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RESEARCH ARTICLE

Evaluation of crop wild relatives from Lahaul valley, Himachal Pradesh, India

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ABSTRACT

Improving domesticated crops using wild relatives is a sustainable and cost-effective solution for human welfare problems. The study provides a promising source of accessed plants, explored during the survey in four different sites viz Kardang, Piyukar, Gumrang and Yurnath present in Keylong region, district Lahaul-Spiti, Himachal Pradesh. To observe the species abundance in different locations, present study was conducted in 2017 and 2018 within an elevation range above 3000m. Species richness and Shannon diversity value (0-4.5) was maximum observed in Piyukar village (2.35; 2. 43), followed by Gumrang (2.32; 2.32), Yurnath (2.26; 2.19) and Kardang (1.91; 2.01). The largest population density of species was recorded as *E. semicostatus* (34.40 plants/m^2), *E. repens* (33.20 plants/m^2), *E. dahuricus* (32.20 plants/m^2), *E. longiaristatus* (20.00 plants/m^2) and *Poa annua* (18.20 plants/m^2). These regions are well known for medicinal properties, but numerous wild relatives for domesticated crops found during germplasm cum exploration survey such as wheat wild grass (*Elymus semicostatus, E. repens* and *E. dahuricus*), condiments (*Carum carvi* and *Ferulajaes chkeana*), tribal food (*Chenopodium foliosum, Dioscora deltoidea* and *Hyppophea rhamnoides*) and fruits (*Ribes alpestris* and *Fragaria vesca*). The study drew the attention of plant researchers toward conservation and kept these plants in the pipeline of crop breeding.

Keywords: conservation; crop improvement; crop wild relative; distribution; Lahaul-Spiti

INTRODUCTION

The degradation of temperate diversity and devastation of natural habitats due to climate change, anthropogenic activities and poor conservation strategies are the foremost causes of relapse in global biodiversity. Thus, in several Himalayan ranges, restoration of disturbed ecosystems is being taken up on a superiority basis to maintain landscape productivity and biodiversity conservation (Rana et al., 2016). Crop wild relatives are wild cousions of domesticated crops that harbour genetic diversity, and valuable traits relevant to biotic and abiotic stress tolerance might be useful in crop improvement. The variability to face changing climate prove their potential and elected them suitable candidates for breeding programs. However, CWR (Crop wild relatives) growing in the wild or some specific habitats are often susceptible to habitat degradation and destruction and may extinct without immediate conservation plans (Chand et al., 2017).

The conservation priorities for CWR taxa have been identified by policymakers and include them in prioritization strategies such as svalvault, Food and agricultural organization (FAO), and Global strategies for plant conservation (CBD, 2011-2020) several International Treaty on Plant Genetic Resources. No doubt, Asia is the origin of many crop relatives and much extensive work carried out on their collection and conservation. We first need to identify other unreported CWR taxa within the country based on their efficiency via regular field surveys and germplasm cum exploration trips. However, the CWR conservation strategy will capture the whole genetic and taxonomic diversity of the Lahaul valley-a tribal and temperate desert of Himachal Pradesh. Due to the remote location and covering of snow for more than six months, the valley opens for a short duration (Saxena et al., 2018). Many close relative's species in these regions will not be explored and utilized but found to be on the verge of threat. They may harbour important adaptations and genetic variation to the Indian flora in general as these endemic diversities can often be morphological and genetically varied from domesticated CWR and must have distinct traits providing adaptation to climate change. Improving crops using CWR is not a new concept, and these already used extensively in crop improvement programs. To empathize the interaction between the functional aspect and biodiversity of flora, the assessment at the current scenario is the primary task before the ecologists move toward conservation. Therefore, any decline of biodiversity is assured to amend the community attributes (Ayaz and Dhali, 2020).

Keeping all the above in mind, we explored Lahaul-Spiti valley, covering more than 13,833 sq. km geographical area of Himachal Pradesh, which lies between 310 44'55"-65014'25" N latitude and 450 45' 74"- 480 45' 34" N longitude. The high mountains, land of Buddhists where the curative and magical properties have been narrated based on superstitions and speculations, effectiveness is bestowed with a diversity of natural resources. Since time, the valley foot has been selected by medicinal practitioners since time age-old suffering, relieving and curative diseases by error and trial. The diverse geography, soil and climatic conditions ratify a unique vegetation pattern in these regions (Kumar and Chander, 2018a; Rana et al., 2019). The forest flora of Lahaul is notable in two aspects. Firstly, it enriched with several threatened taxa of the adjoining states/countries, and secondly, it favours high endemism (Rani et al., 2013). Unskilled agricultural practices and unfettered forest depletion have led to the disturbance for secondary communities on different floristic zones. Instead of these stress drivers, more than half of the area in the district is enclosed by sacred groves, which are being protected and managed by the Tibetan monks, tribal communities and amchis on the dregs of religious faiths. Most of these vegetation's are still uninterrupted. However, their majority is in various phases of degradation. These different groves of selected sites harbour a large number of plant diversity of valuable and endangered plant species (Chander et al., 2018, Choudhary and Kaur, 2020).

MATERIAL AND METHODS

Study area

The surveyed area is located in the Keylong forest division, Lahaul-Spiti district of Himachal Pradesh, India. The whole region is covered with moist deciduous/ temperate dry forest dominated by conifers, mainly Junipers. In these areas, the district's forest is classified as The West Himalayan dry juniper forest, West Himalayan high level dry blue pine forest, West Himalayan dry temperate deciduous forest, Dry broad leaf and coniferous forest, Dry temperate mixed evergreen forest, Dry coniferous forest and alpine pasture. The forest of the district displays different-tiered strata of vegetation. The floristic diversity of trees in these regions is well supported by trees, shrubs, herbs, grasses and climbers (Marpa et al., 2020). These include Acer ceasium, Abies pindrow, Betula utilis, *Cedrus deodara, Ribes grossularia, Junipers sp. Ribes ogiwhtale, Crataegus oxyacantha, Jurinea macrocephala, Thymus serphyllum, Saxifraga ligulata,* Grasses like *Agropyron longearistatum, Elymus semicostatus, E. repens, E. dehuricus, E. thomsonii, Festuca rubra, Bromus aspera, Avena fatua, Dactylis glomerata and Poa anuua*. The Lahaul-spiti district was covered with unexploited forest diversity till the early 1970s. After 1970s, the agricultural practices for different vegetables transform from natural fruit crops, massive anthropogenic activities such as overgrazing, forest fires, clear forest for fodder, food and fuel pressure of exploited tourism during snowfall during summers, shepherd grazing trek follows by Gaddis communities of Lahaul to Chamba and vice-versa. In recent years, these floristic ecological zones have been degraded by the loss of many endemic species of herbs adapted to the certain specific climate of this region (Samant et al., 2000; Kumar et al., 2020).

