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Indigenous Pest Management Practices of Indian Hill Farmers: Introspecting Their Rationale and Communication Pattern for Secure Ecosystems

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Abstract: Indigenous technical knowledge derived from traditional wisdom is an asset of farmers in developing countries. To ensure the continuity of these practices for future generations, we need to understand the scientific rationality and their communication patterns, and then document them. This study aimed to document the indigenous pest management practices, test their scientific rationality, and determine their communication pattern among the farmers. A total of 120 farmers from district Bageshwar in Uttarakhand, India, were selected through the simple random sampling method. Interviews and focussed group discussions were used to collect data. Out of a total of 32 documented indigenous practices, 27 were found to be rational by the scientists. Neighbours ranked first as the source of information, followed by friends and relatives. Knowledge related to managing pests through indigenous methods was shared by the farmers, mainly in temples. They learned the practical application of these indigenous practices during childhood while working with parents in the fields, followed by observing their friends and relatives. The indigenous technical knowledge should be conserved and combined with the scientific cognizance for sustainable agriculture. Next-generation farmers need to be motivated to adopt these practices.

Keywords: indigenous; pest management; Indian; hill farmers; communication; secure ecosystems

1. Introduction

Indigenous technical knowledge (ITK) is knowledge of a particular community developed over a long period spanning multiple generations and continues to evolve with experience. This local knowledge is accepted and validated by society over time, which becomes a part of people's social and cultural lives and consequently becomes the indigenous technical knowledge (ITK) belonging to a particular society [1]. As early as 1987, Paul Feyeabend [2] defined this knowledge as that knowledge often encoded in rituals and the cultural practices of everyday life of individuals. Later, the work of the International Union for Conservation of Nature (IUCN) has given rise to the term 'traditional ecological knowledge' (TEK) [3]. With the course of development in the field of knowledge, TEK began with ethnobotany and proceeded to people's understanding of the ecological processes in nature and their connection with the environment in which they live [4]. Different terms used to refer to ITK include indigenous people's technical know-how and people's knowledge [5]. Thus, indigenous technical knowledge (ITK) is the knowledge of the local environment that is produced, held, and practised by indigenous people and communities [6]. In this paper, we conceptualise ITK as the unique, cultural inheritance that is traditional and has evolved in and around particular cultures indigenous to a specific region [7]. ITK passes from one generation to another and establishes with experience over the years to become accustomed to the local environment and culture [8].

ITK is sustainable since it has grown over many years of observation and practice. Moreover, since time immemorial, indigenous groups have had cultural know-how related to their crop management and production practices [9]. Therefore, indigenous knowledge is valuable for advancing creativity in location-specific crop management practices, safeguarding the natural resources, adaptation, resilience towards the changing climate, and securing food systems [10].

India is home to diverse ethnic, cultural, and linguistic groups with ITK wealth for agricultural practices. India has about 700 tribal groups constituting a population of 104 million, as per the 2011 census. The agriculture sector in India employs approximately half of the country's workforce. However, it only contributes to 16.5% of the gross value added (GVA) as per 2019–2020 data [11]. With the ushering of the green revolution, Indian agriculture is at a crossroads as production loses momentum [12]. Agricultural inputs such as fertilisers and insecticides pollute the soil and underground water and are responsible for polluting the food commodities. In addition, with the consistent use of pesticides, pests have become resistant to these chemicals. These chemical pesticides also have harmful effects on the surrounding flora, fauna, and people [13]. Pesticides are harmful to farmers who are exposed while performing agricultural tasks [14].

Pesticides used to target pests in the field can also be very harmful to people who consume the food produced with pesticide use [15]. Considering the potentially harmful effects has led health-conscious people to choose organic food. Many fruits, vegetables, and grains contain traces of pesticide residues even after washing and peeling [16]. Even if applied in soil, chemicals tend to affect the soil and water, and ultimately food. Indiscriminate use of harmful chemicals in the form of pesticides affects the environment adversely [15], and continued use of chemicals harms animals, wildlife, and valuable insects. It can render the soil unproductive [17]. This indiscriminate, excessive, and continuous use of chemicals has exaggerated problems leading to the fragile ecosystem [18].

Traditionally, farmers have used various herbal solutions and cultural practices to manage insect pests after harvest for many years. The indigenous communities also use several insecticidal plants for insect and pest control [19]. Traditional technical knowledge of ecology [20] is helpful to identify sustainable pest management practices suited to local farming situations [21]. Various ethnobotanical studies have reported using several plant resources in folk medicine and agricultural crop protection before and after harvest for insect pest control [22]. For example, azadirachtin, rotenone, and pyrethrum extracted from *Azadirachta indica*, *Derris elliptica*, and *Tanacetum cinerariifolium*, respectively, are harmless to humans but useful for pest control [23]. The indigenous expertise of farmers can provide a framework to refine current practices or identify new environmentally sound and effective management strategies. Himalayan agriculture has always been environmentally friendly due to its rich traditional and cultural heritage. The agricultural sector is responsible for promoting food and nutritional protection for farmers' livelihoods and ensuring the sustainable development of countries such as India. Agriculture today is increasingly impacted by natural resource depletion and over-exploitation, increased frequency of climate change-influenced extreme weather events, and excessive exploitation of natural resources. The use of environmentally friendly chemical pesticides has helped to encourage beneficial insects, such as spiders and Coccinellidae beetles [24]. From the perspective of biological control of pests, feeding on aphids, scale insects, psyllids, and mites during larval and adult stages, large numbers of the Coccinellidae species are beneficial [25].

