



Traditional knowledge, food uses, and ethnomedicinal applications of *Chenopodium album* L. across five districts of Punjab, India

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Research

Abstract

Background: *Chenopodium album* L. (bathua) is a widely distributed wild edible and medicinal plant that contributes to traditional healthcare and dietary practices in rural communities in India. However, quantitative ethnobotanical information on its traditional uses in Punjab remains limited. This study documented traditional knowledge, food uses, and ethnomedicinal significance of *C. album* across five districts of Punjab.

Methods: Ethnobotanical information was obtained from 220 purposively selected informants using semi-structured interviews, questionnaires, focus group discussions, and field observations during November 2024–October 2025 across Pathankot, Gurdaspur, Hoshiarpur, Jalandhar, and Ludhiana, Punjab, India. A study-specific Ethnobotanical Knowledge Score (EKS) was constructed to summarize the breadth of reported human food-use and ethnomedicinal knowledge. Frequency of Citation (FC), species-level Relative Frequency of Citation (RFC), and Fidelity Level (FL) were calculated to describe medicinal-use reporting among the surveyed informants.

Results: Ethnobotanical knowledge scores differed significantly among age groups, with elderly informants recording the highest scores and younger informants the lowest. Leaves (47.27%) and leaves with tender stems (30.45%) were the most frequently reported plant-part categories. Among the 201 informants included in the human culinary-use analysis, saag was the most frequently reported principal culinary use (61.19%). Overall, 189 of 220 informants (85.9%) reported at least one medicinal use of *C. album*, giving a species-level medicinal Relative Frequency of Citation (RFC) of 0.86. Digestive disorders were the most frequently represented principal medicinal-use category (54 informants; 24.55% of the total sample; FL = 28.57%), followed by skin disorders (30; 13.64%; FL = 15.87%).

Conclusions: *C. album* remains an important component of traditional food systems and ethnomedicinal practices among the surveyed informants in Punjab, India. Knowledge scores differed markedly among age groups, with lower scores among younger informants; however, the cross-sectional design does not establish a historical decline in traditional knowledge. The findings support continued documentation and further ethnobotanical, nutritional, phytochemical, and pharmacological investigation of this widely used wild edible species.

Keywords: *Chenopodium album* L., wild edible plants, traditional knowledge, ethnobotany, ethnomedicine

Background

Traditional knowledge represents a dynamic body of experience, beliefs, and practices that has evolved through the long-term interactions between human societies and their natural environment (Parween and Marchant 2022). In many regions worldwide, such knowledge continues to shape the ways biological resources are utilized for food, healthcare, cultural activities, and livelihood support (Kumar *et al.* 2021; Rani *et al.* 2025). The close relationship between people and plants has resulted in a rich body of ethnobotanical knowledge that reflects both ecological adaptation and cultural heritage. However, increasing urbanization, changing lifestyles, and socio-economic transformations are gradually weakening the continuity of this knowledge, particularly among younger generations (Gitima *et al.* 2025). Consequently, systematic documentation of traditional plant-use practices has become an important research priority for preserving cultural heritage, supporting biodiversity conservation, and identifying plant species with nutritional and therapeutic value (Mohd Salim *et al.* 2023; Negi *et al.* 2018), while also contributing to their sustainable utilization and future pharmacological investigations. Plants have served as fundamental resources for human survival since ancient times. Besides providing food, they have long been incorporated into traditional remedies for various ailments and continue to form an important part of primary healthcare in many developing regions (Azam *et al.* 2014; Karunamoorthi *et al.* 2013; Wang *et al.* 2025). Wild and semi-cultivated edible plants are particularly valuable because they supplement household diets and can contribute to dietary diversity, especially during periods of food scarcity or limited access to market-based food systems (Awoke *et al.* 2025; Borelli *et al.* 2020; Gebre *et al.* 2025). Some of these species also have medicinal applications, linking traditional food practices with community-based healthcare. Ethnobotanical investigations of such multipurpose plants help elucidate their cultural significance and potential roles in sustainable food systems, community health, and resource management (Alemayehu *et al.* 2025; Yusuf *et al.* 2026).

Among the wild edible leafy vegetables of South Asia, *Chenopodium album* L. is recognized for its nutritional and medicinal value. Belonging to the family Amaranthaceae, the species is popularly known by several common names, including bathua, lamb's quarters, and white goosefoot (Jellen *et al.* 2011; Singh *et al.* 2023). The species is distributed throughout Asia, Europe, Africa, and North America, occurring under a wide range of environmental conditions. It commonly occurs in cultivated lands, roadsides, wastelands, and other disturbed habitats, reflecting its broad ecological adaptability (Jellen *et al.* 2011). Its widespread occurrence has enabled its use in traditional food systems. In India, it is commonly found in several states, particularly during the winter season, where its tender leaves and young shoots are consumed in the form of saag, parathas, soups, and other traditional dishes (Yadav *et al.* 2025). Nutritional studies have shown that the species contains proteins, dietary fibre, vitamins, minerals, and diverse bioactive compounds, highlighting its value as a nutritious leafy vegetable (Poonia and Upadhayay 2015). In recent years, the species has also gained increasing scientific attention as an underutilized wild edible plant with potential relevance to nutritional security and dietary diversification. Beyond its nutritional significance, *C. album* has long been recognized as a medicinal plant in traditional healthcare systems. Various plant parts, particularly the leaves, seeds, and roots, are incorporated into folk medicine for the treatment of diverse ailments. Ethnobotanical studies have documented its use in managing liver disorders, skin diseases, inflammatory conditions, and parasitic infections (Arora *et al.* 2020; Das and Borthakur 2022; Poonia and Upadhayay 2015). Experimental investigations have further reported antioxidant, antimicrobial, anti-inflammatory, and anthelmintic activities in the species (Islam *et al.* 2023; Kumari *et al.* 2025; Singh *et al.* 2023). Despite growing scientific interest in its phytochemistry and biological properties, information concerning the traditional knowledge associated with the species remains scattered and inadequately documented in many regions, particularly with respect to quantitative ethnobotanical assessments integrating food uses, medicinal applications, and patterns of knowledge distribution among local communities.