The joint collaborative efforts of the state forest department and local communities and management programme protected these forest stands. However, disturbing events for plant population on these regimes in lopping, cutting and grazing are continuous and become more privileged. Four different locations, such as Piyukar (village of Amachis), Kardang and Gumrang and Yurnath, are selected for the present study to captured maximum plant diversity. The present study was undertaken at an altitude range of 2700-3500m. Piyukar and Kardang are highly sacred in four survey areas and confirm some renowned Buddhist monk activities. These regions are lies at a similar distance from the regional station Punjab agricultural university in Keylong. The formers areas are about 5-8 km from Keylong forest station, the headquarter of Lahaul-Spiti, Himachal Pradesh. The weather pattern of the area is very variable and, based on climate, the year can be broadly categorized into two different seasons, viz. dry summer (April to mid-September) and severe cold winter (Oct-March) as summarised in figure 4 (a, b). The area experiences prolonged chilled winter as the entire region is covered with heavy snowfall—total annual rainfall recorded from 2016 to 2018. The specimens were identified using standard flora published on temperate regions (Pusalkar and singh 2012; Murti 2001; Aswal and Mahrotra, 1994).

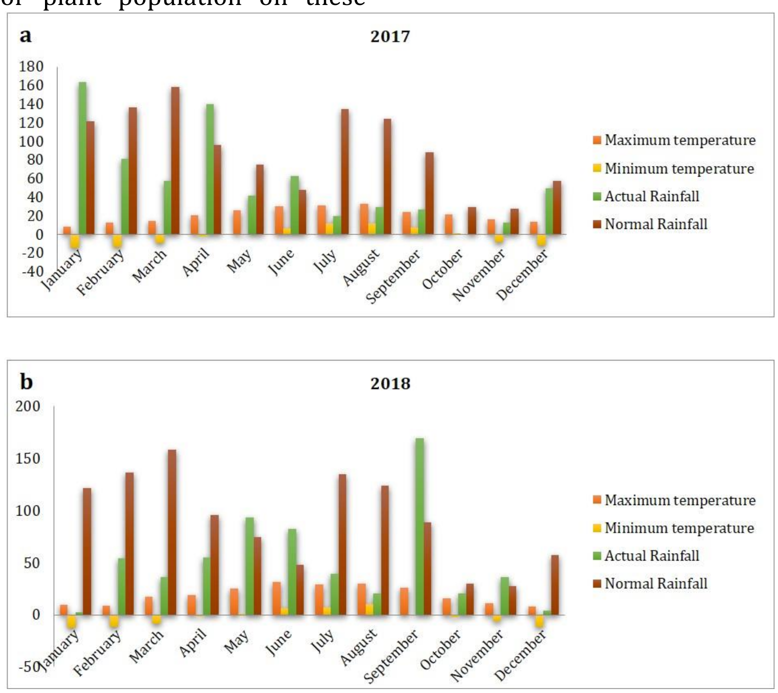

Figure 1 (a & b). Rainfall and mean temperature range recorded from Lahaul Spiti 2017-18 (Meteorological Centre, Shimla).

Out of total rainfall, the rainy season is partially absent. Most of the precipitation recovered during the month of March, with no rain or precipitation recorded in Nov- Dec 2018 (data given by the Indian meteorological department). The maximum temperature was reported to be 32.5 Celsius (August

2017) and 31.1 Celsius (June 2018), whereas the minimum temperature was reported to be -14.9 Celsius (January 2017) and -12.6 (January 2018). The very least rainfall observed in the district recorded in October (2017) and January (2018), while the highest rainfall in the region during January (2017) and September (2018).

Field surveys visits were conducted in four different sites of keylong region during 2016-2018 at elevation lies above 3000m. The floristic composition of selected sites was analyzed with local amchis (Buddhist medicinal practitioners). The size and number of quadrats are used according to the species richness of the site. Collected plant samples from the sites are identified with the help of local as well as standard flora. The similarity index between the study sites was estimated using the community coefficient (Dombois and Ellenburg, 1974).

Density, Frequency, and its basal area were estimated following Misra (1968). Species richness was estimated as a total number of species observed from each region at two same region consecutive years. The abundance of plant species in the selected regions measured in numerical terms for estimated the density of species (Misra,1968). Index of Similarity (IS) or Community Coefficient indicates the species percentage common to four different sites. It was calculated as per Magurran, (1988). Relative density, relative dominance, Relative frequency and importance value index (IVI) for individual species were estimated Cottam and Curtis, (1956). Species evenness and diversity, Simpson's dominance index (C) calculated as per Simpson, (1949). Hill diversity numbers N1 and N2 (Hill 1973) and Shannon–Wiener index (H1) (Magurran, 1988), were calculated.Soil samples were analysed in the department of soil science, Punjab Agricultural University, Ludhiana. The sample was dried and used to measure the electrical conductivity (EC), Organic matter, Potassium (K), Potential of Hydrogen (pH) and soil texture. Information regarding the ethnomedicinal uses was collected from the lahoulis and amchis community and compared with published flora on Lahaul- Spiti (Aswal and Mehrotra, 1994, Sood, Nath and Kalia, 2001).

