characterized by low-cost regenerative agricultural practices based on ecological principles that do not rely on agrochemicals. These principles align with those

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of agroecology, which aims to create agricultural ecosystems that imitate local natural ecosystems.

Agroecology is an alternative paradigm that offers solutions to ecological crises and aspires to build sustainable food systems based on social justice and food sovereignty (Anderson et al. 2021, De Schutter 2011). It emphasizes the importance of local traditional knowledge and places the agency and power of small-scale farmers, including women farmers, above powerful external actors. Agroecology transitions with a focus on gender justice have shown enhanced life outcomes and empowerment for women (Larrauri et al. 2016; Behl et al. 2024). Emergent socio-political dimensions, such as food sovereignty, have distinguished agroecology from other approaches to ecological farming.

The principle of food sovereignty introduced by La Via Campesina in 1996, is "the principle of ensuring that everyone has the right to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and the right to define their own food and agriculture systems" (Nyéléni 2007). This movement protests against the dominance of agribusinesses and seed companies supported by governments to legislate and enforce seed certification and Intellectual Property Rights (IPRs) for agricultural genetic resources. IPR regimes are criticized for privatizing and commodifying what was once part of the commons and under the stewardship of small scale farmers. These exert pressure to decrease diversity, limiting the effectiveness and adaptability of future seed supply (Martínez-Torres and Rosset 2010; Edelman et al. 2014; Halpert and Chappell 2017).

To define agroecology more precisely, the High-Level Panel of Experts (HLPE) of the Committee of World Food Security defined 13 principles of agroecology collated from various frameworks (HLPE 2019). The first seven principles focus on agricultural practices: (1) recycling, (2) input reduction, (3) soil health, (4) animal health and welfare, (5) biodiversity, (6) synergy (managing ecological interactions), and (7) economic diversification. The remaining six principles relate to wider food-systems changes: (8) co-creation of knowledge (embracing local knowledge and global science), (9) social values and diets, (10) fairness, (11) connectivity (between producers and consumers), (12) natural resource governance, and (13) participation.

It is acknowledged that the science and practice of agroecology can only transform agriculture and food within the framework of food sovereignty. Schneider and McMichael (2010) argued that a loss of food sovereignty causes a rupture in farmers' knowledge, practices and skills, described as an epistemic rift. It denies farmers their decision-making role in the use of TVs for cropping patterns that are appropriate for their local conditions and climatic changes. Epistemic justice, on the other hand, involves respecting the knowledge and contributions of farmers and ensuring they have the opportunity to develop their knowledge and skills further. Farmers' traditional agricultural knowledge and their understanding of farm diversity are essential for transitioning to

agroecological food systems. This valuable knowledge includes sustainable practices, local responses to environmental challenges, and biodiversity conservation.

Currently, multiple agroecology initiatives in India seek to address the fallout from the Green Revolution (GR) technologies. The GR was resource-intensive, and in India, it resulted in the marginalization of small-scale farmers, soil degradation, water depletion, deteriorating human health, loss in biodiversity, and farmer indebtedness (GOI 2009; Patel 2013). Furthermore, industrial farming methods diminished the nutrient content of crops (Davis et al. 2004; Montgomery et al. 2022).

The GR centered on open-pollinated (Box 1) high-yielding varieties (HYVs) of wheat and rice bred through conventional crossing and selection. The HYVs were developed using traits primarily from Mexican cereals which incorporated semi-dwarfing genes traced to the Japanese cultivar *Norin-10*. These genes produced shorter plants that supported heavy grain heads and responded strongly to fertilizer and other inputs, enabling large yield gains under high-input management.[1] However, the introduction of semi-dwarf genes into cereals resulted in a decrease in nutrient-use efficiency, lower competitiveness against weeds and greater susceptibility to diseases (Lammerts van Bueren et al. 2011; Gooding et al. 2012). These factors contributed to lowering plant fitness and ultimately lead to diminished yields (Curry 2023).

Although the term "hybrid" (Box 1) is often associated with the GR, it was in 1994 that Indian Council of Agricultural Research (ICAR) released the first F1 hybrid rice cultivar (Negi et al. 2025). Hybrid seeds especially maize, first introduced in the United States, established the basis for a global seed industry.

Box 1: Different types of seeds

Landraces – also known as traditional, indigenous, heirloom, local or farmers varieties – are open pollinated seeds developed and adapted over time to local climatic and geographical conditions. These typically display greater genetic diversity than types bred through formal breeding and represent the collaborative efforts of farmers in selecting and developing seeds.

Open-pollinated seeds come from plants that are pollinated by natural agents such as insects, wind and birds or human hands. In an open-pollinated variety, plants exchange pollen mainly within the same variety, with the result seeds usually produce plants which are similar to the parents, though still retaining genetic diversity. This diversity can help populations adapt gradually to local conditions. Farmers can save and replant open-pollinated seed, though cross-pollinated species require isolation from other varieties to maintain purity. Predominantly self-pollinating crops/cereals such as wheat, barley, oats and rice mostly fertilize themselves but can also cross-pollinate under certain conditions.

Hybrid seeds are created by crossing two distinct parent lines. Breeders first develop uniform parent lines through several generations of self-pollination, e.g., five years for wheat. They then prevent self-pollination in the female parent while crossing it with pollen from the male parent. The resulting seed on the female parent is the F1 (first-generation) hybrid. F1 hybrids are valued for their uniformity and hybrid "vigor." However, seeds saved from F1 plants begin to segregate from the next generation resulting in offspring that do not consistently match the parent type. Therefore, for reliable performance, farmers must purchase fresh F1 hybrids each season. This dependence on new seed distinguishes F1 hybrids from open-pollinated varieties whose saved seed typically breeds true when properly isolated.

The term 'hybrid' in this paper specifically refers to commercially produced F1 hybrids that require external inputs, and where the parental lines are not controlled by farmers. The paper is organized as follows: this section summarizes the key reasons for the importance of agro-biodiversity. Next, we briefly discuss seed conservation efforts in India. The section on Methods and Materials describes the research methods used and the context of the case study. In the Results section, we examine the results of the case study, highlighting the impact of NF practices on farmers, crops, and seed varieties, as well as the support provided by the NF program for the use of TVs. Discussion addresses the tensions arising from the use of hybrid seeds for cash crops and explores potential solutions. Whether the transition mechanisms to NF promote or impede food sovereignty is discussed. Finally, the conclusion emphasizes the need for coherent policies to support farmer seed systems.