1.1. Indigenous Coping Strategies for Handling the Fragile Ecosystem

Indigenous populations have lived in perfect harmony with nature [26]. However, many of these age-old traditional practices find no place in the most developed countries but are prevalent among farmers of third-world countries. Indian farmers have a rich heritage of conserving and cultivating a wide range of food; fodder; medicinal plants; and various fruits, vegetables, and flowers, often under difficult agro-climatic conditions. India, over several millenniums, has been the treasure land of biological wealth, intellectual knowledge, and wisdom. Since time immemorial, farmers have used biodiversity as a buffer for managing the variation, change, and catastrophe. In adverse conditions, if a single crop fails, others will be there to act as a buffer [27].

Traditional farmers often alter the architecture of plants and crops, use biological control, or burn the leaves or other parts of plants for pest management. They also adjust crop density; change the depth of seeding or time of planting; plant different crop species; or use fallowing, flooding, mulching, or plant multiple crops. Other methods could be planting without tillage, using organic sources, raising the plant beds, crop rotation or shade, manipulations, and tillage. Many of these practices are responsible for conserving energy, with reduced chemical usage, maintaining natural resources. In other words, we can say that these practices are undoubtedly associated with saving our fragile ecosystem and, in turn, lead to sustainable food production.

1.2. Why Document ITK?

Documentation of ITK would aid in formulating the contents of ITK, which in turn has the scope of being shared with the concerned farming community for furthering the implications [28]. Due to changing climate, plant protection has become a serious issue nowadays. The biological and ecological nature of various insect pests has also changed, due to which insect pest mechanisms have become quite complicated [29]. The increasing use of chemical-based pesticides in agriculture has contributed to pest resistance development and has degraded the environment [30]. Even practices associated with pest management vary among traditional farming communities in different parts of the same country [1]. ITK has inherent environmental and cultural harmony features and is simultaneously sustainable and cost-effective when applied to pest control [28]. However, shifts in agricultural processes and rural socioeconomic situations have led to a decline in conventional expertise associated with new practices [31]. The main issues of accepting ITK practices on a larger spectrum are the lack of ITK data, shared knowledge of its scientific rationality, and slow advances in science [32].

To conserve biodiversity and intellectual divergence, we must recognise the creativity of the traditional farming communities. Non-chemical pest management and cultural practices derived from traditional wisdom are popular among subsistence farmers in developing countries [33,34]. To ensure the continuity of these practices for future generations, we need to document them [35].

1.3. Indigenous Knowledge Communication

Several researchers and organisations have recognised ITK as a low-cost, locally adapted solution to development issues [36]. In other words, this knowledge can be combined with scientific know-how to increase productivity and improve the living standards of the farmers. Another concern is that this indigenous knowledge, not found in books, is instead held in the heads of these indigenous populations, who pass it down from one generation to another by word of mouth. Thus, it is essential to understand the ways and means of communication of this precious knowledge. Insight regarding who is involved in ITK, its communication, and how people gain this knowledge is needed. Indigenous communication is everything that encompasses the transmission of any news, entertainment, announcements, social exchanges, and persuasion of any kind of village information among the farmers.

The very idea of indigenous knowledge is the belief in indigenous communication [37]. This means indigenous communication is related to indigenous knowledge of the people. Tea stalls, wells/community taps, village organisations, markets, and temples are places where indigenous knowledge sharing occurs. Folk media such as puppets, folk dramas, and interpersonal communication form the basis of indigenous communication channels.

As a hill society, Uttarakhand in India is still very traditional, where penetration of mass media is limited. However, indigenous forms and modes of communication are still prevalent in rural areas. Therefore, it is necessary to study the pattern of knowledge communication related to indigenous pest management. Effective communication of new science mixed with sound indigenous practices would aim for an increased income of farmers and a sustainable agriculture system. Thus, the present study aimed to find out the various ITK related to pest management used by farmers and their scientific rationality and pattern of communication among the farmers in the hill region of Uttarakhand.

2. Materials and Methods

2.1. Selection of District

The locale of the study was the Bageshwar district in the Uttarakhand state of India (Figure 1), which has an area of 889 square metres. The district Bageshwar is hilly with Shivalik ranges and the high Himalayas. It has an average elevation above sea level of 1004 m (3293.96 feet). The average temperature for the year is 20.4 centigrade (68.8 Fahrenheit), and the average amount of precipitation in Bageshwar is 48.1″ (1221.7 mm). The area is predominant with sandy loam soil type. Most of the farmers are practising rain-fed agriculture with very low or no use of agrochemicals. Here, 76.73 per cent of the net sown area is rain-fed. Cropping intensity in district Bageshwar is 170 with 1515 kg per hectare of an average yield of food grains. The average chemical fertiliser consumption is about 3.92 kg per hectare.