RESULTS

Our results consist of 24 CWR families includes 44 species comprised of Poaceae, Apiaceae, Rosaceae, Asteraceae, Amaranthaceae, Polygonaceae, Lamiaceae, Gentianceae and others (Table 1). In all, Poaceae (15%) dominated, followed by Apiaceae (10%), Asteraceae and Rosaceae (7%), Gentianceae, Polygonaceae and Amaranthaceae (5%), whereas other families share 2% in total taxa exploration (Figure 2). Out of the prioritised species conservation, various factors that threaten CWR populations are open habitats and overgrowing of meadows, unskilled agriculture, the introduction of new invasive species along with hybrids, habitat degradation, loss of native fluorochemical disturbance construction of waterways and short-term climate changes. Many species in the list were enlisted in IUCN category for endangered, threatened and critically under the verge of extinction. Out of critically endangered like *Podophyllum hexandrum*, *Rheum webbiana*, *Betula utilis*, *Sassaurea costus*, whereas, *Fragaria vesca*, *Carum carvi*, *Cuminum cyminum*, *Achilleamille folium*, *Aster flaccid*, *Pleurospermum uralense*, *Polygonum alpinum* and *Silene vulgaris*, *M. longifolia*, *Phlomis bracteosa* are categorised under threatened species. The genera *Ribes, Fragaria, Elymus, Carum*, are relevant to current breeding programs and utilised in crop improvement by plant breeders in recent years. Other taxa explained remain underutilised but show their potential to tolerate stress conditions and utilise them in upcoming breeding programs in Asia. In the present study overall, 44 species were recorded from the four locations viz. Piyukar, kardang, Yurnath, and Gumrang of keylong region. These species are categorised into a total 24 families, as summarised in table 1. Among these, Poaceae was the dominant family with seven plant species, followed by Apiaceae, Asteraceae, Lamiaceae and Rosaceae. There was six species (*Bromus ramosus, Elymus dahuricus, Elymus semicostatus, Elymus longiaristatus, Elymus repens* and *Poa annua*) belonging to family Poaceae, followed by four species (*Carum carvi, Cuminum cyminum, Ferula jaeschkeana* and *Pleurospermum uralense*) belong to Apiaceae, three species (*Achillea millefolium, Artemisia brevifolia* and *Causinia thomsonii*) belong to Asteraceae, three species (*Hyssopus officinalis, Mentha longifolia* and *Phlomis bracteosa*) belong to Lamiaceae and three species (*Fragaria nubicola, Fragaria vesca* and *Rosa webbiana*) belong to Rosaceae. There are nineteen dicot families, three monocot families, one pteridophyte family and one gymnosperm family (Chand et al., 2016). The number of plant species individually in the four sites was also recorded in successive years 2017-2018. The Piyukar was observed to show sixteen plant species in both 2017 and 2018; the Gumrang has reported fifteen plant species in 2017, while in 2018, *Pleurospermum* *uralense* added to became sixteen plant species. The Yurnath Trek site was reported with fifteen plant species, whereas in Kardang were recorded with ten plant species in 2017 and 2018.

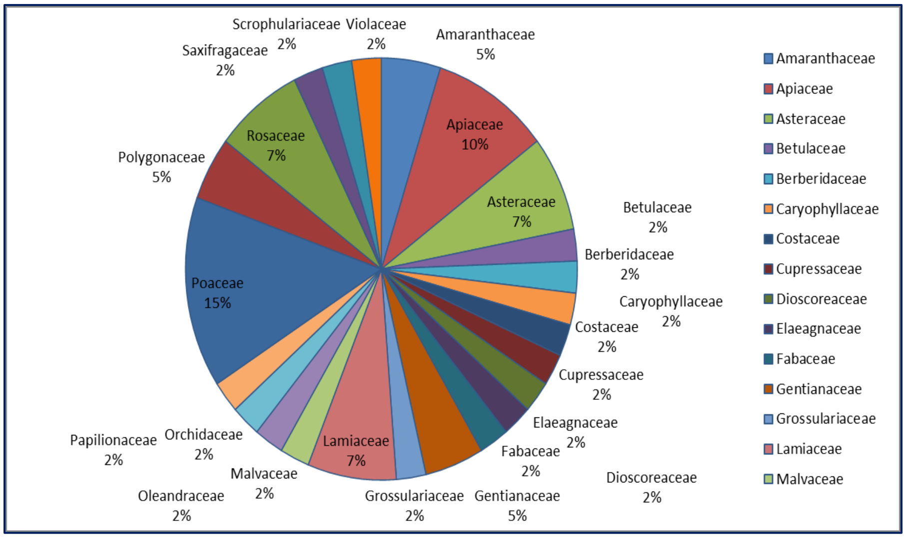

Figure 2. Graphical representation showing availability percentage of families during field survey

Density of plant species at multiplications

The density of plant species observed in the four different locations has been summarised in table 2. It has been observed that *E. repens* having the maximum density value 24.00 plants/m^2 (2017) and 23.20 plants/m^2 (2018) in the Piyukar. It has been followed by *Poa annua,* having density values 18.40 plants/m^2 (2018) and 18.20 plants/m^2 (2017) and *E. himalyansis*16.20 (2017).

In Gumrang, four species were observed to be showing the highest density value. The density value was maximum in *Elymus semicostatus* in 34.40 (2018) and 22.80 (2017) followed by 31.40 (2018) and 20 (2017) of *E. repens,* 21.80 (2018) and 19.80 (2017) of *Bromus ramosus* and 20.80 and 18.80 of *Malva neglecta.* Similarly, there were four species found to be maximum density value in the Yurnath. The density value 33.20 (2018) was leading in *E. repens,* followed by 25.40 (2018) and 24.80 of *E. semicostatus*, 22.40 (2018) of *Malva neglacta* and 18.00 (2018) of *Mentha longifolia*. In Kardang, three species of Elymus were showing the maximum density. It was found that *Elymus dahuricus* having the highest density value 32.20 (2017 and 2018), followed by 28.80 (2018) of *E. repens* and 20.00 (2018) of *E. longiaristatus* as shown in table 2.

Diversity indices

Diversity indices at four different sites were summarised in table 3. In the present study, the Shannon Wiener index represents the maximum value 2.43 (2018), followed by 2.35 (2017) for Piyukar, 2.32 (2017 and 2018) in Gumrang and 2.26 (2017) in Yurnath, whereas the minimum value (1.91) observed in Kardang during 2017.