Why crop biodiversity is important

Introducing HYVs as part of the GR technologies led to an accelerated loss in crop genetic diversity. Although estimates vary, it is estimated that over 100,000 different rice varieties in India were reduced to 7,000 (WEF 2019). The Food and Agriculture Organization of the United Nations (FAO) estimated that 75% of the agrobiodiversity worldwide was lost during the 20th century (FAO 2010).[2] The FAO estimates 20–40% of global crop production is lost each year to pests and diseases, underscoring why conserving and deploying crop genetic diversity is central to food security (FAO [date unknown]).

Crop diversity is critical for resilient agriculture. Large-scale planting of genetically uniform crops over broad areas can amplify epidemic risk because pathogens encounter fewer genetic barriers. Diversity within a crop species preserves alleles[3] that contribute to pest and disease resistance and supports adaptation to local soils, climates, and biotic interactions (Keller et al. 1999; Deb et al. 2024). A well-studied case of wheat yellow rust illustrates how local strains evolve defenses against local diseases: traditional wheat strains found in the Himalayan region developed genes that enable them to resist yellow rust, a disease thought to have originated in that same area. These wheat strains developed their defenses due to a combination of disease pressure, as well as farmer selection and conservation efforts (Jung et al. 2025). Consequently, local or regional plants often exhibit better performance and higher fitness compared to foreign-origin plants. Additionally, reports from tests on many species show that moving seed from distant regions disrupt ecological networks hence the emphasis on careful, region-appropriate sourcing of planting material. Introducing non-native plants can create mismatches with numerous interacting organisms, potentially leading to significant ecosystem consequences (Bucharova et al. 2017).

Furthermore, diverse cropping systems based on indigenous plants are suited to different terrains and climates and ensure food security. In contrast,

when confronted with unfavorable conditions, HYVs and hybrid varieties can be vulnerable and fragile (Ficiciyan et al. 2021; Ajl and Sharma 2022). FEED (2024) found that 40.9% of Indian marginal farmers surveyed had experienced drought, while 32.6% had faced excessive rains. The vast array of TVs provides an invaluable resource for adapting crops to new pressures and needs. For example, Debal Deb (Vidal 2014) reintroduced six salt-tolerant rice varieties into West Bengal, the only ones to survive Cyclone Aila in May 2009.

Studies have revealed the superior nutritional content of indigenous varieties. The first quantitative study comparing B vitamins in about 300 indica rice landraces to 3 modern rice cultivars revealed that many rice landraces were nutritionally superior to modern cultivars. These landraces, therefore, hold great potential in ensuring nutritional security for people with low incomes (Roy et al. 2023). Similarly, Parvez et al. (2019) reported a higher nutrient content in farmers' wheat cultivars. The consumption of nutrient-dense coarse cereals, such as millet and sorghum, declined due to the promotion of modern wheat and rice cultivars by the GR. This decline in coarse cereals has significantly reduced iron intake in rural populations (DeFries et al. 2018). Millets are high in dietary fiber, nutrients, phytochemicals, and antioxidants. They provide numerous health benefits and are considered an ideal food for managing diabetes (Jacob et al. 2024).

Research findings indicate that modern wheat cultivars introduced during the GR show a decrease in mineral density in wheat grains (Fan et al. 2008). A recent study found that widely used HYVs of wheat and rice not only have lower mineral density but also higher levels of toxic metals. (Debnath et al. 2023). Essential minerals, such as zinc and iron, in rice grains decreased by 33% and 27.0%, respectively, while for wheat, these decreased by 30% and 19.0% over the past 50 years. The decline in nutrient density negatively affects diet quality and human health. Equally concerning is the increased absorption of toxic minerals, such as arsenic, aluminum, barium, chromium, and strontium, from the soil, particularly in rice cultivars. This is attributed to modern breeding programs compromising plants' natural evolutionary defense mechanisms against these toxicants.

Furthermore, GR technologies, particularly hybrid seeds, deprived women of decision-making roles in selecting and storing seeds as well as in managing diverse cropping systems that include grains, pulses, beans, tubers, and vegetables. Crops often carry deep socio-cultural significance beyond their culinary use. Women traditionally cultivate a range of plants to preserve their medicinal, cultural and religious traditions (Kuruganti and Ramachandrudu 2022). According to the WHO, 65% to 80% of the populations in developing countries currently use medicinal plants for prevention or remedies (WHO 2011).

Seed conservation efforts in India

The conservation of TVs has mainly been the responsibility of farmers and civil society organizations (CSOs) dedicated to seed preservation. Indigenous

societies are known to preserve an astonishing genetic diversity of crops through continued seed exchange (Pratap and Rawal 2022). These remain outside the purview of the formal seed system, which follows India's seed legislation, beginning with the Seed Act of 1966. The legislation established rules for registration and certification to ensure a supply of standardized seeds for farmers by seed corporations and government institutions.[4] In 2023, the Revitalising Rainfed Agricultural Network along with 60 CSOs launched a program to strengthen local seed systems and integrate TVs into mainstream agriculture (WASSAN 2023).

Seed conservationists grow each variety annually so that the seeds stay viable and evolve with changing climatic conditions. To accomplish the complex task of preserving over 1,000 rice varieties while maintaining the purity of each variety, Debal Deb in Odisha and Syed Ghani Khan in Karnataka devise planting plans to prevent cross-pollination so that varieties are planted adjacent to cultivars based on asynchronous flowering. Deb (2005) argues that the purity of distinctive landraces must be maintained through seed conservation and selection, as the loss of the genetic purity of landraces erodes genetic diversity and distinctive characteristics. Due to cross-pollination between different landraces, distinctive characteristics, such as drought tolerance or pest resistance, can be lost. To preserve these characteristics, selection must occur at each stage of sowing, transplanting, and flowering. Plant quality is maintained through "roguing," which involves the routine removal of "rogue" plants with undesirable traits or off-type characteristics. For example, rice grains are identified by their morphological characteristics, such as plant size, leaf length and width, flag leaf angle, panicle shape, and panicle size. The final selection involves picking out the panicles showing the most desirable characteristics, such as size, aroma, or ripening time. Selection requires traditional skills and knowledge, which farmers who use purchased seeds may have lost.

Methods and materials

This paper is based on qualitative data gathered over four visits to Himachal Pradesh between November 2021 and December 2023. Data was collected in an iterative process split into two phases (Table 1). Phase 1 consisted of focus groups in nine villages across three districts – Mandi, Shimla, and Solan – highlighting issues requiring further investigation. The focus groups used a participatory force-field activity to rank the challenges and benefits of adopting natural farming.

In the second phase, purposive sampling was used to consider different household types, caste, duration of NF practice, various agro-climatic zones, and crop types. Districts and villages were selected to represent three different agroclimatic zones, each specializing in cultivating cereals or vegetables and

Table 1. Details of methods and sampling.