Figure 1. Map of Uttarakhand showing the study area.

Bageshwar district falls in the agriculturally less progressive district with average chemical fertiliser consumption of only 3.92 kg per hectare; as one of the researchers belong to this district and could converse fluently on local dialect (*Kumaoni*), we chose this area as the locale of the study for identifying indigenous pest management practices/technologies.

2.2. Selection of Blocks

There are three blocks in district Bageshwar, namely, Bageshwar, Kapkot and Garud. Since the study identified indigenous pest management practices, it was decided to select an agriculturally less progressive block. Hence, block Bageshwar was selected as it fell in the category of agriculturally less progressive block.

2.3. Selection of Villages

For documenting indigenous pest management practices, two villages, Kalag gajali and Gwar bhilkot, were selected purposively from block Bageshwar. Purposive selection of villages was necessitated to meet the requirement of a sufficiently large number of farming households with experienced old-aged people and remoteness of the village from the marketing centre. The total population of Kalag gajali village is 165, comprising 82 male and 83 females. Total number of households is 32, and literacy rate is 77.62%. The population of Gwar bhikot village is 516, comprising 222 males and 294 females. There are about 129 houses in Gwar bhikot village. The literacy rate of this village is 80.45% [38]. Hinduism is practiced by the majority of the population in both the villages. The Brahmin community dominates in this village. Kumaoni and Hindi are the local spoken languages by the farmers of both the villages. The Bageshwar assembly seat is reserved for a person belonging to the scheduled caste. The majority of the villages' population are either primary agriculture practitioners or work as marginal workers in others' fields. Rice, wheat, and ragi are the primary agricultural commodities grown in these villages.

2.4. Selection of Respondents

Because of migration and habitation dispersion in hilly areas, only 60 farmers were selected from each village through simple random sampling. Thus, the total sample size of the study was 120 farmers. Key informants (old farmers) were selected to obtain detailed information on indigenous pest management and communication patterns. Most of the farmers were performing subsistence farming in the area. Indigenous knowledge systems and traditional practices are more prevalent in subsistence farming than commercial farming [39].

2.5. Data Collection

In the study, ITK collection commenced using a semi-structured interview schedule, focused group discussions, key informant interviews, and participant observation methods. First, however, the identification and documentation of indigenous technical knowledge related to pest management and communication pattern in the locale were inquired through qualitative methods. As a result, those practices that the selected farmers' understudy had learned from their progenitors and were practised for years together were spotted and contemplated as indigenous pest management practices. During the second stage, an investigation into the scientific rationality of indigenous pest management practices was convened using the Hiranand Scale (1979) [40]. We used the modified version of this scale which measured the indigenous pest management practices. The rating points were, 'very rational', 'rational', 'undecided', 'irrational', and 'very irrational', with weightage of 5, 4, 3, 2, and 1, respectively. It also includes comments on the rationality of a particular practice from experts. The standard of evidence to consider a practice to be rational is based on the opinion and scientific justification explained by the scientific panel of experts and based on the calculated weighted mean scores of each practice.

Rationality in behaviour involves the actor choosing of the most efficient means for attaining a particular empirical goal [41]. Here, scientific rationality means the extent to which the indigenous practices have the feature of being described or aided with scientific grounds based on their applications for an extended period. The scientific rationality of 32 documented indigenous pest management practices formed the core of the study. The checklist contained a list of all the documented indigenous practices. A panel of 30 scientists from plant pathology, entomology, and agronomy of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, judged their rationality on a five-point Likert continuum. The rating points were 'very rational', 'rational', 'undecided', 'irrational', and 'very irrational', with weightage of 5, 4, 3, 2, and 1, respectively. The weighted mean scores of individual practices were then calculated. The technology/practices, which were assigned a weighted mean score above 3.0, were considered rational.

$$\text{weighted Mean} = \frac{\sum_{i=1}^{n} (xi * wi)}{\sum_{i=1}^{n} wi}$$

After determining the rationality, identifying the principle underlying the rationality of ITK took place with the help of a scientist forum. For this, a team of multidisciplinary scientists from entomology, pathology, and soil science departments conducted panel discussions. The consensus on the scientific principles and rationale behind the various indigenous practices reached a rigorous dialogue on the responses. The rationales having consensus by the majority formed part of the discussion with ample allowance for strong dissent, which the researcher was noting down. In the third phase of the study, an inquiry into the communication behaviour of farmers in terms of source and manner of learning indigenous pest management practices took place with the help of focused group discussions and observation methods.

After going through the literature related to the communication pattern of people in a rural setting and discussing with communication experts, we found eight occasions or places to be significant. Then, the researcher asked the respondents how they used those places or occasions to share information about indigenous pest management practices. The frequency of usage had been recorded on a three-point scale that is often, occasionally, and never, with scores of 3, 2, and 1, respectively.

3. Results and Discussion

3.1. Demographic, Socioeconomic, and Cultural Backgrounds of Farmers and Communities

The socioeconomic data of farmers showed that in the district of Bageshwar, a majority (64.17%) of respondents were female, with 42.50% belonging to the older age of 43 to 57 years.