Evenness index indicates an equal number of plant species distribution. The value of index generally lies between 0 and 1. The value of this index in present studies lied between 0.63 and 0.78. The maximum value of the evenness index was reported 0.75 (2018) in Kardang. It has been followed by 0.72 in Piyukar (2018), whereas the minimum evenness index 0.63 (2018) in Yurnath.

Simpson diversity index related to the diversity of any community by taking into account dominance. The maximum value was observed 0.89 (2018) in Piyukar followed by 0.88 (2017) in Yurnath, 0.87 (2017) in Piyukar and Gumrang (2017 and 2018). The minimum value was found to be 0.80 (2017) in Kardang.

Menhinick index indicates the richness of any community. The value of index was reported to be a maximum of 1.57(2017) in Piyukar, followed by 1.55 (2017) in Yurnath, 1.51 (2017) in Piyukar. The minimum value was found at 0.90 (2018) in Kardang.

The maximum similarity index was observed to be 20% of Yurnath with the Kardang followed by 19% of Piyukar with Gumrang and 16% of Gumrang field with Yurnath in 2017 and 2018. The minimum similarity index was 4% of Gumrang with Kardang. The variation in similarity index was observed 13 % (2017) and 10% (2018) between Piyukar and Yurnath.

Importance value index (IVI)

The Piyukar site was dominated by *Elymus repens* and *E. himalayensis* having IVI values 28.95 (2017) and 28.87 (2018), as shown in table 4. *Malva neglecta, Dioscorae deltoids* and *Saussaurea costus* were the most dominant species observed in the Gumrang. *Malva neglecta* showed the highest IVI value, 42.21 in 2017, followed by 33.69 *Saussurea costus* in 2018 and *Dioscora edeltoides* 37.01 in 2017. The Yurnath was found to be dominated by *Verbascum thapsis, Hippophae rhamnoides* and *Elymus semicostatus.* The highest IVI value was 60.84 of *Verbascum thapsis* (2018), followed by 51.88 of *Hippophae rhamnoides* (2017) and 48.09 of *Elymus semicostatus* (2018). The most dominant species found in Kadrang were *Elymus repens and Elymus longiaristatus*. The dominant species was found to be *Elymus repens* having 60.35 IVI in the year 2018. It is followed by the *Elymus longiaristatus* having 55.24 IVI (2017) and *Elymus longiaristatus* having 55.24 IVI 46.62 (2018). Thus, all these four sites are considered important potential sources of wheat wild relative (*Elymus* species) known for abiotic stress tolerance donors.

Soil analysis

Comparatively basic soil properties concerning diversity were calculated from soil samples up to 10cm depth in four sites viz Gumrang, Piyukar, Kardang and Yurnath regions of Lahaul-Spiti. The finding indicated that field layer soil had promising relationships with soil variables and plant abundance. As shown in table 6, soil pH observed to highest 6.13 (Piyukar) followed by 6.10 (Gumrang), 5.89 (Kardang), and 5.6 (Yurnath) reflected that acidic soil promotes well diversity richness. The organic matter is ranged in 3.2-5.03%, electrical conductivity 1.38-1.51(mmhos/cm) and potassium (Kg/ha) 77 (Piyukar), 72 (Gumrang), 56 (Kardang) and 39 (Yurnath). Species diversity exhibits a positive correlation with soil factors such as organic matter content, soil pH, electrical conductivity and potassium ion. Soil texture almost similar and more relies upon loam categories; Loamy silt (Piyukar), Loamy (Gumrang), Kardang (Loam with small stones) and Yurnath (Loamy), whereas colour variation is almost negligible in all samples.

DISCUSSION

According to Singh, Lal and Samant, (2009), the Asteraceae and Rosaceae were found to be the dominant families in all their studies landscape elements at Rohtang pass, Himachal Pradesh. Different families are present in these four sites, as shown in figure 3. The family Asteraceae was also found to be dominant in the Sangla Valley of Lahaul Spiti (Sharma et al., 2014) and suggested floras of the high altitude of Western Himalayas (Chowdhery and Wadhwa, 1984). In our study, *H. rhamnoides* was showed dominance in the Yurnath trek as closely related to the reported dominance of *H. rhamnoides* in the Jahlmanal watershed in the cold desert of the Lahaul valley, north-western Himalaya along the margins of grasslands and agricultural fields, and the watershed stream. The *H. rhamnoides* has a high microbial association to fix the nitrogen and thus helps in land restoration (Rongsen, 1992). It was also reported to be the major contributor of fuelwood in the cold desert of the Lahaul valley (Rawat and Vishvakarma, 2010) (Table 1). The diversity of species is under the control of evolutionary time and community stability to remain heterogenous at macro and micro environmental levels among various communities. More the value of diversity indices is indicating the variability in species type and heterogeneity. On the other hand, less value corresponds with the homogeneity of the community. The similarity index for the species under study between different locations was low, as summarised in table 5. Thus, it was indicating more dissimilarity of species between the locations of Lahaul valley.

The species composition and its surroundings act as a detrimental factor to design the nature of plant community at a particular place. However, the differences in species composition are most likely due to micro-environmental changes (Misra., 1989). Four wheatgrass species from the genus Elymus have been reported in these regions and already proved their potential in crop improvement. The rust, salt, cold and drought tolerance traits have been successfully introgressed in wheat cultivars and other advanced wheat lines. Natural stress conditions in growing habitats, including high altitude, dry conditions, and intensive UV radiation, indicated their ability to withstand stress environments. Identifying and successfully introducing the tolerant gene in upcoming years makes them ideal candidates for crop improvement, especially in staple foods. The local spices and condiments might be used for increasing the chemical profile, aromaticity and tolerance ability of domesticated plants.

Table 1. The potent use of species, ploidy level, medicinal properties and other uses from species collected from various sites during exploration 2017-18.