The rapid pace of modernization has intensified concerns regarding the erosion of ethnobotanical knowledge. As rural lifestyles change and dependence on natural resources declines, traditional information related to the collection, preparation, and use of edible and medicinal plants may become increasingly vulnerable to loss (Hassen 2021; Goshe *et al.* 2026). Recording such knowledge is therefore essential not only for cultural preservation but also for understanding the sustainable use of plant resources and safeguarding valuable local traditions for future generations. Such documentation is particularly relevant for widely distributed wild edible species whose traditional uses may vary among communities and regions. Punjab, one of the major agricultural states of India, possesses a long history of plant utilization embedded within its rural communities. Traditional knowledge concerning edible and medicinal plants continues to coexist with modern agricultural practices, particularly among farmers, elderly individuals, and local healers (Bakshi *et al.* 2025; Soni and Sidhu 2025). In this region, *Chenopodium album* is recognized as a seasonal edible vegetable and medicinal plant and forms part of local food and healthcare practices. Ethnomedicinal surveys in Punjab have documented traditional medicinal-plant knowledge, including a survey conducted in Jalandhar district (Sidhu *et al.* 2012). The culinary relevance of *C. album* in Punjab is also supported by work on traditional Punjabi vegetable preparations in which bathua leaves were included as an ingredient in mustard saag (Singla *et al.* 2015). However, quantitative ethnobotanical studies focusing specifically on its food

uses, ethnomedicinal applications, and cultural significance across different districts of Punjab remain limited. Furthermore, age-related and socio-demographic variations in traditional knowledge and utilization patterns of the species have received relatively little attention. Against this background, the present study was undertaken to document and quantitatively evaluate the traditional knowledge associated with *Chenopodium album* across five districts of Punjab, India. Specifically, the study aimed to: (i) document its food and ethnomedicinal uses; (ii) identify the plant parts utilized and methods of preparation; (iii) assess its cultural importance using quantitative ethnobotanical indices; and (iv) examine patterns of knowledge distribution among the surveyed informants. The findings provide a district-level account for the surveyed sample, generate baseline information for future ethnobotanical, nutritional, phytochemical, and pharmacological investigations, and support the documentation of traditional knowledge associated with this wild edible species.

Materials and Methods

Study area

The present investigation was carried out between November 2024 and October 2025 in five districts of Punjab, India, namely Pathankot, Gurdaspur, Hoshiarpur, Jalandhar, and Ludhiana. These districts were selected to include the major geographical regions and contrasting agro-climatic conditions of the state, thereby providing an opportunity to examine variations in the traditional knowledge, food uses, and ethnomedicinal applications of *Chenopodium album* L. Punjab is situated in northwestern India between 29°30'–32°32' N latitude and 73°55'–76°50' E longitude, occupying an area of approximately 50,362 km². The state experiences a semi-arid subtropical climate characterized by extremely hot summers, a southwest monsoon extending from July to September, and cool winters. Climatic conditions, together with fertile alluvial plains and an extensive agricultural landscape, have supported the long-standing dependence of rural communities on cultivated and wild plant resources. From a geographical perspective, Punjab is traditionally divided into three regions—Majha, Doaba, and Malwa—based on its river systems. Among the selected districts, Pathankot and Gurdaspur belong to the Majha region, Hoshiarpur and Jalandhar are located in the Doaba region, whereas Ludhiana represents the Malwa region. These regions differ in their physiography, agricultural practices, and cultural traditions, factors that are known to influence the utilization of plant resources and the preservation of indigenous ethnobotanical knowledge (Prabhjyot-Kaur *et al.* 2021).

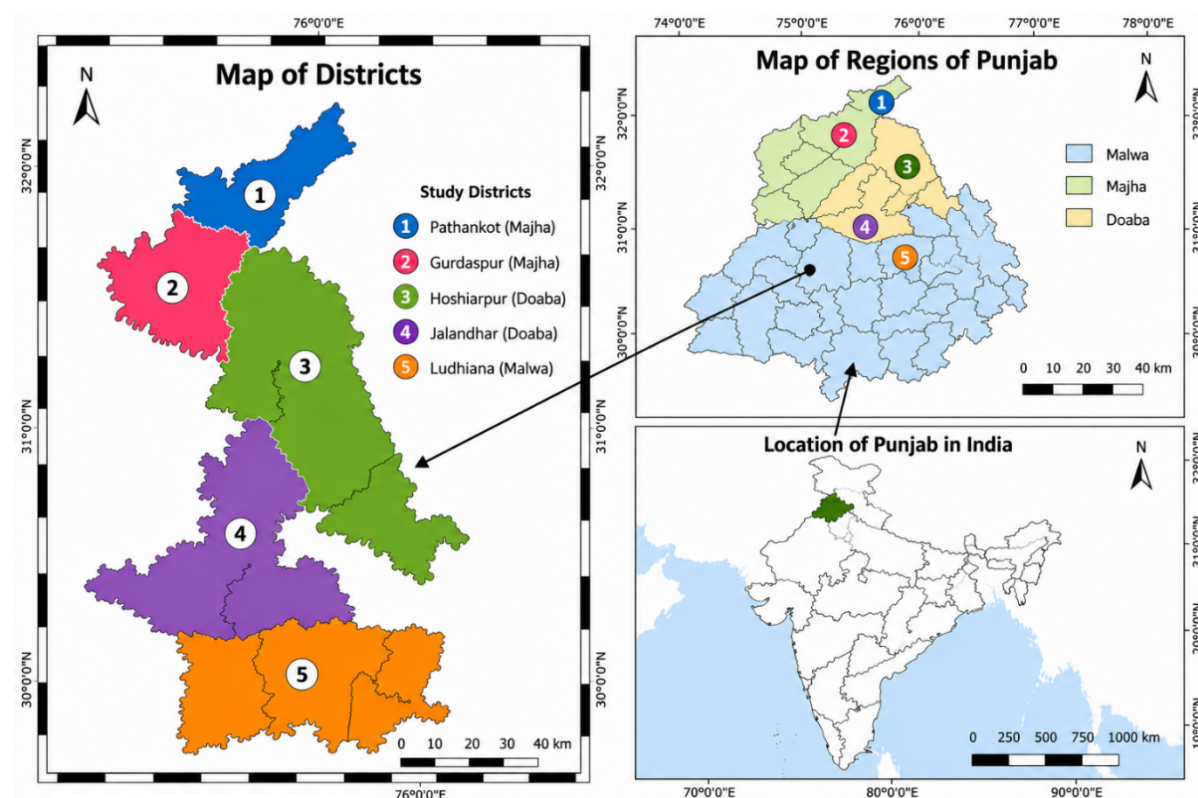


Figure 1. Map of five district of Punjab India, showing the study area

According to the agro-climatic classification developed by Punjab Agricultural University, Ludhiana, the selected districts fall within two major agro-climatic zones of the state. Pathankot, Gurdaspur, and Hoshiarpur are included in the Sub-mountain Undulating Zone, while Jalandhar and Ludhiana are part of the Central Plain Zone. The Central Plain Zone is characterized by

fertile alluvial soils, intensive rice–wheat cropping systems, and extensive agricultural production. In contrast, the Sub-mountain Undulating Zone receives comparatively higher rainfall and is characterized by undulating topography, gravelly and sandy soils, and mixed farming systems that include horticulture and agroforestry (Kaur *et al.* 2026). These environmental differences contribute to variations in vegetation composition and the availability of edible and medicinal plant species. Agriculture forms the primary source of livelihood for the majority of rural households within the study area. Despite the widespread adoption of modern farming practices, local communities continue to possess valuable traditional knowledge regarding the identification, harvesting, processing, and utilization of wild edible and medicinal plants. *Chenopodium album* L. is one of the commonly occurring species throughout the selected districts and is widely recognized for its dual role as a nutritious leafy vegetable and a medicinal resource in traditional healthcare. The ecological diversity, agro-climatic heterogeneity, and cultural richness of the selected districts therefore provide an appropriate setting for documenting and examining the traditional knowledge associated with this species. The geographical characteristics and agro-climatic features of the study districts are summarized in Table 1.