The older age is often related to more experience in farming practices and more accumulation of resources and indigenous knowledge among the farmers. The education status of the farmers revealed that the maximum number of farmers (41.67%) had passed primary education, and a quarter of them passed the intermediate level. Education is an essential tool of human capital that can increase the ability of farmers to perceive, absorb, and implement innovations in the field, and thus may positively impact the adoption of indigenous pest management practices. A majority (83.33%) of the farmers possessed up to 50 *nali* landholdings, and a maximum (41.67%) had more than 25 years of farming experience. Further, almost half of the respondents (48.33%) had low exposure to mass media. Although most farmers were small and subsistence farmers, they are often more associated with adopting indigenous technical knowledge than commercial farmers. These findings were consistent with previous findings [10], which found that ITK use was highest among subsistence farmers (85%) and lowest among commercial farmers (10%).

3.2. Indigenous Pest Management Practices and Their Scientific Rationality

Farming in the Himalayas is a natural and eco-friendly practice due to their rich practices, which are traditional and distinctive. Despite having restricted water supply, as well as scattered and fragmented small-sized farms with a lack of access to modern tools and technologies, Himalayan agriculture has been helping its people in adverse conditions. For generations, agriculture has been the primary occupation of the people for livelihoods in the Himalayas [42].

The farmers of the study follow mixed cropping and subsistence farming. They grow rice, wheat, and finger millet (*Eleusine coracana*), and these three crops account for most of the gross cropped area. Almost all farmers of the locale take mustard crop as mixed cropping with wheat.

In this condition, pests also come to have their share of the harvest. Major pests found in the villages are white grub, rat, and stored grain pests. White grub is a polyphagous and nefarious pest of specific significance as it adversely affects the economic status of the farmers. Out of 31 species of white grubs found thus far in the Western Himalayas, *Anomala dimidiata* (Hope) (Rutelinae: Coleoptera) were the most prominent ones [43,44]. Between 1400 and 2000 m elevation in the terraced slopes of the hills, which is primarily rain-fed, white grub depredations are especially extreme [45].

Indigenous pest management practices were documented for controlling white grubs, as shown in Table 1. All the seven practices documented for controlling white grubs were considered scientifically rational. They were fire after wheat harvesting, spreading properly decomposed farmyard manure (FYM), burning cow dung cakes in holes before transplanting chilli crop in the field, and burning pine leaves after wheat harvesting. In addition, maintaining a water depth of two centimetres in a paddy field, preferring transplanting to direct sowing in rice, and broadcasting common salt in fields were also considered rational. It shows that farmers had developed sound practices for controlling white grubs due to continuously grappling with them. Similar findings were reported by researchers in that smoking is one of the techniques used by farmers to eradicate fruit flies [46]. Even for controlling onion blight and wilting in potatoes in the kitchen garden, farmers used indigenous practices. Another scientist from India reported that at the rate of 2%, cow dung extract is an effective ITK used to control caterpillars, bugs, stem borer, leaf folders, and any other chewers of rice [47]. Moreover, it was found that the cow dung solution has a good balance of growth factors and nutrients at the plant's root [48].

Further, in addition to white grub, other pests which cause crop damage, such as aphids and lepidopteron insects in paddy and finger millet, were also controlled by the hill farmers through indigenous methods. Table 1 shows that farmers in the area were practising 12 indigenous methods (S. No. 8 to 19) for controlling general pests, out of which 9 practices (S. No. 8 to 16) were considered scientifically rational by scientists. They were summer ploughing, broadcasting ash in the field to control chewing-type insects, uprooting aphid-infested plants (*Brassica* spp.), and then burring in the soil. Spraying cow urine to check wilt in the kitchen garden was another widespread practice followed by the farmers. Farmers said they maintained cleanliness in the field to check rodents and trimming the field bunds during summer in paddy to destroy the alternate hosts of pests/pathogens. Earthing of potatoes up to one foot during second weeding to check exposure to sunlight and broadcasting ash in the fields of chilis and potatoes for protection from biting- and sucking-type insects were some of the other ITK used by the farmers. The farmers were also planting trap crops/repellent crops on the borders of the field. Trap cropping means growing plants susceptible to pest attack in the perimeter of the field. These attractive plants attract the pests towards them, thus saving the cash crop because insects pests attack the trap crop. It was further reported that cow urine, which has a molluscicidal effect, is used in rice fields to prevent snail and slug damage [49].

On the other hand, scientists were undecided about two practices (S. No. 17 and 18). They were sowing barnyard millet and foxtail millet at the margin of the plot to control pests and applying half a kilogram of common salt for one *nali* paddy crop to protect it from stem borer. The agricultural scientists could not find any scientific rationale for the practice (S. No. 19) of spraying a solution of cow dung at one kilogram of cow dung in two litres of water for controlling onion blight, but farmers were using it to get benefited. Ploughing is a critical ITK practice before planting crops for removing weeds and killing insect eggs [10].

Table 1. Scientific rationality of ITK related to pest management.