	Methods used	No. of participants	Districts and villages
Phase 1	Focus groups using participative activities; key informant interviews (KIIs); observations of training; ethnography	Focus groups: 100 women farmers Family interviews: 2	9 villages in 3 districts
Phase 2	Women's time-use and life-story interviews; observations of training; ethnography; focus groups; family and KII interviews	Women's interviews: 53 Women in focus groups: 42 Families: 14 Male farmers: 13	27 additional villages across 5 districts

fruits as cash crops. Thirty-five villages were visited across five districts – Shimla, Solan, Mandi, Kangra, and Kullu. Semi-structured interviews comprised two sets of questions. One set aimed to discover the NF practices adopted, the mechanisms used, the challenges encountered, the crops grown, the types of seeds used, and the results achieved. Another set of questions asked farmers how the NF transition processes had affected their lives in specific domains (Behl et al. 2024).

Context

Himachal Pradesh is a mountainous state in the western Himalayas. It is a major producer of fruits and vegetables and is known as India's "apple state." Agriculture is the source of livelihood for 69% of the population, and 78% of the total cultivated area in the state is rainfed. Land holdings in the Himalayan states tend to be small, scattered and fragmented. According to the 2015/16 agricultural census, Himachal Pradesh has 997,000 holdings comprising of 944,000 hectares. 89% of all farms were marginal or small, with less than 2 ha. of land. 71% were marginal with an average size holding of 0.4 ha, equivalent to I acre, i.e., 5 bighas (GOI 2019). Marginal farmers cultivate cereals, beans and pulses, oil seeds, fruits, and vegetables and still rely on traditional manure-based practices with limited use of pesticides. In contrast, apple and high-value vegetable farmers use a range of agrochemicals. Since the mid-1990s, farmers have been encouraged to shift from growing cereals to more profitable vegetables raised from hybrid seeds. Currently, more than 80% of all vegetable seeds sold by private companies in India are hybrids (Dadlani 2024). The move to conventional agriculture, however, has come at a price – increased use of agrochemicals, susceptibility to pests, diseases, falling yields, and soil degradation (TERI 2015).

To address the challenges of conventional agriculture, Himachal Pradesh implemented an organic farming policy in 2002. However, using purchased organic inputs was costly for farmers and led to financial losses. In its place, a State Project Implementing Unit was set up in 2018 to launch a program called *Prakritik Kheti Kisan Khushal Yojana* (PK3Y) based on practices popularized by a farmer promoter, Palekar, referred to as Subhash Palekar Natural

Box: 2 Subhash Palekar Natural Farming (SPNF) techniques

SPNF adopted by PK3Y was based on four practices that aimed to rejuvenate the soil microbiome, with indigenous cows being considered essential:

Jeevamrit – a fermented microbial culture as a key component of soil regeneration.
Beejamrit - treatment for seeds comprising local cow dung, cow urine, lime, and soil.
Acchadan - mulching comprises soil, straw, and live mulch, using the symbiotic ground cover of intercrops and mixed crops.
Whapasa - reducing the water requirement by improving the soil's water-holding capacity.

Additional practices aimed at redesigning a system as a whole to regenerate the soil and promote integrated pest management included multi-cropping and intercropping, line sowing, trap crops, several farm-made biopesticides, and agro-forestry.

Farming (Box 2). The main objectives were to reduce the cost of cultivation, increase incomes for small and marginal farmers, grow healthy food, build climate resilience, and improve soil fertility and water holding capacity. PK3Y used an existing extension system, the Agricultural Technology Management Agency (ATMA), which had previously offered training in organic and conventional farming. The state had 961,000 farmers, of which 170,000 were reportedly trained in SPNF by the end of 2023.

Results

This section will first present data on the crops cultivated and the types of TVs and hybrid seed used by three small and marginal farmers, illustrating typical practices among 89% of farmers in the state. The selected farmers come from different districts and agro-climatic zones: Kullu, Solan, and Kangra. Their experiences highlight the diverse range of crops grown in Himachal Pradesh, which includes both subsistence crops for personal use and cash crops intended primarily for income. These farmers had been practising NF for three to four years; however, they encountered difficulties in transitioning to NF due to previous state policies that encouraged the use of agrochemicals and the cultivation of cash crops.

The first characterization is from Kullu, a high-altitude zone specializing in horticulture, particularly apples. Figure 1 depicts vegetables and cereals cultivated by Usha, a 28-year-old farmer, during a standard calendar year. Usha's family owned 2.4 acres (approx. 1 ha) of land, of which one acre was dedicated to growing fruits – apples, pears, plums, and persimmons – as cash crops. She farmed the land with help from her in-laws and her husband, who held another job.

Usha cultivated 31 vegetables, legumes and cereals in addition to growing fruits. Other than wheat, cultivated entirely as a subsistence crop, most crops fulfilled subsistence requirements and were also sold to a greater or lesser degree. A few vegetables, such as tomatoes, red onions, and cabbages, were

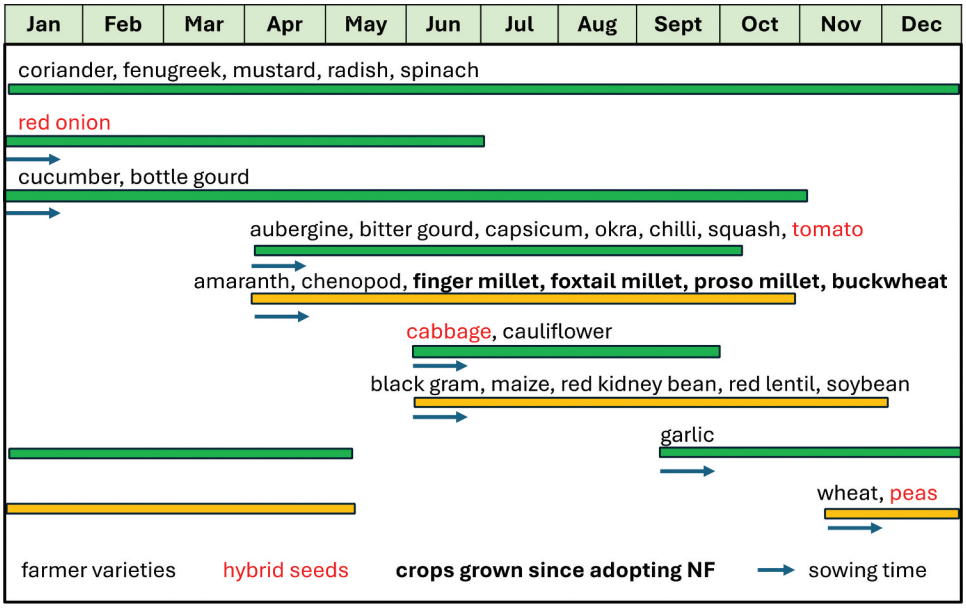

Figure 1. Crops grown by Usha, a marginal women farmer in Kullu district.

grown primarily for income. Usha reported that many farmers wished for indigenous seeds, and ATMA staff occasionally provided these if they had been sourced from other farmers. Usha made attempts to find TVs to replace the hybrid varieties of vegetables she grew. She reported that TVs required less work as they were more disease-resistant. She was successful in finding a TV of cauliflower from a local nursery. In NF trainings, Usha was informed that the old grains were disappearing from farmers' fields and she learned about their superior nutrition and climate resilience. Thereupon, Usha resolved to revive these grains.