Family	Species	Group	Ploidy level	Crop improvement (Food & fodder)	Medicinal property	Commercial purpose	Aromatic property	Reference
Amaranthaceae	*Chenopodium botrys*	Dicot	2x (x=8,9)	Leaves and seeds in making tea	Antimicrobial, giardicidal and Nematicide activities, anti-inflammatory and allergenic activities	Gold/green dyes can be obtained	Whole plant	Morteza-Semnani (2015)
	Chenopodium foliosum	Dicot	4x (x=9)	Edible fruit, as leafy vegetable and forage	Potential source of nutraceuticals with radical-scavenging activity	Gold/green dyes can be obtained	-	Risi and Galwey, (1989)
Apiaceae	*Carum carvi*	Dicot	2n (x= 10)	Condiment	Antioxidant, antimicrobial, anticancer, antidiabetic, analgesic, diuretic, and gastrointestinal activities	Used in perfumery, for scenting soap, as a parasiticide	Essential oil in seeds	Chakraborty et al. (2016)
	Cuminum cyminum	Dicot	2n (x=7)	Condiment	Antioxidant, antimicrobial, anti-inflammatory, analgesic, anticancer, antidiabetic, antiplatelet aggregation, bronchodilatory, contraceptive, anti-osteoporotic activities.	Insecticidal, perfumery and for flavouring beverages	Scented plant	Al-Snafi, (2016) Srinivasan, (2018)
	Ferula jaeschkeana	Dicot	2n (x=13)	Condiment	Anti-inflammatory, analgestic, hypocholesterolemic, antidiabetic, antifungal, fungistatic and molluscidal activities	Gum “asafoetida” in root	Scented plant	Yaqoob et al. (2016)
	Pleurospermu muralense	Dicot	2x & 4x (x=11)	Leaves are cooked	-	-	-	Rani et al. (2014)
Asteraceae	*Achillea millefolium*	Dicot	2x, 4x and 6x (x=9)	Condiment	Antidiarrhoeal, anti-inflammatory, antiseptic, antispasmodic properties; Digestive, emmenagogue, odontalgic, tonic, vasodilator and vulnerary	Repellent, and dye	Essential oil	Afshari et al. (2013)
	Artemisia brevifolia	Dicot	2n (x=8,9)	-	Laxative, blood purifier, spasmosdic, antidots, antihelmenthic, aphrodisiac	Ethnoveterne ry uses particular to cattles	Scented plant	Nigam et al. (2019)
	Causinia thomsonii	Dicot	2n (x=9)	Leaves edible	Rheumatic arthritis and inflammation	Crop fencing from cattle	-	Singh (2012)
Betulaceae	*Betula utilis*	Dicot	2n = 2x, 4x (x= 14)	-	Antioxidant, anticancer, anti-HIV, anti-inflammatory, and antibacterial activities.	Incense, Paper, Water proofing and Wood	-	Singh et al. (2012)

Berberida-ceae	*Sinopodophyllumhexandrum*	Dicot	2n= 2x (x=6)	-	Immense potential to treat cancer, rheumatic, cholagogue, cytostatic and purgative	-	-	Nag et al. (2015)
Caryophyllaceae	*Silene vulgaris*	Dicot	2n (x=12)	Cooked as a vegetable	Bronchitis & asthma	-	-	Nag and Rajkumar, (2011)
Costaceae	*Saussurea costus*	Dicot	2n (n= 17)	Leaves edible	Asthma, dysentery, rheumatism, anti-inflammatory, hepatoprotective, antiulcer, anticancer, immunomodulatory and pesticidal activities	For ornamental purpose and sacred purposes	-	Pandey et al. (2007)
Cupressaceae	*Juniper polycarpos*	Gymnosperm	2n (x=)	Seed cones edible raw or cooked	Wound healing, antibacterial, antifungal, antiparasite, antioxidant cardiovascular, antidiabetes, gastrointestinal, respiratory, antiangiogenic, immunomodulatory, antinociceptive, phytotoxic, cytotoxic activity, and anticancer activities	Durable wood, source of various essential oils, room fresheners, soaps, insect repellents, cosmetics, fragrant candles and lotions	Foliage aromatic	Parvizi et al. (2018)
Dioscoreaceae	*Dioscorea deltoides*	Monocot	2n or 2x & 4x (x= 10)	Edible tuber	Against constipation and roundworm	Raw material for steroidal drugs as soap	-	Rani et al. (2016)
Elaeagnaceae	*Hippophae rhamnoides*	Dicot	2n (x= 24)	Most nutritious fruit	Skin disorders, cardiovascular diseases, cancer, burns, digestive tract disorders, anti-inflammation and UV radiations protecting effects	Charcoal, Cosmetic, Dye, Fuel, Oil and Wood	-	Stobdan et al. (2017)
Fabaceae	*Trigonella emodi*	Dicot	2n (x=8)	-	Indigestion, Fever, anaemia and peptic ulcer	Insect repellent, Dried plants used as perfume and fresh flowers worn as garland	-	Jain et al. (1996)