S. No	Indigenous Pest Management Practices	WMS *	Rationality	Scientific Rationale (as Perceived by Experts)
	Control of White Grub			
1.	To control white grub, fire is set in the field after harvesting the wheat crop.	4.8	R	This technique is performed to kill white grub or their eggs present in the field. Field burning improves yield and cuts back the need for pesticides and fertilisers.
2.	Spreading of properly decomposed farmyard manure.	4.6	R	This is done because white grubs lay eggs in undecomposed FYM on which early-stage larvae are fed. Thus, the use of adequately decomposed FYM reduces the chances of white grub attack.
3.	In order to protect the chilli crop from white grub, holes are made and cow-dung cakes are burnt in them before transplanting each plant.	4.4	R	Cow dung solution boosts microbial activity and provides nutrients. At the root, the cow dung solution has a strong balance of growth factors and nutrients [44].
4.	After harvesting the wheat crop, pine leaves are burnt in the field. It reduces chances of white grub attack in the following paddy crop.	4.4	R	Dried pine leaves were collected and burned in a fallow field to destroy the herniating stage of white grub, termites, and ants.
5.	Keeping 2 cm depth of water continuously in the field of paddy decreases the chances of white grub attack.	4.2	R	Flooded or submerged fields with water can prevent the occurrence of soil pests such as a white grub. It will also kill the larvae of pests.
6.	Preferring transplanting instead of direct sowing for white grub control.	4.0	R	In the transplanting method of rice, sowing puddling destroys the home of insects by disturbing the soil. It also helps to kill the weeds by decomposition.
7.	Broadcasting of common salt (NaCl) at 1 kg/*nali*, and in the severe condition it is preferred to leave land fallow.	3.8	R	Salt is used as a pesticide. By exosmosis, salt may kill the grubs. It also prevents the weevil from entering the stem and laying eggs.
	General Pest Management Practices			
8.	Summer ploughing.	5.0	R	Ploughing exposes soil insects to adverse weather conditions, birds, and other predators. In addition, deep ploughing will bury some insects and prevent their emergence.
9.	In the fields of garlic and onion, ash is used to protect plants from chewing type insects.	4.6	R	Aphids or other insects are repelled by ash, which serves as a physical toxin. Ash also enriches the potassium level of the soil.
10.	Uprooting of mahu (aphid)-infested plants (*Brassica* spp.) and then burring in the soil to check the disease.	4.4	R	Aphid-infested plants were uprooted and buried in the soil to check the insect pest spread in the field.
11.	Spraying of cow urine in the kitchen garden to check wilting symptoms in plants.	4.4	R	The plant is sprayed with cow urine, which serves as an insect repellent. Cabbage plants may be treated with a mixture of cow urine, ash, and soil. The presence of nitrogen in the urine also aids the growth of crops. Cow urine is used in rice fields to prevent snail and slug damage because it has a molluscicidal effect [45].
12.	Maintaining cleanliness in and around the field does not provide space for rat breeding.	3.8	R	The population of rats is kept under control in the field.

Table 1. *Cont.*

S. No	Indigenous Pest Management Practices	WMS *	Rationality	Scientific Rationale (as Perceived by Experts)
13.	In paddy crops, trimming the field bunds during summer destroys the alternate hosts of pests/pathogens.	3.6	R	Killing the various stages of pest and destroying the alternate hosts of pests/pathogens.
14.	Earthing up in potato is performed at second weeding up to one foot in height to prevent exposure of tubers to sunlight.	3.6	R	To prevent exposure of tubers to sunlight and to destroy weeds. It also helps to prevent potato blight.
15.	Ash is broadcasted in the fields of chillis and potato for protecting plants from biting- and sucking-type insects.	3.6	R	Ash contains silica which interferes with insect feeding and also hinders fungal pathogen multiplication.
16.	Planting trap crop/repellent crop on the borders of the field.	3.2	R	Mustard crops are planted on the border of the wheat crop and marigold on the border of the vegetable crop to act as a trap crop. By growing such crops on the border of the fields, the pest population develops there, which can be either killed by using pesticides or its natural enemies are allowed to develop for natural control.
17.	Sowing of barnyard millet (*Echinochloa* spp.) and konri millet at the margin of the plot instead of the middle to control pests.	3.0	UD	Undecided.
18.	A half kilogram of common salt is applied for one *nali* paddy crop to protect it from stem borer.	3.0	UD	Undecided.
19.	To control onion blight, 100 L of cow dung solution is sprayed at one kilogram of cow dung in two litres of water.	2.8	IR	Irrational.
	Rodent Management Practices			
20.	For killing rats, one-kilogram wheat flour and half a kilogram of glass ground and kneaded with little water.	3.6	R	Baiting is a common practice done to get rid of rats. Bait made by wheat flour act as a poison for the rat as glass ground is a toxic poison leads to death.
21.	Urea is kept at the entrance of the mouse hole to distract the mouse from the field.	3.2	R	Urea is rat repellent. When ingested by the rats, they become incredibly ill and begin to vomit, eventually resulting in death.
22.	Placing the bichhu ghaas (*Urtica dioica*) and thorny bushes of kilmora (*Berberis asiatica*) plant at the entrance of a mouse hole.	2.8	IR	Irrational.
23.	Horse faeces is used to fill the holes.	2.8	IR	Irrational.