> We have lost our old cereals and we are trying to revive them. I have started growing millets and buckwheat. ATMA staff motivated us and stressed that it is essential to grow old grains.

She sourced millets and buckwheat from other farmers and began to grow these for the benefit of the community and also to sell. The ATMA staff offered support by purchasing some millet seeds from her to distribute to other farmers.

Usha noted that the crops began demonstrating greater climate resilience from the 2nd year of using NF practices. For example, maize stayed upright and did not flatten with the weight of the corn heads in strong winds and heavy rain. It also stayed green during a drought compared to the maize crops of other farmers practising conventional farming. Usha enjoyed NF not only for its practical benefits but also for how it reinstated her right to be in control and increased her decision-making over how to produce food.

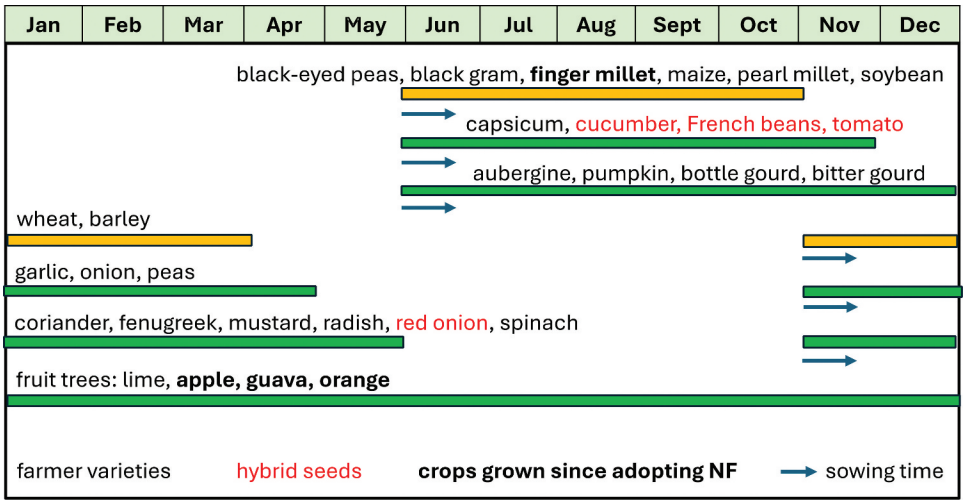

Figure 2. Crops grown by Radha, a marginal farmer in Solan.

The second characterization (Figure 2) comes from Solan district, which lies in a low hill zone and specializes in vegetable cash crops. Solan accounts for a third of tomatoes produced in Himachal Pradesh. Radha, a 40-year-old woman, farmed 1 acre of land with her husband, who also has a part-time job. Radha cultivated 30 crops, consisting of both TVs and cash crops produced from hybrid seeds or rootstock. She used the 1-acre plot intensively, where vegetables are grown amongst fruit trees. The primary sources of her income were tomatoes, capsicum, and cucumber. However, growing tomatoes was a gamble as the price fluctuated widely each year. It was often too low to cover costs, i.e., Rs 200 for a crate of tomatoes, interspersed with fewer years when it was highly profitable. Radha reported that farmers continue to cultivate tomatoes, hoping for good profits and to offset losses incurred in previous years due to the high cost of chemicals.

Radha stated that hybrid seeds were more disease-prone than TVs. She found that the seedlings were prone to fungal infections during transplanting, which was not the case with TVs. Radha also preferred TVs since hybrid seeds were expensive and needed to be purchased annually. She used to grow hybrid capsicum but replaced this with an TV purchased from a local farmer. The yield was comparable to the previously grown hybrid variety. ATMA staff occasionally distributed TV seeds, and Radha received seeds for radishes, peas, fenugreek, coriander, and black gram. When Radha learned about the nutritional properties of millets in ATMA meetings, she began to grow finger millet and cook with pearl millet, which had so far been grown for fodder. All vegetables responded well to NF practices, particularly legumes.

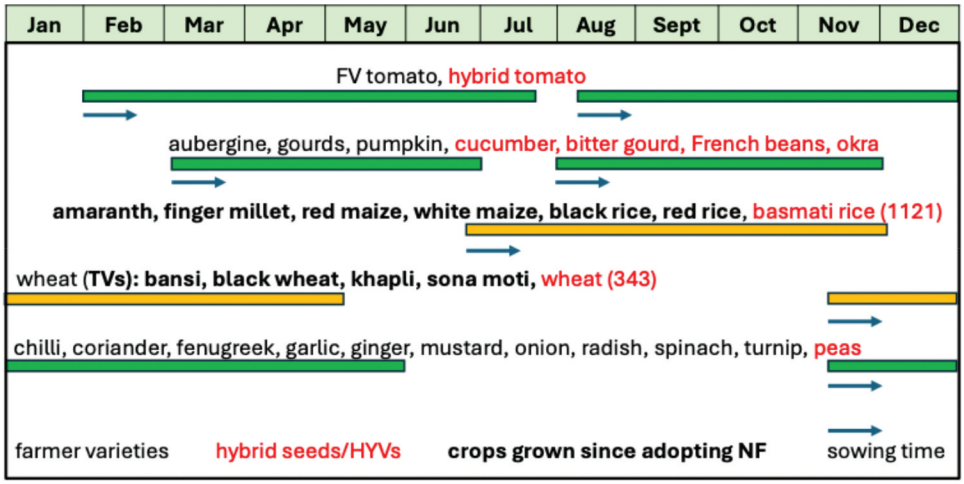

Figure 3. Meenaji and Yudhbir Singh – farmers in Kangra district.

> Normally, the tomatoes would be 4 to 4 ½ feet tall. With NF, the tomatoes grew taller and, therefore, had more flowers and fruit. But we have to spray them with NF anti-fungal and pesticide preparations right from the start. They need to be sprayed every 3 or 4 days.

Tomatoes also achieved a higher yield because they weren't sprayed with pesticides that damaged the plant. Radha reported that chemical pesticides would cause the flowers to wither, thus affecting the yield. Over the years, using conventional farming had resulted in decreasing yields, while with NF, the yield stabilized after an initial drop in the first year. Additionally, applying synthetic fertilizers to a TV wheat had made it vulnerable to yellow rust; whereas with NF, the wheat had become disease-free.