Gentianaceae	*Gentiana phyllocalyx*	Dicot	-	-	Cough, cold and headache	-	-	Chakrabortyet al (2016)
	Gentianella moorcroftiana	Dicot	2n (x= 13)	-	Antibacterial and antioxidant property, antipyretic, urinary compliments, cough, rheumatism, blood purifier and gastric ailments	-	-	Cao et al. (2019)
Grossulariaceae	*Ribes alpestre*	Dicot	-	Nutritious food with high vitamin C	Treatment of rheumatism, Jaundice, backache and joint pain	Ornamental purposes, fruit used in jam jellies, softdrinks and wines	-	Bisht and Badoni, (2009)
Lamiaceae	*Hyssopus officinalis*	Dicot	2n (x=6)	Condiment, flower and leaves edible	Aromatherapy, antiseptic, carminative, pectoral, tonic, Stomachic	controlling bacterial plant disease	Scented Plants	Fathiazad and Hamedeyazdan (2011)
	Mentha longifolia	Dicot	2n (x=12)	-	Antimicrobial, antioxidant, antimutagenic, antinociceptive, anti-inflammatory, keratoprotective, hepatoprotective, antidiarrhea, and spasmolytic effects	-	Scented plant	Srivastava and Saggoo, (2018)
	Phlomis bracteosa	Dicot	2n or 4x or 6x (x=7)	-	Treatment of bone fractures, and lymph fluid disorder	-	-	Ullah et al. (2013)
Malvaceae	*Malva neglecta*	Dicot	2n (x=21)	-	Antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, antiulcerogenic, and antiurolithiasis	-	-	Keyrouz et al. (2017)
Oleandraceae	*Equisetum arvense*	Pteridoph-yte	2n (x= 108)	Edible stem and root	Treatment of diuretic, haemostatic, urinary diseases urinogenital and dyspepsia, antidiabetic and anti-cancer	dye, sandpaper and scrubber	-	Soltis et al. (1988)
Orchidaceae	*Malaxis muscifera*	Monocot	-	-	An aphrodisiac, to cure burning sensation, dysentery, fever, as febrifuge, internal and external hemorrhage, seminal weakness, sterility	-	-	Chauhan et al. (2008)
Papilionaceae	*Astragalus candollensis*	Dicot	-	-	Antihaemorrhagic, analgesic, urinogenital ailment, hypertension, antidote, spasmodic pain and respiratory disorder	-	-	Li et al. (2014)
Poaceae	*Bromus ramosus*	Monocot	2n or 4x (x= 7)	-	Bach flower remedies	Fodder grass	-	Armstrong (1984)
	Elymus dahuricus	Monocot	2n or 4x or 6x (x= 7)	Wheat wild relative and Fodder grass	-	-	-	Singhal et al. (2018)

	Elymus semicostatus	Monocot	2n or 4x (x=7)	Wheat wild relative and Fodder grass	-	-	-	Singhal et al. (2018)
	Elymus longiaristatus	Monocot	2n or 4x (x=7)	Wheat wild relative and Fodder grass	-	-	-	Singhal et al. (2018)
	Elymus repens	Monocot	2n= 6x (x= 7)	Wheat wild relative and Fodder grass	Anit-diabets, it has been used for treat bladder catarrh and bladder/kidney stones, gout, rheumatic disorders, and chronic skin disorders.	-	-	Singhal et al. (2018)
	Poa annua	Monocot	2n or 4x (x= 14)	Fodder grass	-	-	-	Dhaliwal et al. (2018)
Polygonaceae	*Polygonum alpinum*	Dicot	2n (x=10)	Edible leaves, seeds and stem	Anti-inflammatory and anthelmintic activity, coughs and colds	-	-	Sharma et al. (2013)
	Rheum webbianum	Dicot	2n or 4x (x=11)	-	Laxative, purgative, indigestion, abdominal disorders, boils, wounds and flatulence, and managing cancers	Source of anthraquinoe	-	Siddique et al. (2015) Tabin et al. (2018)
Rosaceae	*Fragaria nubicola*	Dicot	2n (x=7)	Edible fruit	Menstrual problems, laxative and purgative	-	Aromatic fruit	Roshan et al. (2019)
	Fragaria vesca	Dicot	2n (x=7)	Edible fruit and leaf for tea	Antidiarrhoeal, antirheumatic, astringent, diuretic, laxative and tonic	Cosmetic	Aromatic fruit	Couto et al. (2020)
	Rosa webbiana	Dicot	2n (x=7)	Nutritious fruit	Stomach ache and against cancer	Used as biofence	Aromatic flower	Singh et al., 2020
Saxifragaceae	*Parnassia nubicola*	Dicot	2n (x=8)	-	Low blood pressure and gastric trouble	-	-	Gastony et al. (1977)
Scrophulariaceae	*Verbascum thapsis*	Dicot	2n or 4x (x=18)	Tea	Migraine headaches, asthma, diarrhoea, and inflammatory diseases	Dye, insecticide, insulation and lighting	Leaves and flower	Turker and Gurel (2005)
Violaceae	*Viola biflora*	Dicot	2n (x=12, 20)	Tea, young leaves raw or cooked	Fever, cold, cough, antiseptic, antispasmodic, , diaphoretic, and skin disease	Incense	Stem and flower	Chandra et al. (2015)

Table 2. Density of plant species at studied locations in 2017 & 2018

S. no.	Plant Species	Locations							
		Piyukar		Gumrang		Yurnath		Kardang	
		2017	2018	2017	2018	2017	2018	2017	2018
1.	*Achillea millefolium*	*	*	2.75	8.00	*	*	*	*
2.	*Artemisia brevifolia*	*	*	*	*	3.20	5.00	*	*
3.	*Aster flacid*	10.80	12.80	*	*	*	*	*	*
4.	*Astragalus candolleanus*	*	*	*	*	4.20	5.80	4.00	4.00
5.	*Betula utilis*	3.00	3.00	*	*	*	*	1.00	3.00
6.	*Bromus ramosus*	*	*	19.80	21.80	*	*	*	*
7.	*Carum carvi*	5.00	13.20	*	*	*	*	*	*
8.	*Causinia thomsonii*	*	*	*	*	2.40	2.40	*	*
9.	*Chenopodium botrys*	4.00	4.40	*	*	2.75	3.75	*	*
10.	*Chenopodium foliosum*	*	*	*	*	*	*	4.60	5.80
11.	*Cuminum cyminum*	5.20	5.60	*	*	*	*	*	*
12.	*Dioscora deltoides*	*	*	1.75	1.75	*	*	*	*
13.	*Elymus dahuricus*	*	*	*	*	*	*	32.20	32.20
14.	*E. himalyansis*	16.20	14.60	*	*	*	*	*	*
15.	*E. longiaristatus*	*	*	*	*	*	*	17.60	20.00
16.	*E.repens*	24.00	23.20	20.00	31.40	9.00	33.20	10.20	28.80
17.	*E. semicostatus*	*	*	22.80	34.40	24.80	25.40	*	*
18.	*Ferula jaeschkeana*	*	*	3.80	4.80	*	*	*	*
19.	*Fragaria sp.*	*	*	*	*	*	*	3.00	12.60
20.	*Fragaria vallariana*	1.20	1.50	*	*	*	*	*	*
21.	*Fragaria vesca*	*	*	4.00	4.00	*	*	*	*
22.	*Gentiana phyllocalyx*	*	*	4.25	4.25	*	*	*	*