Table 1. *Cont.*

S. No	Indigenous Pest Management Practices	WMS *	Rationality	Scientific Rationale (as Perceived by Experts)
	Indigenous Storage Pest Management Practices			
24.	Wheat, green gram and black gram are dried for two days under the sun before storage to prevent pest infestation	4.4	R	Drying of the grains before storage reduces the moisture content of grains and increase their shelf life for storage because moisture content forms a congenial environment for insect pest attack and disease development. Sun-drying kills existing insect pest and their different stages.
25.	Green gram is stored after pasting with mustard oil, dried leaves of walnut, and immature turmeric. One kilogram mixture contains immature turmeric (500g), powder of dried leaves of walnut (250g), and mustard oil (250g).	4.4	R	Turmeric's active ingredients are insect repellents in general. Turmerones and arturmerone are two components of turmeric that act as insect repellents. Mustard oil's strong smell keeps the insect pest away.
26.	After milling the grains of black gram, there are lesser chances of storage insect pest infestation.	4.4	R	This reduces the chances of insect pest infestation as, during milling, grains are cleaned, graded, and dried for storage purposes.
27.	For storage of green gram, 1 kg grain is mixed with 10 g of chalk powder.	4.2	R	Chalk powder (calcium carbonate) has repellent and antifeedant properties, as well as the ability to prevent insects from multiplying.
28.	One kilogram grain of black gram is mixed with 50 g of mustard oil.	3.8	R	Mustard oil has insecticidal and fungicidal properties, and thus it repels pests and helps to prevent diseases.
29.	Ten kilogram wheat seed is stored after mixing with 1 kg dung ash.	3.6	R	Wheat grains are filled in earthen pots with cow dung ash. The relative humidity of the storage state is reduced by ash particles, which also dries the seed surface. Since ash dust covers grain seeds, egg-laying and larval production of storage pests can be hindered.
30.	Storing black gram with the whole salt for prevention from pests of stored grains.	3.6	R	Salt keeps the grain dry by removing moisture, preventing spoilage, and allowing for safe storage. Salt has an abrasive effect on insects' skin, preventing them from moving inside storage containers and thus inhibiting their development.
31.	For the purpose of storage of black gram seed, a 1 kg seed is mixed with 20 mL of cow urine.	3.6	R	Cow urine acts as a repellent for storage insect pests.
32.	After drying for two days, paddy/pulses and millet seed is stored with the walnut (*Juglas regia*), timur (*Z. alatum*), and neem leaves (*Azadirachta indica*) for protection from storage insect pests.	3.4	R	Walnut leaves (*Juglas regia*) and timur (*Z. alatum*) plant leaves are dried for two days and kept in the storage container. They fill the intergranular space and check the insect pest movements, and act as a repellent of storage pests.

* R = relevant; IR = irrelevant; and UD = undecided. Source: compiled by authors.

For rodent control, out of the total four practices (S. No. 20 to 23) documented, only two practices (S. No. 20 and 21) were considered rational. They were mixing one kilogram of wheat flour with half a kilogram of glass powder and a little water to make dough to kill rodents and placing urea at the mouse hole entrance to distract mice from the field. In contrast, the other two were considered scientifically irrational practices for controlling rodent pests.

All (S. No. 24 to 32) documented indigenous pest management practices of stored grain were considered scientifically rational by the plant protection scientists. These were sun-drying of infested stored grain for two days; storing green gram after pasting with mustard oil, dried leaves of walnut, and immature turmeric; and storing black gram after milling. One kilogram of green gram (*Vigna radiata*) and one kilogram of black gram (*Vigna mungo*), each mixed with 10 g of chalk powder and 50 g of mustard oil, respectively, would save stored grains from pests. Farmers stored wheat seeds after mixing with dung ash, and black gram was stored with the whole salt to prevent pests of stored grains. For storage of black gram seed, a 1 kg seed is mixed with 20 mL of cow urine, and dried paddy seed is stored with the walnut leaves (*Juglas regia*), neem (*Azadirachta indica*) leaves, and timur (*Z. alatum*) plant for protecting from storage insect pests. The neem leaves contain the active ingredient azadirachtin, which is non-toxic and serves the purpose of insect repellent, is antifungal, inhibits insect feeding, and is sterilant [50]. Studies conducted in the area of post-harvest management reveal that drying decreases the moisture content of crops and resists the storage of insect pests in grains [51].

Most of the practices followed by the farmers in their specific situations were considered scientifically rational by the scientists. Only three practices (S. No. 19, 22, and 23) were disliked by scientists because they lacked a scientific rationale for their usage.

Yet, another two practices (S. No. 17 and 18) were undecided by scientists. Thus, we conclude that out of 32, only 27 indigenous pest management practices were rational, and 3 practices were irrational. Similar findings were reported by other scientists in that most of the indigenous practices used by the farmers were considered rational by the scientists [52,53]. Reports of another study conducted in the Indian Himalayas also reported that bait, urea, and powdered horse faeces are some indigenous pest management practices used for rodents' control [54]. Farmers adopt some more indigenous pest management practices for controlling white grubs and aphids in the field, such as burning cakes made of cow dung, a sprinkling of farmyard manure (FYM), and putting fire in the field.