Table 1. Geographical and agro-climatic characteristics of the study districts in Punjab, India.

District	Traditional Region	Latitude (N)	Longitude (E)	Elevation (m a.m.s.l.)*	Agro-climatic Zone
Pathankot	Majha	32°16′	75°39′	332	Sub-mountain Undulating Zone
Gurdaspur	Majha	31°55′	75°16′	264	Sub-mountain Undulating Zone
Hoshiarpur	Doaba	31°32′	75°55′	296	Sub-mountain Undulating Zone
Jalandhar	Doaba	31°19′	75°35′	228	Central Plain Zone
Ludhiana	Malwa	30°54′	75°51′	244	Central Plain Zone

* a.m.s.l. = above mean sea level

Source: Geographic coordinates and elevation data correspond to district headquarters. Traditional regional classification (Majha, Doaba, and Malwa) and associated geographical information were adapted from Prabhjyot-Kaur *et al.* (2021), whereas agro-climatic zonation follows the Punjab Agricultural University classification (Kaur *et al.* 2026).

Ethnobotanical Survey and Informant Selection

A field survey was undertaken in the five selected districts of Punjab to record local knowledge concerning the food and medicinal uses of *Chenopodium album* L. Data were obtained through semi-structured interviews, informal discussions, and field observations. Informants were identified through purposive sampling, with preference given to individuals familiar with local plant resources and traditional food and medicinal practices. A total of 220 informants participated, comprising 85 males and 135 females between 20 and 99 years of age. The informants represented a range of occupational and social backgrounds, including farmers, homemakers, traditional healers, teachers, students, local vendors, and elderly community members. Because purposive rather than probability-based sampling was used, the reported frequencies, percentages, ethnobotanical indices, and knowledge patterns characterize the surveyed informants and should not be interpreted as statistically representative estimates of the wider populations of the five study districts or Punjab as a whole. Before the interviews were conducted, the purpose of the study was explained to each participant and voluntary informed consent was obtained. Information provided by informants was treated confidentially. A semi-structured questionnaire was developed in English based on the study objectives and relevant ethnobotanical literature. It covered demographic characteristics, vernacular names, traditional food uses, plant parts utilized, preparation methods, modes of administration, medicinal applications, and ailments treated with *Chenopodium album* L. The questionnaire was translated into Punjabi and Hindi by Reena Rathore. The translated versions were reviewed by Dipti Bisarya for linguistic clarity and conceptual consistency with the English questionnaire, and were back-translated into English by Reena Rathore to check consistency across language versions. Before the main survey, the questionnaire was pre-tested with 25 informants from the study area who were not included in the final sample; minor modifications were made to improve clarity, wording, and cultural appropriateness. Field observations were conducted in agricultural fields, household gardens, village markets, and other locations where *C. album* was collected, prepared, sold, or used. The following aspects were specifically observed: species presence and availability, plant parts collected or utilized, harvesting practices, food preparation and use, and local handling or marketing where applicable. Observations were documented through field notes and photographic records and were used qualitatively to cross-check interview information and identify consistencies or discrepancies. Observational evidence informed interpretation and was not treated as an independent quantitative dataset.

Focus Group Discussions

Along with the individual interviews, five focus group discussions (FGDs), one in each study district, were conducted with 6–10 participants per group. The FGD participants were drawn from the same 220 informants included in the individual

interviews and therefore did not constitute an additional study sample. Discussions were conducted in Punjabi or Hindi according to the participants' language preference and were documented through written field notes during the discussions. The field notes were organized and reviewed by Reena Rathore using a thematic approach, whereby recurring information was grouped into relevant categories, including local names, traditional food uses, ethnomedicinal applications, preparation methods, seasonal availability, cultural relevance, and intergenerational transmission of knowledge. Relevant information was translated into English where required. Information obtained from individual interviews, FGDs, and field observations was compared qualitatively to identify convergent, complementary, and divergent information. Convergent information was used to support interpretation of commonly reported traditional uses, while complementary information from FGDs and field observations provided contextual detail regarding plant use, preparation practices, and local knowledge. Where differences occurred among the three sources, these were retained as contextual variation and considered during qualitative interpretation rather than being combined or treated as separate quantitative observations. Quantitative frequencies, percentages, and ethnobotanical indices were calculated exclusively from the individual interview data.

Plant Collection and Identification

Specimens of *Chenopodium album* L. were obtained from different sites across the five selected districts during the field survey. Samples representing the principal morphological structures, including leaves, stems, roots, flowers, and seeds, were collected for taxonomic study and preparation of herbarium material. The freshly collected plants were photographed at their respective collection sites and subsequently handled following the herbarium procedures outlined by Jain and Rao (1977). After collection, the specimens were pressed, air-dried, provided with appropriate field labels, and retained for further taxonomic examination. Initial identification was undertaken with the help of taxonomic literature, regional floras, and reliable online botanical resources. The accepted nomenclature and taxonomic identity were cross-checked against Plants of the World Online (POWO), Tropicos, World Flora Online (WFO), eFlora of India, and Flora of India. Final authentication of the collected material was carried out by Dr. Kumar Ambrish, Scientist-F and In-Charge, Botanical Survey of India (BSI), High Altitude Western Himalayan Regional Centre, Nauni, Solan, Himachal Pradesh, India. The authenticated specimen (Voucher No. BSS-748) was deposited in the BSS Herbarium of the Botanical Survey of India, High Altitude Western Himalayan Regional Centre, Nauni, Solan, Himachal Pradesh, India, and is retained there as a reference specimen for this study.

Quantitative Ethnobotanical Indices

The ethnomedicinal importance of *Chenopodium album* L. was evaluated using the Frequency of Citation (FC), species-level Relative Frequency of Citation (RFC), and Fidelity Level (FL). These citation-based measures were used descriptively to summarize the extent to which medicinal uses were reported among the surveyed informants.

Frequency of Citation (FC)

Frequency of Citation (FC) represents the number of medicinal-use informants classified under a particular principal medicinal-use category. Higher FC values therefore indicate that a greater number of surveyed informants reported a particular principal medicinal-use category. FC reflects citation/reporting within the study and should not be interpreted as a measure of the actual frequency, regularity, or repetition of remedy use, which was not independently measured.

Relative Frequency of Citation (RFC)

Relative Frequency of Citation (RFC) was used at the species level to describe the proportion of surveyed informants who reported at least one medicinal use of *Chenopodium album* L. and was calculated as $RFC = FC/N$ (Vitalini *et al.* 2013).

$$RFC = FC/N \quad (0 < RFC < 1)$$

For the species-level medicinal RFC, FC was the number of informants reporting at least one medicinal use of *C. album* (189), and N was the total number interviewed (220), giving $RFC = 189/220 = 0.859$ (approximately 0.86). Higher RFC indicates that the species was cited for medicinal use by a greater proportion of surveyed informants; it is citation-based and does not measure the actual frequency of medicinal practice. For individual medicinal-use categories, the proportion of the total survey sample represented by each principal medicinal-use category was calculated separately as $FC/220 \times 100$. These category-specific percentages were treated descriptively and were not interpreted as species-level RFC values.