23.	*Gentianella moocroftiana*	*	*	*	*	*	*	9.80	9.80
24.	*Hippophae rhamnoides*	*	*	*	*	1.00	1.00	*	*
25.	*Hyssopus officinalis*	*	*	*	*	6.25	3.75	*	*
26.	*Jointed fern*	*	*	8.80	8.80	*	*	*	*
27.	*Juniper polycarpos*	3.00	3.00	*	*	*	*	*	*
28.	*Malaxis muscifera*	*	*	2.40	3.20	4.20	4.80	*	*
29.	*Malva neglecta*	*	*	18.80	20.80	12.20	22.40	*	*
30.	*Mentha longifolia*	5.40	11.00	*	*	5.40	18.00	*	*
31.	*Parnassia nubicola*	*	*	*	*	15.75	8.50	9.80	10.40
32.	*Phlomis bracteosa*	*	*	*	*			2.60	4.60
33.	*Pleurosper mumuralense*	*	*	0	5.00	*	*	*	*
34.	*Poa annua*	18.20	18.40			*	*	*	*
35.	*Polygonium alpinum*	2.60	2.60	2.60	4.40	*	*	*	*
36.	*Rheum webbiana*	*	*	2.60	2.80	*	*	*	*
37.	*Ribes alpestre*	*	*	*	*	2.00	4.00	*	*
38.	*Rosa webbiana*	2.00	2.00	2.00	2.60	2	2	*	*
39.	*Saussaurea costus*	*	*	6.40	2.00	*	*	*	*
40.	*Silene vulgare*	2.80	2.60	*	*	*	*	*	*
41.	*Sinopodophyllym hexandrum*	3.00	3.20	*	*	*	*	*	*
42.	*Trigonella emodi*	1.60	2.20	*	*	*	*	*	*
43.	*Verbascum thapsis*	*	*	*	*	2.20	7.20	*	*
44.	*Viola biflora*	*	*	4.25	8.20	*	*	*	*

Table 3. Diversity indices of studied location in 2017 & 2018

Year Indices	Locations							
	Piyukar		Gumrang		Yurnath		Kardang	
	2017	2018	2017	2018	2017	2018	2017	2018
Shannon Wiener Index	2.35	2.43	2.32	2.32	2.26	2.19	1.91	2.01
Eveness Index	0.68	0.72	0.67	0.64	0.69	0.63	0.67	0.75
Simpson Diversity Index	0.87	0.89	0.87	0.87	0.88	0.84	0.80	0.84
Menhinick index	1.57	1.51	1.37	1.28	1.55	1.23	1.07	0.90

Table 4. IVI of plant species at multi-location

S. No.	Plant Species	Locations							
		Piyukar		Gumrang		Yurnath		Kardang	
		2017	2018	2017	2018	2017	2018	2017	2018
1.	*Achillea millefolium*	*	*	2.75	8.00	*	*	*	*
2.	*Artemisia brevifolia*	*	*	*	*	14.91	13.25	*	*
3.	*Aster flaccid*	16.50	18.08	*	*	*	*	*	*
4.	*Astragalus candolleanus*	*	*	*	*	15.48	13.22	18.14	19.73
5.	*Betulautilis*	20.79	19.69	*	*	*	*	13.31	23.83
6.	*Bromus ramosus*	*	*	8.17	11.83	*	*	*	*
7.	*Carum carvi*	11.14	20.10	*	*	*	*	*	*
8.	*Causinia thomsonii*	*	*	*	*	11.01	9.26	*	*
9.	*Chenopodium botrys*	10.15	10.42	*	*	9.84	8.92	*	*
10.	*Chenopodium foliosum*	*	*	*	*	*	*	16.48	17.91
11.	*Cuminum cyminum*	11.27	11.51	*	*	*	*	*	*
12.	*Dioscorae deltoides*	*	*	28.83	37.01	*	*	*	*
13.	*Elymus dahuricus*	*	*	*	*	*	*	55.24	41.69
14.	*Elymus himalyansis*	21.55	28.87	*	*	*	*	*	*
15.	*Elymus longiaristatus*	*	*	*	*	*	*	39.62	46.62
16.	*Elymus repens*	28.95	6.41	6.94	7.50	25.12	31.14	30.77	60.35
17.	*Elymus semicostatus*	*	*	29.06	32.27	48.09	25.14	*	*
18.	*Ferula jaeschkeana*	*	*	29.44	32.41	*	*	*	*
19.	*Fragaria sp.*	*	*	*	*	*	*	14.22	27.18
20.	*Fragaria vallariana*	6.25	7.62	*	*	*	*	*	*
21.	*Fragaria vesca*	*	*	10.39	10.62	*	*	*	*
22.	*Gentiana phyllocalyx*	*	*	10.22	9.58	*	*	*	*
23.	*Gentianella moocroftiana*	*	*	*	*	*	*	21.88	20.09
24.	*Hippophae rhamnoides*	*	*	*	*	51.88	24.06	*	*
25.	*Hyssopus officinalis*	*	*	*	*	13.80	8.59	*	*

26.	*Jointed fern*	*	*	8.79	7.53	*	*	*	*
27.	*Juniper polycarpos*	14.98	15.96	*	*	*	*	*	*
28.	*Malaxis muscifera*	*	*	15.40	16.61	15.48	12.15	*	*
29.	*Malva neglecta*	*	*	42.21	38.30	31.55	27.27	*	*
30.	*Mentha longifolia*	11.44	11.00	*	*	14.50	21.77	*	*
31.	*Parnassia nubicola*	*	*	*	*	26.26	12.35	23.80	24.18
32.	*Phlomi sbracteosa*	*	*	*	*	*	*	14.38	18.42
33.	*Pleurosper mumuralense*	*	*	27.71	24.65	*	*	*	*
34.	*Poa annum*	23.42	23.18	*	*	*	*	*	*
35.	*Polygonium alpinum*	8.83	8.67	8.94	9.67	*	*	*	*
36.	*Rheum webbiana*	*	*	14.54	12.87	*	*	*	*
37.	*Ribes alpestres*	*	*	*	*	15.46	14.75	*	*
38.	*Rosa webbiana*	8.57	11.66	15.91	13.74	31.78	17.30	*	*
39.	*Saussaureacostus*	*	*	33.69	19.97	*	*	*	*
40.	*Silene vulgare*	9.03	8.78	*	*	*	*	*	*
41.	*Sinopodophyllym hexandrum*	9.50	12.94	*	*	*	*	*	*
42.	*Trigonella emodi*	6.64	7.41	*	*	*	*	*	*
43.	*Verbascum thapsis*	*	*	*	*	47.37	60.84	*	*
44.	*Viola biflora*	*	*	9.75	12.91	*	*	*	*