3.3. Sources of Indigenous Pest Management Practices

We know that indigenous pest management practices are a boon to the farmers in this era where it is commonplace to discuss safe and secure food production and the ecosystem. Organic food production is the result of practicing indigenous methods of managing pests. Profit margins in organic products are higher compared to conventional products [55]. Thus, it is necessary to fetch the maximum benefit from this indigenous knowledge by inquiring into the sources of this knowledge. Communication behaviour in terms of sources of information was studied by preparing indices. Each index enlisted the communication channels that farmers were utilising for indigenous pest management practices (Table 2).

Table 2 depicts that among the non-institutional sources of indigenous pest management practices, a majority (83.33%) of the farmers said that they used elderly persons as a source, often followed by friends and relatives (79.17%) and neighbours (75%). A significant chunk of the respondents (83.33%) expressed they used local leaders occasionally, followed by progressive farmers (75%) and neighbours to gain indigenous knowledge regarding pest management. Similarly, Berkes and co-workers [56] stated that the direction of cultural transmission of indigenous knowledge is usually from the older persons to the young because of the wisdom and experience of age. Further, we calculated the weighted mean score of each source of information regarding IPM practices of the farmers to give them a ranking. On the basis of WMS, neighbours ranked first (WMS 2.91), elderly persons and friends or relatives ranked second (WMS2.79), progressive farmers ranked third (WMS

2.50), and local leaders ranked fourth (WMS 2.16) as an informal source of information regarding indigenous pest management practices.

Table 2. Distribution of farmers according to the sources of information regarding indigenous pest management practices (IPM) used (n = 120) on the basis of weighted mean scores (WMS).

S. No.	Sources	Often	Occasionally	Never	WMS *	Ranking
1.	Neighbours	90 (75.0)	30 (25.0)	0	2.91	**I**
2.	Elderly persons	100 (83.33)	15 (12.5)	5 (4.17)	2.79	**II**
3.	Friends and relatives	95 (79.17)	25 (20.83)	0	2.79	**II**
4.	Progressive farmers	30 (25.0)	90 (75.0)	0	2.50	**III**
5.	Local leaders	20 (16.67)	100 (83.33)	0	2.16	**IV**

Note: Figures in parentheses indicate percentages; * weighted mean scores. Source: compiled by authors.

3.4. Manner of Learning Indigenous Pest Management Practices

Communication behaviour in terms of the manner of learning was studied by preparing indices. Each index enlisted the different manners that respondents could have utilised for learning the indigenous pest management practices (Table 3).

Table 3. Distribution of farmers in terms of the manner of learning IPM practices (n = 120), with regards to weighted mean scores (WMS).

S. No.	Way of Learning	Largely	Not Much	Never	WMS *	Ranking
1.	Working with parents	114 (95.0)	6 (5.0)	0	2.98	**I**
2.	By observing friends and relatives using indigenous knowledge	102 (85.0)	12 (10.0)	6 (5.0)	2.8	**II**
3.	By the stories from old-aged persons	10 (8.33)	24 (20.0)	86 (71.67)	1.36	**III**
4.	Reading magazines and other religious books	6 (5.0)	6 (5.0)	108 (90)	1.15	**IV**

Note: Figures in parentheses indicate percentages. * weighted mean scores. Source: compiled by authors.

Table 3 shows that most (95%) of the farmers learned many indigenous pest management practices by working with parents, followed by observing friends and relatives (85%) using indigenous pest management knowledge. At the same time, a good majority (90%) of the farmers reported that they never learned indigenous pest management practices through reading magazines or other religious books, followed by stories from old-aged persons (71.67%). On the basis of the weighted mean scores (WMS), we found that working with parents ranked first (WMS 2.98) in indigenous pest management practice learning. Further, by observing friends and relatives using indigenous knowledge ranked second (WMS 2.8), and learning the stories from an old-aged person ranked third (WMS 1.36). Reading magazines/other religious books ranked as the fourth (WMS 1.15) way of learning indigenous pest management practice among the farmers of the study area.

It was concluded that early childhood training was the preferred and most effective method of transmission of traditional ecological knowledge [57]. ITK is not a formal knowledge seldom learned through training or reading books and magazines, but this is passed on from one generation to another informally by the previous generation to the next generation farmers through practical observation and listening to stories from older wisdom.

3.5. Places and Occasions for Learning Indigenous Pest Management Practices

In villages, people have different places and occasions of social interaction such as temples, visiting a neighbour/friend, and meeting people while collecting water from wells, lakes, or rivers. Villagers also socialise while travelling in public transport such as bullock carts, taxis, or buses; meeting in farms; celebrating festivals; attending village fairs; or visiting a market or panchayat house (Table 4).