Figure 2. Field surveys, plant documentation, and ethnobotanical interviews conducted across the study sites in Punjab, India.

Fidelity Level (FL)

Fidelity Level (FL) was calculated as the proportion of medicinal-use informants represented in a particular principal medicinal-use category relative to all informants who reported at least one medicinal use of *C. album*. FL was calculated following Friedman *et al.* (1986):

$$FL (\%) = (N_p/N) \times 100$$

where N_p is the number of medicinal-use informants classified under a particular principal medicinal-use category (equivalent to FC for that category), and N is the total number of informants who reported at least one medicinal use of *C. album* ($N = 189$). Higher FL values indicate greater specificity/fidelity of the reported medicinal use toward that particular principal medicinal-use category rather than direct informant consensus about remedy preparation, effectiveness, or frequency of use.

For coding of traditional-use categories Informants described several traditional uses of *C. album* during the interviews. For the categorical frequency summaries, informants were asked to identify their principal use, which was recorded during the interview, and each informant was represented once according to the principal category reported for the respective analysis. Additional uses reported by the same informant were retained as ethnobotanical information but were not counted as

separate observations in these mutually exclusive categorical distributions. The plant-part distribution included all 220 informants in five mutually exclusive categories; the human culinary-use distribution included 201 informants across eight culinary-use categories; and the medicinal-use distribution included the 189 informants who reported at least one medicinal use. Percentages were calculated using the number of informants included in the respective analysis as the denominator.

Ethnobotanical Knowledge Score (EKS)

To examine variation in the breadth of *Chenopodium album* knowledge among individual informants, a study-specific Ethnobotanical Knowledge Score (EKS) was constructed from the human food and ethnomedicinal uses recorded during the individual interviews. Quantitative approaches have been used in ethnobotanical research to characterize variation in plant-use knowledge among individuals and groups, although the way such knowledge is conceptualized and measured differs among studies (Reyes-García *et al.* 2007; De Beer and Van Wyk 2011; Sulaiman 2025). Accordingly, the EKS used here was developed as an operational measure specific to the objectives and dataset of the present study rather than as an adaptation of an existing standardized ethnobotanical knowledge index. The EKS consisted of 20 binary items, comprising eight human food-use items (saag, addition to sarson ka saag, leaf juice, salad, cooked vegetable, paratha, raita, and stuffed bread) and 12 ethnomedicinal-use items (digestive disorders, skin disorders, blood purification, colic/abdominal pain, hemorrhoids/piles, inflammatory disorders, liver disorders including jaundice, urinary disorders, cough and sore throat, rheumatism, menstrual disorders, and wounds/cuts). For each informant, a score of 1 was assigned when a particular use was reported and 0 when it was not reported. Each distinct use contributed only once to an informant's score, irrespective of repeated mention. The item scores were summed as:

$$\text{EKS} = \sum X_i, i = 1-20$$

where X_i represents the binary score (0 or 1) for each knowledge item. The possible EKS therefore ranged from 0 to 20, while the scores observed among the 220 informants ranged from 3 to 8. A higher EKS represents a greater breadth of reported *C. album* human food and ethnomedicinal knowledge within the study sample; it does not represent the frequency or regularity with which individual uses were practiced.

The EKS was calculated independently of the mutually exclusive principal-use summaries presented for categorical frequency analyses. Thus, whereas an informant was represented once according to the principal category in those analyses, all distinct qualifying human food and ethnomedicinal uses reported by that informant could contribute to the EKS.

Statistical Analysis

The collected data were organized and coded in Microsoft Excel 2021 prior to statistical analysis. The distribution of ethnobotanical knowledge scores was assessed using the Shapiro–Wilk test to determine whether the data satisfied the assumption of normality. As the test indicated a significant departure from a normal distribution ($p < 0.05$), non-parametric statistical methods were selected for subsequent analyses. Variations in knowledge scores among different age groups and across the five study districts were evaluated using the Kruskal–Wallis test. When a significant Kruskal–Wallis test was obtained, pairwise comparisons were performed using Dunn's test with Bonferroni adjustment. No post hoc pairwise comparisons were performed following a non-significant omnibus Kruskal–Wallis test. Differences in knowledge scores between male and female informants were examined using the Mann–Whitney U test. Descriptive statistical measures, including frequencies, percentages, means, standard deviations, and medians, were calculated to summarize the demographic characteristics of the informants and the documented ethnobotanical use reports. Age was recorded as a continuous variable and subsequently grouped for statistical comparison as young (<40 years), middle-aged (40–59 years), and elderly (≥ 60 years). These broad categories were defined after data collection for group-based analysis, were not pre-specified in the questionnaire, and were not selected on the basis of observed knowledge-score differences; unequal group sizes reflect the observed age distribution. All statistical analyses were performed using Jamovi version 2.7.3 (The Jamovi Project, Sydney, Australia), and statistical significance was established at $p < 0.05$.

Results

Demographic Characteristics of Informants

A total of 220 informants from five districts of Punjab participated in the ethnobotanical survey of bathua (*Chenopodium album* L.). The distribution of informants across the study districts was nearly uniform, with Hoshiarpur contributing the highest number of informants (46; 20.91%), followed by Jalandhar (45; 20.45%), Pathankot (44; 20.00%), Ludhiana (43; 19.55%), and Gurdaspur (42; 19.09%) (Figure 3a). The overall gender composition of the informants is presented in Figure 3b. Female informants constituted the majority of the participants (135; 61.36%), while male informants accounted for 85

(38.64%). The age distribution of the informants is illustrated in Figure 3c. Informants ranged in age from 20 to 99 years. The largest proportion belonged to the 60–69-years age group (51; 23.18%), followed by the 50–59-years (42; 19.09%), 70–79-years (38; 17.27%), and 40–49-years (32; 14.55%) age groups. The remaining informants comprised 24 (10.91%) individuals aged 80–89 years, 15 (6.82%) aged 30–39 years, 9 (4.09%) aged 90–99 years, and 9 (4.09%) aged 20–29 years. The occupational profile of the informants is shown in Figure 3d. Homemakers represented the largest occupational group (56; 25.45%), followed by farmers (47; 21.36%) and retired elderly community members (44; 20.00%). Traditional healers accounted for 37 (16.82%) informants, while teachers, students, and vendors/local traders contributed 19 (8.64%), 12 (5.45%), and 5 (2.27%) informants, respectively. These occupational categories describe the composition of the purposively selected study sample.