The third characterization (Figure 3) is from Kangra district. Kangra lies in a low hill zone where the farmers specialize in growing cereals, including paddy. Yudhbir Singh, age 55, and his wife Meenaji farmed a 4.5 acre plot. Yudhbir retired from the police in 2016 and began farming full-time with Meenaji who had so far managed the farm using conventional methods. Yudhbir participated in a Palekar 6-day training camp in 2018, and both Meenaji and he began to practise NF. The farm comprised two plots: 2.5 acres close to the house and 2 acres about 1.5 km away. They found it difficult to transport *jeevamrit* to the more distant plot, nor was it possible to make *jeevamrit* in situ as the containers would get stolen. Consequently, they continued to use conventional farming on the distant plot, while the closer plot was fully converted to NF.

Meenaji and Yudhbir were interested in filling a gap in the market for TVs. They began growing a range of cereal TVs for their nutritional value. These were especially sought after by individuals with medical conditions like diabetes. Meenaji and Yudhbir believed that TVs needed to be publicized and

promoted for their nutritional and medicinal use. Also, people needed to be informed about the benefits of naturally farmed produce.

> If people were made aware of the nutritional benefits of indigenous wheat and rice varieties, we could cultivate and sell more of those crops. At present, there is not enough demand.

ATMA agents in Kangra had provided farmers with open pollinated red rice seeds developed by the Department of Agriculture. They did not purchase indigenous seeds from farmers, such as Meenaji and Yudhbir, for distribution to other farmers but made the seed availability known on WhatsApp groups and other networks. Meenaji undertook the role of storing the seeds and dealing with farmer requests.

Meenaji and Yudhbir began cultivating a hybrid rice variety "1121 Basmati Rice," renowned for its long grains, aroma, and yield (Singh et al. 2018) 3 years ago. However, they found it to be highly disease-prone. Yudhbir experimented with selecting the best rice seeds to grow the next crop. He found that the second crop exhibited better disease resistance. Meenaji and Yudhbir preferred using their own seeds as they knew how the crop would respond to local conditions, which wasn't the case when growing newly purchased hybrid varieties. They also found that hybrids were not drought-resistant. The hybrid crops could not survive without water for ten successive days, whereas the TV would. They found that using NF on hybrid or HYV cereal cultivars presented challenges: wheat 343, a HYV grown for income, experienced a yield reduction of approximately 10% when cultivated with NF.

Meenaji and Yudhbir cultivated hybrid as well as local tomato varieties because both sold well in the market. The local variety was known for its tangy taste and was used in traditional dishes for special events and celebrations. On the other hand, the hybrid tomatoes, which were taller and had a high yield, were primarily sold for salads. Yudhbir reported that both tomato crops required extra spraying with bio-pesticides to keep diseases at bay.

As shown in the characterizations above, marginal farmers cultivated a rich diversity of crops: they grew between 15 to 35 vegetables, grains, legumes, and oilseeds in addition to fruits. The majority were raised from indigenous seeds in rainfed conditions (Table 2).

This research did not examine infraspecific crop diversity. However, it was noted that infraspecific crop diversity was limited to mostly 2 or 3 types of each vegetable in each district. In the case of cereals, farmer families maintained one or two wheat or rice varieties, including notable landraces such as red rice in Kangra district. Many farmers could not name the wheat or rice variety they cultivated. Older farmers could name two or three landraces of maize or rice which were no longer found in farmer fields. Kullu, a high-elevation district is rich in biological diversity and valuable medicinal plants. An ATMA officer

Table 2. Crops commonly grown from indigenous seeds.

Cereals	maize, wheat, rice, barley, buckwheat, millets, sorghum, chenopod, amaranth
Vegetables	garlic, mustard, spinach, fenugreek, radish, cucumber, red and green chillies, okra, aubergines, bitter gourd, bottle gourd, sponge gourd, pumpkin, beetroot, coriander, turmeric, onions
Legumes	black gram, red-kidney beans, black eyes peas, soya bean, chick peas, red lentils, peas

reported the presence of a wide variety of beets in the area that had not been documented.

Farmers growing a diverse diet for their own consumption and selling to local markets had, in previous years, been encouraged by the state to focus on cash crops to increase their incomes. These cash crops included hybrid varieties such as tomatoes, capsicum, cabbages, cauliflower, seedless cucumbers, and French beans. The cultivation of cash crops created tensions when adopting NF. Farmers faced a choice between using agroecological practices that prioritize ecological integrity, biodiversity, and sustainability versus planting cash crops for increased income. Some farmers reverted to indigenous crops due to concerns about soil damage from the chemicals required for hybrid varieties.

The impact of natural farming on crops grown from hybrid seeds

Table 3 quantifies key farmers responses related to hybrid seeds and TVs. 38% of farmers reported increased shelf life, improved appearance and taste, or prolonged fruiting periods for their vegetables and fruits from the second year of practising NF. In many instances, these results were achieved for crops raised from both TVs and hybrid seeds, contributing to increased income and diet diversity.

The quotes below illustrate effects of NF practices on some hybrid fruits and vegetables.

> The capsicums (hybrid) lasted long and continue to stay green because of jeevamrit applications. The fruiting time was also prolonged. [H2-Me-Kul]

Table 3. Quantified farmer responses from focus group discussions and interviews.

Description of responses	Number of farmers	No of responses	%
Hybrid seeds			
Associating hybrid seeds with agrochemicals and low disease resistance.	62	62	100%
Using NF on crops grown from hybrid seeds increased workloads.	49	46	94%
Highlighting the practical, cultural, and ecological drawbacks of hybrid seeds compared to TVs, e.g., TVs were more resilient in adverse weather conditions.	49	24	49%
Benefits of natural farming			
Increased shelf life, improved appearance, better taste or a longer fruiting period for fruit and vegetables.	95	36	38%
Cultivating coarse grain varieties upon being introduced to NF.	62	36	58%

> The growth of apple trees is better. 3-year-old trees have the growth that you would expect from a 5-year-old tree. [H2-An-Kul]

> The French beans are continuing to fruit longer than we expected. But now, we must pull out the plants to make space for the next crop. [H1-Sha-Sim]

62 farmers were asked about their views on hybrid seeds, and 100% of respondents associated these with agrochemicals. They identified several issues linked to agrochemicals, including high costs, challenges in controlling plant diseases, and negative impacts on their health. Many women reported experiencing body aches, headaches, and allergic reactions such as skin rashes, burning sensations, and eye irritation when using pesticides and chemical fertilizers. Three farmers reported that chemical fertilizers had adversely affected their health to the degree that they could no longer work.