Table 4 reveals that often-used places for learning about indigenous pest management by the farmers were temples (33.33%), local water sources (25.83%), residence places (24.17%), during travel (20.83%), and in the fields (16.67%). Further, 46.67% of the farmers occasionally used residence places, followed by travelling (41.67%), the fields (40%), and temples (37.5%) as places for learning indigenous pest management knowledge. On the other hand, 90% of farmers had never used *panchayats*, fairs and festivals (77.55), and markets (71.67%) for learning indigenous pest management. On the basis of the WMS, we found that temples ranked first (WMS 2.04), followed by places of residence (WMS 1.95), and water source and traveling (WMS 1.83). Fields (WMS 1.73) ranked fourth, marketplace ranked fifth (WMS 1.28), and fairs and festivals (WMS 1.22) ranked sixth. In contrast, the *panchayat* house ranked last (WMS 1.09) as a local place utilised for communicating indigenous pest management knowledge.

Table 4. Distribution of farmers according to the occasions and local places utilised for communicating IPM knowledge (n = 120) as per weighted mean scores (WMS).

S. No.	Places	Often	Occasionally	Never	WMS *	Rankings
1.	Temple	40 (33.33)	45 (37.5)	35 (29.17)	2.04	**I**
2.	Residence places	29 (24.17)	56 (46.67)	35 (29.16)	1.95	**II**
3.	Near the water source	31 (25.83)	38 (31.67)	51 (42.5)	1.83	**III**
4.	During travel	25 (20.83)	50 (41.67)	45 (37.5)	1.83	**III**
5.	Fields	20 (16.67)	48 (40)	52 (43.33)	1.73	**IV**
6.	Fairs and festivals	0	27 (22.5)	93 (77.5)	1.22	**VI**
7.	Market	0	34 (28.33)	86 (71.67)	1.28	**V**
8.	*Panchayat* house	0	11 (9.17)	109 (90.83)	1.09	**VII**

Note: Figures in parentheses indicate percentages; * weighted mean scores. Source: compiled by authors.

All the respondent farmers and farm women belonged to the Hindu religion, and therefore they regularly visited temples and shared their knowledge. Water is a vital natural resource used for drinking, washing, cooking, bathing, and irrigating the fields. Therefore, fetching water was another essential place to communicate indigenous pest management practices for the hill farmers under study. Wells and temples are places of importance where people meet in villages and transfer indigenous knowledge [58].

4. Conclusions

Indigenous pest management practices are an essential knowledge resource that is native to rural communities. However, a good number of farmers practice these ITK without knowing the scientific rationale behind using them. Environmentalists and agricultural extension personnel should take necessary measures to conserve and promote these traditional practices. The custodians of this knowledge base are older farmers who pass this information from one generation to another. Reducing the crop losses from insect pests via indigenous pest management will increase food availability and boost the economic condition of poor farmers in India.

The present study documented 32 traditional pest management practices in hill agriculture, out of which the majority were rational as per the perspectives of the specialists in the field. In contrast, only a few practices had no scientific rationale. Scientifically sound practices had extensive applications in the farmers' fields of the Indian Himalayas and were undoubtedly found adequate by the farmers of the study area. Examples are setting a fire and spreading properly decomposed farmyard manure in the field. Moreover, others include using cow dung cakes, burning pine leaves, using the translating method over direct seeding in rice, and use of common salt, all being indigenous practices used for controlling white grub.

Further, summer ploughing, use of ash in vegetables, the spray of cow urine in the kitchen garden, trimming the field bunds in paddy, earthing up in potato, and planting of trap crops are some rational indigenous practices used for general pest management in fields. Use of wheat flour and powdered glass mixture and placing urea at the entrance of the mouse hole are reasonable indigenous practices for rodent control. Drying of grains in sunlight; milling of grains; use of a paste of turmeric, mustard oil, and dried leaves of walnut; and using chalk powder/dung ash and common salt in the storage tank are some sound indigenous practices used to control storage pests.

Still, a few practices had no scientific rationality, such as placing the grass of *Urtica dioica* and thorny bushes of *Berberis asiatica* plant at the entrance of a mouse hole and use of horse faeces to fill mouse holes. However, these practices are much more popular and are used among a good number of indigenous people. Scientists in plant pathology and entomology should conduct further research to find the scientific basis behind the indigenous pest management practices that were either found to be irrational by them or to which they were not entirely sure. There is an urgent need to use the ITK along with scientific cognisance. For this, documentation of ITK is an essential step. Then comes the motivation of the new generation farmers to adopt those practices and methods that are cheap and local and would effectively manage the pests without damage to the environment. Not only this, but the scientifically rational practices have chances of being replicated in similar hilly terrains of India and other countries of the globe for safe and secure ecosystems. This study was conducted in the Bageshwar district, where most of the farming has been performed under rain-fed conditions. Thus, the findings of the study may not be applicable to irrigated plains. The findings of this study could not be generalised as such beyond the area under investigation as the study was carried out under specific socio-cultural and geographical backgrounds. For future reference, a comparative study of the use of indigenous as well as modern pest management practices can be conducted on larger sample size.

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Nomenclature

Nali: *Nali* is the unit of land measurement in the Uttarakhand state of India. 1 *nali* = 2160 square feet (sq ft).

Panchayat: Panchayat is a primary functional institute of governance in villages of India, or it can be referred to as a village council.

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