Traditional Knowledge and Local Nomenclature

All 220 informants were familiar with *Chenopodium album* L. and readily recognized the species during field interviews. The plant was predominantly known by the vernacular name "Bathua", which was consistently used across the five study districts. Informants identified the species based on its characteristic morphological features, including its tender green leaves, branched stem, and farinose (mealy) leaf surface. Informants also regarded *C. album* as an important wild edible vegetable with long-standing culinary and ethnomedicinal significance. Traditional knowledge regarding its identification, seasonal availability, food uses, and medicinal applications was consistently shared by informants across all five study districts.

Plant Parts Used

The survey showed that different parts of *Chenopodium album* L. were reported for food and medicinal purposes (Figure 4). For the plant-part distribution, each of the 220 informants was counted once in one mutually exclusive plant-part category. Leaves were the most frequently reported category (104 informants; 47.27%), followed by leaves with tender stems (67; 30.45%), whole plant (28; 12.73%), roots (12; 5.45%), and seeds (9; 4.09%). Although informants could describe different food and medicinal uses, multiple use reports were not counted as additional observations in this plant-part distribution.

Traditional Food Uses of *Chenopodium album*

Among the 220 surveyed informants, 201 were classified in the human culinary-use analysis and 19 reported livestock fodder as their principal non-human use. For the human culinary-use distribution, each of the 201 informants was counted once according to the principal culinary use reported and recorded during the interview. Saag was the most frequently reported principal culinary use (123 informants; 61.19%), followed by addition to *sarson ka saag* (30; 14.93%), leaf juice (15; 7.46%), salad (12; 5.97%), cooked vegetable (7; 3.48%), paratha (7; 3.48%), raita (5; 2.49%), and stuffed bread (2; 1.00%). Livestock fodder was reported separately by 19 informants (8.64% of the total survey sample, N = 220) and was not included in the human culinary-use percentages shown in Figure 5.

Ethnomedicinal Uses and Quantitative Ethnobotanical Indices

Chenopodium album L. was reported to possess a wide range of traditional medicinal applications for the treatment of various human ailments (Table 2). Overall, 189 of the 220 informants reported at least one medicinal use of *Chenopodium album*, resulting in a species-level medicinal Relative Frequency of Citation (RFC) of 0.86. Leaves, roots, seeds, and the whole plant were reported as medicinally utilized plant parts, while fresh leaf paste, fresh juice, seed powder, and decoction were the principal preparation methods. Remedies were administered orally or topically according to the reported medicinal application. For the categorical medicinal-use summary, each of these 189 medicinal-use informants was represented once according to the principal medicinal use reported and recorded during the interview. Digestive disorders, including indigestion and constipation, were the most frequently reported therapeutic use, with the highest Frequency of Citation (FC = 54; 24.55% of all informants; FL = 28.57%). Skin disorders, including burns, infections, and irritation, were the second most frequently reported category (FC = 30; 13.64%; FL = 15.87%). Blood purification was reported by 18 informants (8.18%; FL = 9.52%), followed by colic/abdominal pain and hemorrhoids, each with an FC of 15 (6.82%; FL = 7.94%).

Inflammatory disorders were reported by 14 informants (6.36%; FL = 7.41%), whereas liver disorders, including jaundice, were reported by 11 informants (5.00%; FL = 5.82%). Less frequently reported medicinal applications included urinary disorders (FC = 9; 4.09%; FL = 4.76%), cough and sore throat (FC = 7; 3.18%; FL = 3.70%), rheumatism (FC = 7; 3.18%; FL = 3.70%), menstrual disorders (FC = 6; 2.73%; FL = 3.17%), and wound healing (FC = 3; 1.36%; FL = 1.59%). These findings describe the distribution of principal medicinal-use reports within the surveyed sample and should not be interpreted as measures of the actual frequency, regularity, efficacy, or effectiveness of remedy use.

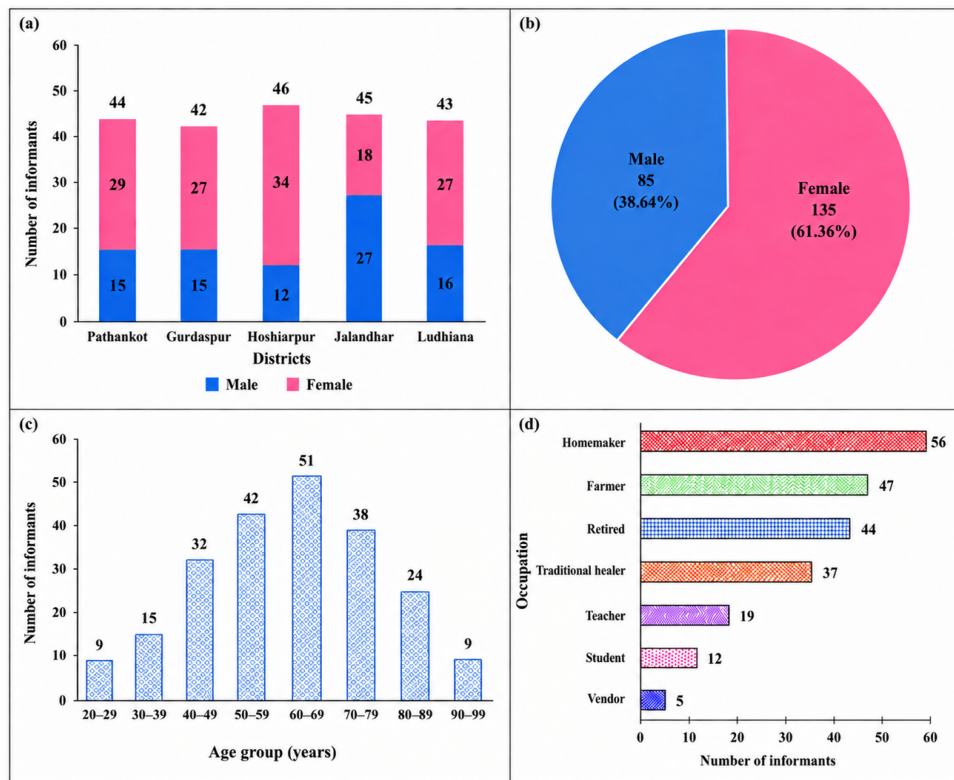


Figure 3. Demographic characteristics of informants participating in the ethnobotanical survey of *Chenopodium album* across the study districts of Punjab, India (N = 220): (a) distribution of male and female informants across the study districts; (b) overall gender distribution of informants; (c) age distribution of informants; and (d) occupational profile of informants.