Additionally, 49% of the respondents spontaneously highlighted the practical, cultural, and ecological drawbacks of hybrid seeds compared to TVs, noting that traditional varieties demonstrated greater resilience in adverse weather conditions.

Furthermore, farmers who grew hybrid cereals, such as rice and maize, reported a drop in yield of between 10% and 25% when these were grown with NF practices. How different hybrid crops react to NF practices under different conditions remains an area for further research. Key factors may be the length of time NF has been practised and the extent of agroecological integration. A farmer in their fourth year of NF reported that the diseases had decreased. Tomatoes, for example, were no longer being attacked by root nematodes.

Table 4 highlights illustrative quotes from farmers as further evidence of how farmers associated hybrid seeds with poor climate resilience, cultural and practical unsuitability, and high use of agrochemicals. Older farmers recalled how cash crops had led to agrochemical use and changed their diet.

Difficulties with controlling diseases in hybrid plants

Scientists researching NF at the agricultural university in Himachal Pradesh reported that certain pests that attacked tomato crops, such as fruit flies, fruit borers, and whiteflies, were difficult to eradicate using NF bio-pesticides during the rainy season. Whiteflies and fruit borers had also become resistant to chemical pesticides.

It was evident that using NF practices on hybrid crops increased workloads significantly due to the increased spraying required to control diseases. Out of a sample of 49 farmers, 94% or 46 respondents felt that greater effort was needed. The amount of effort varied according to the crops grown and the agroecological context. Farmers agreed that cabbages and tomatoes were the most disease-prone. Tomatoes, in particular, needed to be sprayed twice a week. Two apple farmers reported that their spraying schedule had doubled. A male farmer growing yellow capsicums in polytunnels had developed a spraying regimen through trial and

Table 4. Quotes about farmer experiences with hybrid seeds and TVs.

Characteristics of hybrid seeds	Illustrative farmer quotes
Cultural and practical (Socio-ecological) unsuitability	*Before the year 2000, we used to eat a different cereal every day of the week – maize, barley, millets, etc. Now people mainly eat rice and wheat. These changes to the diet occurred when cash crops began to be promoted. There is also less hay for animals. The cereals we grew earlier provided enough hay.* ([H3-Go-Kul] – a 53 year old apple farmer).
	I tried hybrid maize but the stalks were too thick for my cows to eat, so, last year, I went back to the local seeds. ([H2-Ka-Kul] – a 39 year old marginal woman farmer in the 4th year of NF).
	Local tomatoes have a thinner skin and are much better to cook with. Hybrids have a thicker skin and don't cook easily. ([H3-Ra-Kul] – a 40 year old woman farmer in the 4th year of NF).
	New varieties of plants are weak plants. They need to be supported if they grow tall. The older plants were stronger and did not get diseases. In the interests of improving plants, they have been ruined. ([H2-Sa-Kul] – a 48 year old male apple farmer in the 4th year of NF).
	Chuirri, a red tall wheat that was resilient in rain and hail storms is no longer available. The grains would not fall down unlike hybrid varieties where grains are shed if it rains. ([H2- Ka-Kul] – a 38 year old marginal woman farmer).
Link to diseases and chemical use	*We cultivated cabbages with chemicals for about 4 years and then dropped them when we found out that chemicals harmed our health and the soil. ([H2-Me-Mas]* – a 47 year old woman farmer farming 4 acres with her family since 2018).
	We have adopted vegetables that are not traditional to this area. Cabbages and tomatoes are the most disease prone. With local seeds that is not the case. ([H2-Me-Mas] – a 50 year old small holding male farmer from Shimla district).
	The seeds for wheat and maize are local; we keep them at home. They don't get any diseases. ([H2- Ra-Sol] – 40 year old marginal woman farmer from Solan district).
	Growing indigenous seeds with natural farming is fine, but if you are growing hybrid seeds which need chemicals, a lot of effort and changes are needed. Instead of using 50 litres of jeevamrit, you would need 400 litres. ([H2-Sh-Sol] – a 40 year old commercial farmer).
	Hybrid seeds are for businesses not for farmers. We grow crops primarily for our health. ([H3-Ra-Kul] – a 44 year old woman apple farmer in the 4th year of NF).
	We have an old rice variety from our grandparents time called Kasturi Basmati. If we add urea to it the entire crop flattens and dies. ([H3-So-Kang] – a 40 year old woman farmer in 4th of NF).

error that was four times as intensive as that required by conventional farming. Nevertheless, he was pleased with the crops' resulting high yield and good condition.

The need for additional spraying often discouraged farmers from adopting NF, as they believed it would increase their workload to an intolerable level. Increased workloads were particularly relevant for women farmers. A time-use survey of 26 female farmers found that women already bore a substantial workload – the average workday lasted 14 hours, comprising both care and productive work.

State efforts to promote traditional seeds

One of the key efforts made by ATMA staff was encouraging farmers to use and revive TVs. 58% of 62 farmers (Table 3) who had been introduced to NF made an attempt to begin cultivating coarse grains or other TVs. These farmers noted that they used to plant millets and other coarse grains in the past; they began placing greater value on TVs, sourcing these from other farmers and promoting their cultivation. However, efforts to supply farmers with seeds were perceived by farmers to be inadequate as the demand for indigenous seeds far exceeded supply. This limited farmers' ability to plant and preserve local crop diversity. There was a lack of coordination within the PK3Y program, and practices varied among districts. In some districts, ATMA staff purchased TVs from farmers to distribute to other farmers within the district. While in other districts, only certified open-pollinated seeds either developed or purchased by the agricultural department, were distributed to farmers as and when available. Farmers used the WhatsApp groups established by ATMA to source seeds. ATMA staff also shared information within these networks regarding which farmers could provide seeds. On the other hand, some ATMA staff continued distributing hybrid seeds to farmers. In one training session, ATMA agents supplied farmers with hybrid maize to start a Farm School[5] even though the farmers grew a local variety of maize. This raises the question of whether the practice of providing farmers with free seeds as an incentive should be dispensed with.

PK3Y had initially attempted to establish seed groups with Rs 25,000 allocated for set-up expenses to multiply indigenous seeds for distribution to farmers, but few were successful. An ATMA agent reported that they did not receive training on how to set up a seed group. Given that the agricultural degrees focused on conventional agriculture, the skills and knowledge related to traditional techniques were not covered. Their agricultural courses at the state universities had not addressed core knowledge about seed multiplication, selection, and storage. In 2022, PK3Y collaborated with a CSO, HimRRA, to train farmers in growing millets, conserving and distributing seeds, and cooking with millets. However, this initiative was limited to 10 *panchayats* (village councils). In 2023, recognized as the Year of Millets, PK3Y distributed millet seed kits and organized community events to promote the nutritional benefits of millets, as well as to showcase traditional dishes prepared with them. Also, in 2021 plans were being developed to multiply local seeds jointly with 130 farmer associations (Prashar 2021).

In addition, PK3Y was developing alternative food networks and providing marketing support for farmers which could be used to market traditional crops. In 2022, they started working on a platform for certification and an efficient marketing system to ensure fair prices for natural farming (NF) produce. This involved an online self-certification and evaluation tool called

the "Certified Evaluation Tool for Agriculture Resource Analysis for Natural Farming" (CETARA NF). Furthermore, the formation of Natural Farming Producer Companies (N-FPCs) was supported through a multi-stakeholder partnership that included a state university.

Discussion

Literature suggests that hybrid seeds are high-yielding, disease-resistant, and climate-tolerant. However, farmer experiences from this case study challenge the narrative that hybrid seeds are more disease-resistant than indigenous seeds. Most farmers associated hybrid crops with high costs, damaging chemicals, diseases that were difficult to control, and poor climate resilience. The results reinforce the benefits of indigenous seeds; they have cultural and practical advantages and are essential to adapting to climate change, and maintaining food and nutritional security.

The drive to grow cash crops undermines the HLPE's agroecology principle of Synergy, which is to enhance positive ecological interaction, synergy, integration and complementarity among the elements of agroecosystems (animals, crops, trees, soil, and water) (HLPE 2019). For example, moving away from cultivating diverse cereals in favor of cash crops affected nutrition adversely, led to an increased use of agrochemicals and caused a shortage in biomass. Maikhuri et al. (1996) found that farmers who had cultivated traditional crop varieties alongside various fodder-yielding trees removed the trees to cultivate HYVs that required more sunlight to achieve greater crop yields. Debnath et al. (2023) highlighted the poor nutritional quality of commonly used HYVs of cereals and called for urgent nutrient profiling before releasing a cultivar of staples like rice and wheat. This must apply to all HYVs including hybrid cultivars that farmers use for cash crops.

It was unclear whether PK3Y aimed to achieve food sovereignty for marginal farmers in Himachal Pradesh. Their vision of NF described a more sustainable farming system that raised farmer incomes by reducing dependence on external inputs, regenerating the soil, producing healthy foods, and enhancing biodiversity and ecosystem services (GoHP 2020). However, hybrid seeds were not mentioned, nor was their relation to biodiversity loss highlighted. Without a clear policy and plan for promoting indigenous seed varieties, PK3Y ground staff lacked clarity on the role of modern seeds. Some continued to distribute hybrid seeds, which gave mixed messages to farmers and undermined the NF project. This raises the wider question about whether the State can foster a deeper transformation of agriculture. This requires political commitment from policymakers to reform existing institutions and policies that currently hinder sustainable agricultural progress.

The significance of TVs derived from the literature review and farmer experiences is summarized in Figure 4 below:

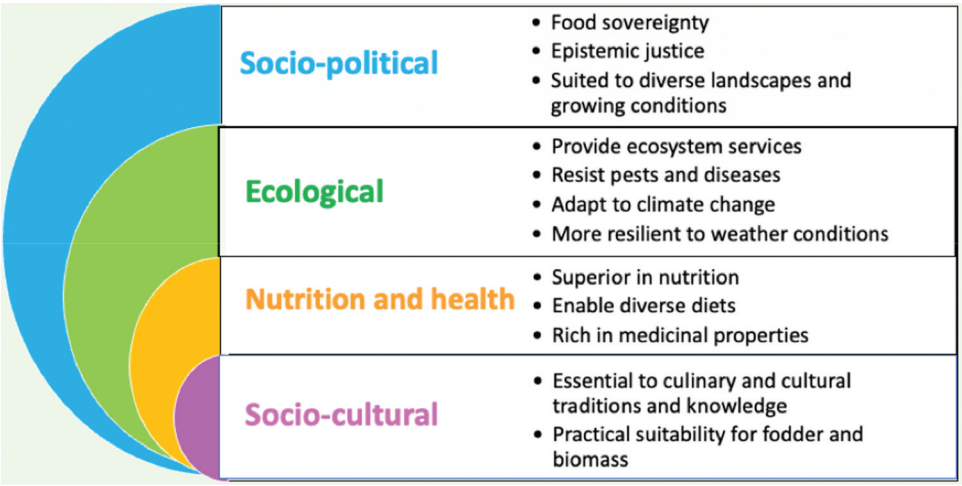

Figure 4. Importance of traditional seed varieties.

Challenges posed by commercial agriculture

The trend toward commercial agriculture is leading to a reduction in crop diversity. In Kinnaur district, for example, the cultivation of buckwheat (*ogla*, *phafra*) has been superseded by higher value red kidney beans and apples. Also, in Kinnaur, pine nut and wild apricot forests are lost to hydropower projects or apple orchards (Gupta 2022). Pine nut trees are not only ecologically important but, as a high-value cash crop, can contribute to the socio-economic welfare of the local communities.

Farmers attempting a transition to NF in Himachal Pradesh found themselves caught between two conflicting paradigms. On the one hand, they were encouraged to grow hybrid cultivars as cash crops to maximize yields and monetary returns. While these cultivars promise high yields, they undermine the farmers' role as stewards of the land. This approach risks repeating the mistakes of the GR, which led to increased debt, a loss of biodiversity, and the poisoning of people, soil, and water. In opposition to this, farmers were being urged to adopt an agroecological approach to mitigate the negative impacts of industrial agriculture.

The key challenge for the State is to increase farmer incomes without eroding indigenous crop diversity, health and the environment. To address this challenge, the focus should shift to cultivating indigenous crops. Himachal Pradesh boasts a rich agro-biodiversity, featuring a variety of indigenous herbs, vegetables, and cereals that are nutritious and resilient to climate change. These local vegetables and grains are abundant in micronutrients, dietary fiber, antioxidants, and polyphenols (Dwivedi et al. 2024). There is significant potential to revive, popularize, and market these crops among urban populations due to their nutritional, medicinal, and therapeutic

benefits, that have yet to be realized (Bhattacharyya et al. 2023). For instance, the Himalayan grain, chenopod – related to quinoa – has high nutritional value and promising potential for development and marketing (Partap and Kapoor 1987).

Indian states have promoted landraces in some cases. The state of Odisha implemented the Odisha Millets Mission program in collaboration with CSOs to preserve and promote millets in tribal areas in 2016 (NCDS Study Team 2021). This involved farmers mapping TVs and selecting the most suitable seeds through participatory varietal selections conducted between 2018 and 2020. To enable farmers to access these varieties, community managed seed centers were established in each block.