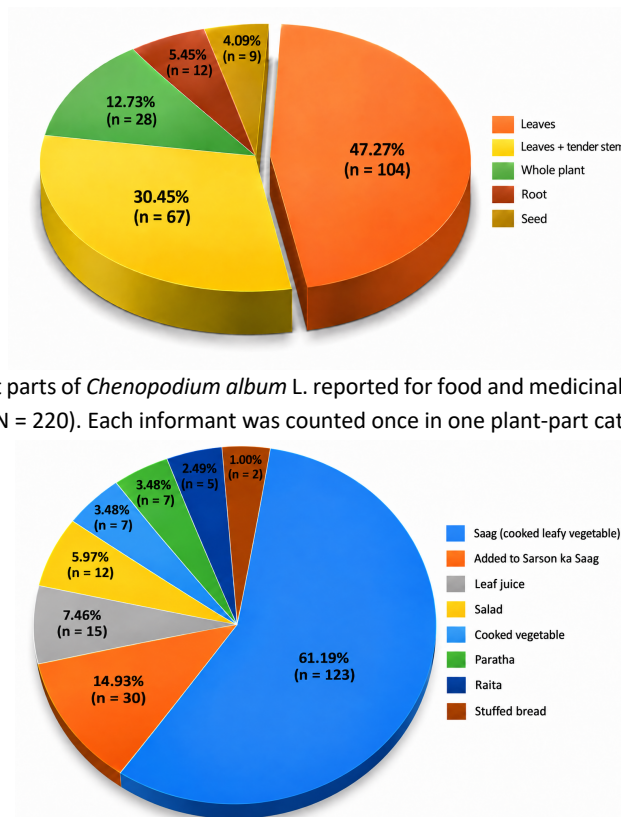


Figure 4. Distribution of plant parts of *Chenopodium album* L. reported for food and medicinal purposes among the surveyed informants in Punjab, India (N = 220). Each informant was counted once in one plant-part category.

Figure 5. Distribution of principal human culinary uses of *Chenopodium album* L. among informants included in the human culinary-use analysis in Punjab, India (n = 201).

Each informant was counted once according to the principal human culinary use reported and recorded during the interview. Livestock fodder (n = 19; 8.64% of the total survey sample, N = 220) was considered separately and is not included in this figure.

Table 2. Ethnomedicinal uses and quantitative ethnobotanical measures of *Chenopodium album* L. among surveyed informants in Punjab, India

Ailment category	Plant part(s) used	Preparation method	Mode of administration	FC	Proportion of Informants Reporting the Use (%)	FL (%)
Digestive disorders (indigestion and constipation)	Leaves, roots	Fresh juice / Decoction	Oral	54	24.55	28.57
Skin disorders (burns, infections, irritation)	Leaves	Fresh paste	Topical	30	13.64	15.87
Blood purification	Leaves, seeds	Fresh juice / Seed powder	Oral	18	8.18	9.52
Colic/abdominal pain	Roots	Decoction	Oral	15	6.82	7.94
Hemorrhoids (piles)	Whole plant	Decoction	Oral	15	6.82	7.94
Inflammatory disorders	Leaves	Fresh paste	Topical	14	6.36	7.41
Liver disorders (including jaundice)	Whole plant	Decoction	Oral	11	5.00	5.82
Urinary disorders	Seeds	Seed powder / Decoction	Oral	9	4.09	4.76
Cough and sore throat	Leaves	Decoction	Oral	7	3.18	3.70
Rheumatism	Whole plant	Decoction	Oral	7	3.18	3.70
Menstrual disorders	Seeds	Seed powder / Decoction	Oral	6	2.73	3.17
Wounds/cuts	Leaves	Fresh paste	Topical	3	1.36	1.59

Note: FC = Frequency of Citation, defined here as the number of informants who reported *C. album* for the corresponding medicinal-use category. The 12 medicinal-use categories collectively account for 189 informants reporting at least one medicinal use. Proportion of Informants Reporting the Use (%) = $FC/220 \times 100$, where 220 is the total number of informants interviewed. FL = Fidelity Level = $FC/189 \times 100$, where 189 is the number of informants who reported at least one medicinal use. FL therefore indicates the proportion of medicinal-use informants who associated *C. album* with a particular medicinal-use category. Category-specific proportions are descriptive and should not be interpreted as species-level RFC values.

Findings from Focus Group Discussions

The five focus group discussions (FGDs) provided qualitative context for, and were used to cross-check, patterns identified through the individual interviews. Three main areas emerged from the discussions: seasonal food use, preferences regarding plant parts and food preparation, and traditional medicinal practices. FGD participants consistently described *Chenopodium album* L. as a seasonal leafy vegetable and identified saag as a common preparation, corresponding with its prominence in the individual interview data. Participants further indicated that tender leaves and stems were preferred for cooking, while specific preparation methods varied among households. The FGDs also provided qualitative context for medicinal uses documented through individual interviews. Participants discussed remedies prepared from leaves, seeds, and roots, broadly corresponding to plant parts and medicinal applications reported during individual interviews; however, the particular remedies and preparation methods described varied among participants and communities. Overall, the FGDs showed broad convergence with the principal interview patterns while revealing household-level variation. FGD findings were used exclusively for qualitative contextualization and cross-checking and were not added to frequencies, percentages, or ethnobotanical indices calculated from the 220 individual interviews.

Distribution of Ethnobotanical Knowledge Among Informants

The distribution of ethnobotanical knowledge scores according to age group, gender, and district is presented in Table 3. The Shapiro–Wilk test indicated significant departures from normality ($p < 0.05$), and non-parametric tests were therefore

used. The Kruskal–Wallis test revealed a highly significant difference in ethnobotanical knowledge scores among the three age groups ($\chi^2 = 53.30$, $df = 2$, $p < 0.001$). Young informants exhibited the lowest mean knowledge score (3.88 ± 0.99 ; median = 4.00), followed by middle-aged informants (5.30 ± 1.28 ; median = 5.00), whereas elderly informants demonstrated the highest mean knowledge score (6.20 ± 1.38 ; median = 6.00). Dunn’s pairwise comparisons with Bonferroni adjustment showed significant differences for all three age-group comparisons (all adjusted $p < 0.001$). In the unadjusted comparison, knowledge scores differed significantly between male and female informants ($U = 4704$, $p = 0.022$). Male informants (5.93 ± 1.49 ; median = 6.00) had higher knowledge scores than female informants (5.47 ± 1.49 ; median = 5.00). However, this finding represents an unadjusted bivariate association within the surveyed sample and should not be interpreted as evidence that gender independently explains variation in ethnobotanical knowledge. In contrast, no significant variation in ethnobotanical knowledge was observed among the five surveyed districts (Kruskal–Wallis $\chi^2 = 8.14$, $df = 4$, $p = 0.087$). Although informants from Jalandhar exhibited the highest mean knowledge score (6.13 ± 1.56), followed by Hoshiarpur (5.70 ± 1.46), Ludhiana (5.67 ± 1.51), Pathankot (5.36 ± 1.60), and Gurdaspur (5.33 ± 1.30), these differences were not statistically significant. Because the omnibus Kruskal–Wallis test was non-significant, no post hoc pairwise comparisons among districts were conducted or interpreted.

Table 3. Comparison of ethnobotanical knowledge scores according to demographic characteristics and study districts.