In 2016, the Department of Agriculture in Odisha introduced *Kalachampa*, a high-yielding local variety of paddy, to the formal seed supply system (Kuruganti and Ramachandrudu 2022). In 2022, the West Bengal Biodiversity Board began large-scale cultivation of 25 indigenous rice varieties to revive their use. These include varieties with high nutritional content, climate resilience, and aroma. In response to a request from the Indian government, the Food and Agriculture Organization (FAO) declared 2023 as the International Year of Millets to revive the tradition of millet consumption. However, this agroecological effort is being undermined by multinational corporations like Syngenta, which are profiting from marketing hybrid seeds intended for monoculture farming.

Strategies to support farmer seed systems

Many seed activists and CSOs argue that local seed varieties should be integrated into formal seed systems and policies, as well as evolving related operational strategies such as those listed in Table 5 (Kochupillai et al. 2019;

Table 5. Strategies to Support Farmers' Seed Systems.

National level	• Prevent farmers' seed rights from being eroded as reaffirmed in UN treaties and conventions. • Undertake the digital documentation and cataloguing of shared farmers' varieties to establish a national People's Biodiversity Register, as mandated by the Biological Diversity Act, which should be exempt from IPR registration. • Develop institutional and financial capacities of State Biodiversity Boards to maintain People's Biodiversity Registers. • Establish mandatory nutritional analysis for new cultivars in the formal seed system.
State level	• Establish biodiversity blocks to map and characterize the existing diversity in crops with farmer participation, including infraspecific diversity • Restore lost landraces through seed banks and the National Gene Bank of India. • Conserve local seed stocks with attention to purity. • Include popular landraces in the government seed delivery system. • Publicize nutritional benefits of traditional varieties based on nutritional profiling.
Farm level	• Build capacity of farmers and agriculturists in seed selection, seed multiplication, and storage. • Establish a supportive system for farmers to preserve local seed varieties in seed banks. • Create seed catalogues to facilitate free seed exchange among farmers.

ACT Alliance EU 2020; Kuruganti and Ramachandrudu 2022; WASSAN 2023). They ask that the focus shift from creating new HYVs to discovering and cultivating more resilient, productive, nutritious farmers' varieties and maintaining their traditional knowledge. Transitioning to an agroecological food system faces a major challenge because of limited access to local cultivars.

When the United Nations Convention on Biological Diversity (CBD) came into force in 1993, it explicitly recognized that "states have sovereign rights over their own biological resources." In response, India enacted the Plant Varieties and Farmers' Rights (PVPFR) Act in 2001. This act combines plant breeders' rights with elements from the CBD and the International Treaty on Plant Genetic Resources (ITPGR), allowing farmers to save, use, exchange, and sell new plant varieties. In 2018, a further UN resolution, the UN Declaration on Peasants' Rights and Other People Working in Rural Areas (UNDROP), required states to respect and fulfill peasants' rights to seeds. Despite its limitations as not being a legally binding treaty itself, the UNDROP has significant legal implications as it establishes a framework and norms to influence national and international law related to seed issues (ACT Alliance EU 2022).

As a signatory to the CBD, India enacted the Biological Diversity Act (BDA) in 2002. In 2003, the National Biodiversity Authority was established to implement the provisions of the BDA. Following this, State Biodiversity Boards were also set up. One of their key tasks was to create the People's Biodiversity Register (PBR), which serves as a repository for local flora and fauna, as well as the traditional knowledge related to medicinal herbs and plants. This database is designed to safeguard biodiversity and protect these from IPRs. However, efforts to maintain PBRs have been inadequate due to insufficient funding and a lack of expertise, which must be addressed (Shekhar 2024).

Conclusion

A number of conclusions can be drawn, ranging from the immediate experiences of farmers in the research field to the wider implications that may serve to inform wider debate and further work at the national and international levels.

The importance of farmer experiences in Himachal Pradesh

In relation to hybrid seeds, farmer experiences in Himachal Pradesh challenge the narrative that hybrid seeds are more disease-resistant than indigenous seeds or TVs. Instead, the results reinforce the benefits of indigenous seeds.

Farmers' knowledge and experiences of traditional varieties show that indigenous seeds hold cultural and practical advantages. They are essential to adapting to climate change and ensuring food security.

Wider issue of integrating agroecological practices

The findings highlight a wider issue about whether using hybrid seeds as a component of the industrial agricultural paradigm conflicts with natural farming. This article has addressed this issue, with proposals to be further explored and pursued. Initiatives seeking to transition agricultural systems to agroecological practices must include coherent policies to support farmer seed systems, identify local traditional seeds, and design a plan for ensuring access to those seeds.

Rethinking the approach of international frameworks

At both national and international levels, it is imperative that instead of a focus on granting new powers and privileges to corporations, significant action is taken to uphold the rights of farmers and access to seeds, as recognized in UNDROP. It is essential that at the international level, a higher priority is given to protecting local communities' rights to seeds that maintain local biodiversity, as well as providing financial support. This process should involve relevant international institutions and international regimes.

Support for farmers' seed systems that allow unrestricted access to local seed varieties will be pivotal for future food security and nutrition, spreading the risk and enhancing the resilience of family farmers to climate shocks and crises. For example, a UN fund should be established to help countries identify, characterize, and register local indigenous seeds and integrate them into formal seed distribution systems. Finally, this paper finds that supporting farmers' traditional seed systems and access to seeds is a key enabling factor for agroecology. Implementing the principles of agroecology will be crucial to maintaining food security and sovereignty, enhancing health and nutrition, and building resilience to climate change.

Notes

1. Semi-dwarf wheat often shows equal or improved nitrogen-use efficiency leading to reduced performance in low input or stress prone environments.
2. The world's food supply depends on approximately 120 out of 7,000 edible plant species. However, 90% of the total calories consumed are provided by just 12 plant species (Coupe and Lewins 2007). Four plant species – rice, potatoes, wheat and maize – that account for 50% of dietary intake globally are increasingly limited to a few varieties.

3. Alleles are alternative forms or variants of a gene, differing in their DNA sequence and located at the same position (locus) on a chromosome. These genetic variations determine different traits, such as flower color or disease resistance.
4. The public sector agencies involved in the research and production of certified seeds and planting materials include 65 ICAR Institutes, 3 Central Agricultural Universities, 48 State Agricultural Universities, the National Seed Corporation Ltd, and 17 State Seed Corporations. In addition, there are 25 State Seed Certification Agencies and 145 Notified Seed Testing Laboratories (Dadlani 2024).
5. A Farm School involved working with five farmers in a village during a crop season. ATMA staff would conduct six field visits, two visits at each stage of growth, to discuss techniques and progress and share solutions to challenges.

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