Parameter	Category	n	Mean $\pm$ SD	Median	Test statistic	p-value
Age group	Young (<40 years)	24	3.88 ± 0.99	4.00	Kruskal–Wallis $\chi^2 = 53.30$ ($df = 2$)	< 0.001
	Middle-aged (40–59 years)	74	5.30 ± 1.28	5.00		
	Elderly (≥ 60 years)	122	6.20 ± 1.38	6.00		
Gender	Female	135	5.47 ± 1.49	5.00	Mann–Whitney $U = 4704$	0.022
	Male	85	5.93 ± 1.49	6.00		
District	Pathankot	44	5.36 ± 1.60	5.50	Kruskal–Wallis $\chi^2 = 8.14$ ($df = 4$)	0.087
	Gurdaspur	42	5.33 ± 1.30	5.00		
	Hoshiarpur	46	5.70 ± 1.46	6.00		
	Jalandhar	45	6.13 ± 1.56	7.00		
	Ludhiana	43	5.67 ± 1.51	5.00		

Note: Values are presented as mean $\pm$ standard deviation and median. Age-group and district comparisons were performed using the Kruskal–Wallis test, whereas the gender comparison was performed using the Mann–Whitney U test. Dunn’s pairwise comparisons with Bonferroni adjustment were conducted only following a significant omnibus Kruskal–Wallis test. No post hoc pairwise comparisons were conducted for districts because the omnibus Kruskal–Wallis test was not significant ($p = 0.087$). Statistical significance was set at $p < 0.05$.

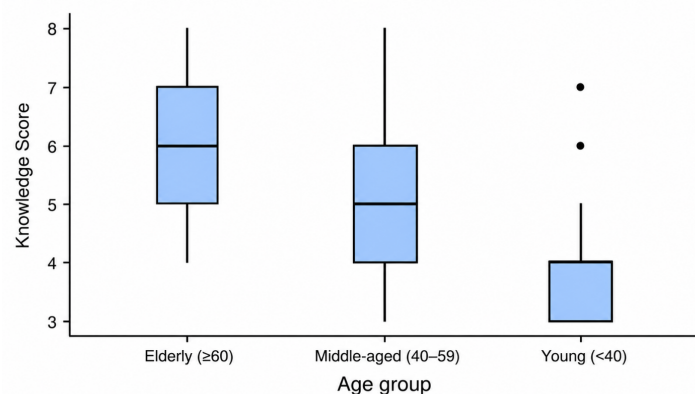


Figure 6. Boxplot showing the distribution of ethnobotanical knowledge scores among young (<40 years), middle-aged (40–59 years), and elderly (≥ 60 years) informants regarding *Chenopodium album* L. in Punjab, India (N = 220).

Discussion

The universal recognition of *Chenopodium album* L. among the informants and its consistent identification by the vernacular name “Bathua” indicate a high level of familiarity with the species across the five surveyed districts. Despite the geographical separation of the study sites, informants consistently recognized and used the plant, indicating that knowledge of *C. album* remains well established among the surveyed informants. This observation is in agreement with earlier ethnobotanical

reports that have identified *C. album* as a widely recognized wild edible leafy vegetable with multiple traditional uses (Abd El-Hack *et al.* 2025; Bonifacio 2003; Poonia and Upadhayay 2015; Saini and Saini 2020; Singh *et al.* 2023). The high level of familiarity recorded among the surveyed informants therefore indicates that *C. album* continues to occupy an important position in local plant-use traditions. The predominance of *saag* as the principal culinary preparation indicates that *C. album* continues to be used as a traditional winter leafy vegetable in North India, particularly in Punjab. Its incorporation into *Sarson da Saag*, together with its reported use as salad, cooked vegetable, paratha, raita, stuffed bread, and fresh leaf juice, demonstrates considerable culinary versatility. These findings are consistent with previous reports describing the use of *C. album* in traditional food systems (Bonifacio 2003; Singh *et al.* 2023; Abd El-Hack *et al.* 2025). In Punjab, *Sarson da Saag* is widely regarded as a cultural emblem of the winter season and is associated with the region's agrarian heritage and seasonal culinary traditions (Hoque and Taufique 2019; Jain *et al.* 2024). The continued inclusion of *C. album* in this preparation therefore reflects the persistence of its culinary role within local food practices (Kaur *et al.* 2024; Kumari *et al.* 2025). Its reported consumption may further be related to its seasonal availability, palatability, ease of collection, and nutritional value (Fukalova *et al.* 2021; Maroyi 2013).

The nutritional attributes reported for *C. album* in earlier studies provide further context for its continued use as a food resource in the present study. Previous investigations have described the species as a source of proteins, dietary fibre, vitamins, minerals, carotenoids, phenolic compounds, and natural antioxidants (Abd El-Hack *et al.* 2025; Afolayan and Jimoh 2009; Chute and Dakhane 2024; Poonia and Upadhayay 2015). In the present investigation, its use as human food was reported more frequently than its use as livestock fodder. Nevertheless, the occurrence of fodder use further demonstrates the multipurpose nature of the species within rural production systems. Comparable food and fodder uses have been reported from the Himalayan and Indo-Gangetic regions, where *C. album* contributes to both human diets and livestock nutrition (Kazemi and Ariapour 2025; Mustafa *et al.* 2009). Besides its dietary uses, *C. album* was reported for medicinal purposes by 189 of the 220 surveyed informants. The recorded remedies covered digestive disorders, skin disorders, inflammatory conditions, blood purification, urinary disorders, liver disorders, rheumatism, menstrual disorders, cough and sore throat, hemorrhoids, wounds, and abdominal pain. The range of applications documented in the present study corresponds with earlier reports of the species being used for gastrointestinal, dermatological, inflammatory, and hepatoprotective conditions (Majumdar *et al.* 2025; Said *et al.* 2020; Saini and Saini 2020; Singh *et al.* 2023). Digestive and skin-related applications were the most represented principal medicinal-use categories in the surveyed sample. Experimental studies have also reported antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, gastroprotective, and wound-healing activities associated with the species, providing a basis for further investigation of some of its reported traditional applications (Abd El-Hack *et al.* 2025; Kaur *et al.* 2024; Kumari *et al.* 2025). These observations support further investigation of the reported ethnomedicinal applications while emphasizing the need for phytochemical, pharmacological, and clinical evaluation.

In the present study, leaves, either alone or together with tender stems, were the most frequently reported plant-part categories, whereas roots and seeds were reported less often. The predominance of leaves is consistent with earlier ethnobotanical investigations in which leaves were frequently identified as the principal plant part used for edible and medicinal purposes because they are readily accessible, comparatively easy to harvest, and suitable for different preparations (Abd El-Hack *et al.* 2025; Bonifacio 2003; Poonia and Upadhayay 2015). Their frequent reporting may also be related to their nutritional composition and the presence of various bioactive constituents (Abd El-Hack *et al.* 2025; Kumari *et al.* 2025; Singh *et al.* 2023). The greater reporting of these aerial parts may additionally reflect their easy collection during the vegetative stage and their suitability for both culinary and traditional medicinal applications. A significant variation in ethnobotanical knowledge was observed among the three age groups, with elderly informants possessing the highest knowledge scores, followed by middle-aged informants, while younger informants recorded the lowest scores. The observed age-related pattern indicates that knowledge associated with *C. album* is unevenly distributed across generations. The lower scores among younger informants may reflect changes in lifestyle, dietary preferences, exposure to traditional plant-use practices, and opportunities for learning from older community members. Similar age-related patterns have been reported in ethnobotanical studies, where older people often retain greater knowledge of wild edible and medicinal plants as a consequence of longer experience with local resources and traditional practices (Alrhoun *et al.* 2025; Turner *et al.* 2011). Although the present cross-sectional data cannot by themselves establish a historical decline in knowledge, the marked difference between age groups raises concern about the continuity of knowledge transmission. Strengthening opportunities for intergenerational exchange and community-based documentation may therefore help maintain knowledge associated with *C. album*.

Quantitative assessment of individual ethnobotanical knowledge has been approached using a range of operational measures and indices across ethnobotanical studies (Reyes-García *et al.* 2007; De Beer and Van Wyk 2011; Sulaiman 2025). However, the conceptualization and measurement of ethnobotanical knowledge vary considerably among studies, which can limit direct comparison among different scoring systems (Reyes-García *et al.* 2007). Accordingly, the EKS used in the present study was treated as a study-specific, count-based operational measure of the breadth of reported *C. album* human food-use and ethnomedicinal knowledge rather than as a standardized ethnobotanical knowledge index. The resulting differences among age and gender groups should therefore be interpreted as within-sample differences in the breadth of reported *C. album* knowledge rather than as directly comparable measures of ethnobotanical knowledge across populations or studies. The higher knowledge scores observed among male informants in the unadjusted analysis should be interpreted cautiously. One possible contextual explanation may involve differences in engagement with agricultural activities, plant collection, or other livelihood-related practices that could influence opportunities for acquiring ethnobotanical knowledge. However, these relationships were not directly examined in the present study, and this explanation therefore remains speculative. Moreover, age, occupation, district, and other sociodemographic characteristics may be interrelated with gender in the purposively selected sample. Consequently, the observed difference should be regarded as an unadjusted association within the surveyed informants rather than as evidence that gender independently determines ethnobotanical knowledge. Knowledge scores did not differ significantly among informants from the five surveyed districts. This finding applies to the purposively selected participants; it does not establish that knowledge is equally distributed across the wider populations of those districts. Shared food practices or the widespread availability of *C. album* may be possible explanations, but these explanations were not tested.

The quantitative ethnobotanical measures further describe the medicinal knowledge reported for *C. album* within the surveyed sample. The species-level medicinal RFC of 0.86 indicates that a large proportion of surveyed informants reported at least one medicinal use. Variation in FL among principal medicinal-use categories reflects differences in the specificity/fidelity with which medicinal-use informants were represented in particular ailment categories; FL should not be interpreted as a direct measure of consensus regarding remedy preparation, effectiveness, or frequency of use. Overall, the findings show that *Chenopodium album* L. remains relevant to the food and traditional healthcare practices reported by the surveyed informants across the five selected districts of Punjab. Its diverse culinary applications, range of reported medicinal uses, and recognition by all surveyed informants document the continuing importance of the species within the plant-use traditions represented in the study sample. The pronounced age-related variation in knowledge scores highlights differences in the breadth of reported knowledge among age groups, while the cross-sectional design does not establish historical decline. The absence of a significant difference in knowledge scores among districts applies only to the purposively selected informants and should not be interpreted as evidence that knowledge or use is uniform across the wider district populations. The findings provide a basis for continued documentation and further ethnobotanical, nutritional, phytochemical, pharmacological, and clinical investigation of *C. album*.

Study Limitations

Several limitations should be considered when interpreting the findings of this study. First, informants and study districts were selected purposively; therefore, the findings characterize the knowledge and practices of the surveyed informants and should not be considered statistically representative of the wider population of Punjab. Second, the distribution of informants across age groups was unequal, with comparatively greater representation of older informants. Although the age-group analyses describe patterns within the surveyed sample, the unequal group sizes should be considered when interpreting comparisons among age categories. Third, the cross-sectional design provides information on ethnobotanical knowledge and practices at the time of the survey but does not permit causal inference or establish historical changes or decline in traditional knowledge over time. Longitudinal or repeated studies would be required to evaluate temporal changes directly. The study also relied primarily on self-reported traditional knowledge and practices, which may be affected by recall bias or social desirability bias. Although focus group discussions and field observations provided qualitative context and were used to cross-check information obtained through individual interviews, these approaches cannot completely eliminate potential reporting biases. In addition, associations between ethnobotanical knowledge scores and sociodemographic characteristics were examined using separate unadjusted analyses. Because age, gender, occupation, district, and other characteristics may be interrelated, potential sociodemographic confounding cannot be excluded, and the observed associations should not be interpreted as independent or causal effects. The ethnobotanical knowledge score was developed as a study-specific, count-based operational measure and was not subjected to formal psychometric validation or reliability testing; it should therefore be interpreted as an indicator of the breadth of reported *C. album* human food-use and ethnomedicinal knowledge within the surveyed sample rather than as a standardized measure directly comparable across populations or studies. Finally, the investigation focused on a single species, *Chenopodium album* L., across five purposively

selected districts of Punjab. Consequently, the findings should not be generalized to other plant species, districts, or populations without further investigation.

Conclusion

The findings show that *Chenopodium album* L. remains an important wild edible and medicinal plant among the surveyed informants in Punjab, India. The species was associated with diverse culinary preparations and ethnomedicinal applications, and knowledge scores differed significantly among age groups. Lower scores among younger informants indicate an age-related difference within the surveyed sample; however, the cross-sectional design does not establish historical decline in traditional knowledge. Because the study used purposive sampling, these findings should be interpreted as characterizing the surveyed informants rather than the wider population of Punjab. Continued documentation and further ethnobotanical, nutritional, phytochemical, pharmacological, and clinical investigation may help clarify the significance and responsible utilization of *C. album* while preserving knowledge associated with its traditional uses.

Declarations

Ethics approval and consent to participate: Prior informed consent was obtained from all participants before data collection. Participants were informed about the objectives and procedures of the study, and participation was voluntary. The study documents were reviewed by the Institutional Ethics Committee of Lovely Professional University following completion of data collection, and ethical clearance was subsequently issued under Reference No. LPU/IEC-LPU/2026/05/9. Confidentiality and anonymity were maintained throughout the study, and no personal identifiers were disclosed.

Consent for publication: All participants shown in images agreed to have their image published.

Competing interests: The authors declare that they have no competing interests.

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Availability of data and materials: The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Author contributions: Reena Rathore: Field investigation, data collection, visualization, and writing of the original draft. Vinai Kumar: Conceptualization, methodology, supervision, data analysis, interpretation of results, and manuscript review and editing. Rahul Vinayak Salve: Provided critical suggestions and contributed to manuscript revision. Dipti Bisarya: Conceptualization, methodology, Supervision, validation, and critical revision of the manuscript. All authors read and approved the final manuscript.

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