Table 5. Similarity and dissimilarity index between multi-locations in 2017-18

	2017				2018			
	Piyukar village	Gumrang field	Yurnath Trek	Kardang Gompha	Piyukar village	Gumrang field	Yurnath Trek	Kardang Gompha
Piyukar village	1	0.19 (0.81)	0.13 (0.87)	0.08 (0.92)	1	0.19 (0.81)	0.10 (0.90)	0.08 (0.92)
Gumrang field		1	0.16 (0.84)	0.04 (0.96)		1	0.16 (0.84)	0.04 (0.96)
Yurnath Trek			1	0.20 (0.80)			1	0.20 (0.80)
Kardang Gompha				1				1

Note: Values in parenthesis are index of dissimilarity

Table 6. Soil analysis for basic parameters help in diversity at four different sites

Location/ Parameters	Gumrang	Yurnath	Kardang	Piyukar
OC	4.8	3.2	5.02	5.03
pH	5.6	5.89	6.10	6.13
EC	1.14	1.38	1.46	1.51
K(Kg /hectare)	56	39	72	77
Soil texture	Loamy clay	Loamy	Loam with small stones	Loam with silt

Potential uses in Crop improvement

The *Elymus* genus in Piyukar, Yurnath, and Kardang was showed dominance in our study. Negi et al. (2019) suggested the genus *Elymus* as one of the dominant species in the Lahaul and Spiti district of Himachal Pradesh. The contagious kind of distribution pattern is most common, whereas random distribution is observed only in uniform environments. Several workers reported the contagious type of distribution (Kershaw, 1973; Kunhikannan et al., 1998; Verma, 2014).

The overall abundance of wheat grasses in all four alpine regions including *Elymus repens, E.semicostatus, E. himalayensis, Bromus racemosus, Poa annua* indicates their wide distribution at varied ecological amplitude. The successful transfer of disease resistance observed in the wheat by the hybridisation with close wild relative species.

For instance, few *Aegilopsis* species such as *Ae. triuncialis, Ae. kotschyi, Ae. ovata* and *Ae. umbellulata* having the tolerant genes for black and yellow rust and encouraged for leaf disease resistance in wheat (Edae et al., 2016; Liu et al., 2010). Leaf rust resistance genes such as *Yr40/Lr57, Lr58* and *Yr70/Lr76*, from *Aegilopsis ovata*, *Ae. tauschii* and *Ae. triunicialis* respectively provide rust resistance in bread wheat using marker-assisted selection (MAS). The crop wild relatives proved their immense potential to improve the resistance to pests and provide a standing tool in adverse environmental conditions.

The bread wheat ancestor *Aegilops speltoides* provided the genes for drought, heat and salinity tolerance. The protein quality of wheat was also observed to be strengthened in durum wheat using *T. dicoccoides* (Maxted and Kell, 2009). The *Nax1* and *Nax2* were successfully introgressed from wild relative *Triticum monococcum* into bread wheat for salinity tolerance trait. These genes allow the removal of excessive Na^+ from xylem tissues in roots (Munns et al., 2012).

The crop wild relative gains much importance because of their genetic diversity and already showed their success in important gene contributions. Many reasons slow down the pace of gene transfer from crop wild relative. Primarily, the use of wild species takes much time and high cost in classical breeding techniques due to the requirement of repeated backcrossing and un tapping of non-desirable genes. Transcriptomic, New Generation Sequencing and Marker-assisted selection are the well-developed techniques of genome analysis that overcome the limitation of time requirement and capacity to disrupt the linkage for non-desirable genes. The overwintering strategies of pests and severity of abiotic stresses in the near future pose an excessive burden to agriculture and the population explosion. Here, the crop wild relative fitted best to tackle the possible emerging environmental challenges. In our study, the habitat of crop wild relatives was in the hit-list of climate change. Thus, the calculated approach will be developed for their conservation, either in-situ or ex-situ.

Potential use as food

Out of more than 20000 wild edible plants, 1532 wild edible species are used as food in India and over 675 of which found in the Indian Himalayas. The two species of Chenopodium Singh et al. (2009) reported the *Chenopodium album, C. botrys, C. foliosum* and *C. hybridum* from Lahaul valley. According to Bhargava et al. 2019, *Chenopodium* species can be cultivated for vegetables enriched in high protein and carotenoid contents. The foliage quality and yield traits can be improved by means of rigorous selection centrally based on the component traits (Marpa et al., 2020). In Figure 3, there is a list of species that involves in medicinal properties.

Dioscorea is the rich source of carbohydrates, protein and vitamins, and utilised as food chiefly in the hilly areas. *D. dumerorum, Dioscorea praehensilis, D. preussii*, *D. latifolia,* and *D. smilacifolia* are used as emergency food in West Africa (Dalziel, 1937). Several wild forms are consumed as famine food in the east and central Africa (Walker, 1952). *D. hispida*, the Asiatic species is also offered as food during the shortage in certain parts of China and India (Burkill, 1939).

Singh et al. (2009) reported the *D. deltoides* from the cold desert of Lahaul valley traditionally used as an oral contraceptive. The genus received attention as a source of diosgenin (steroidal sapogenin) to provide a precursor for steroidal drugs. The starting material of cortisone derived from the plant and is used to treat rheumatic arthritis and sex hormone preparation (Jain, 1968).

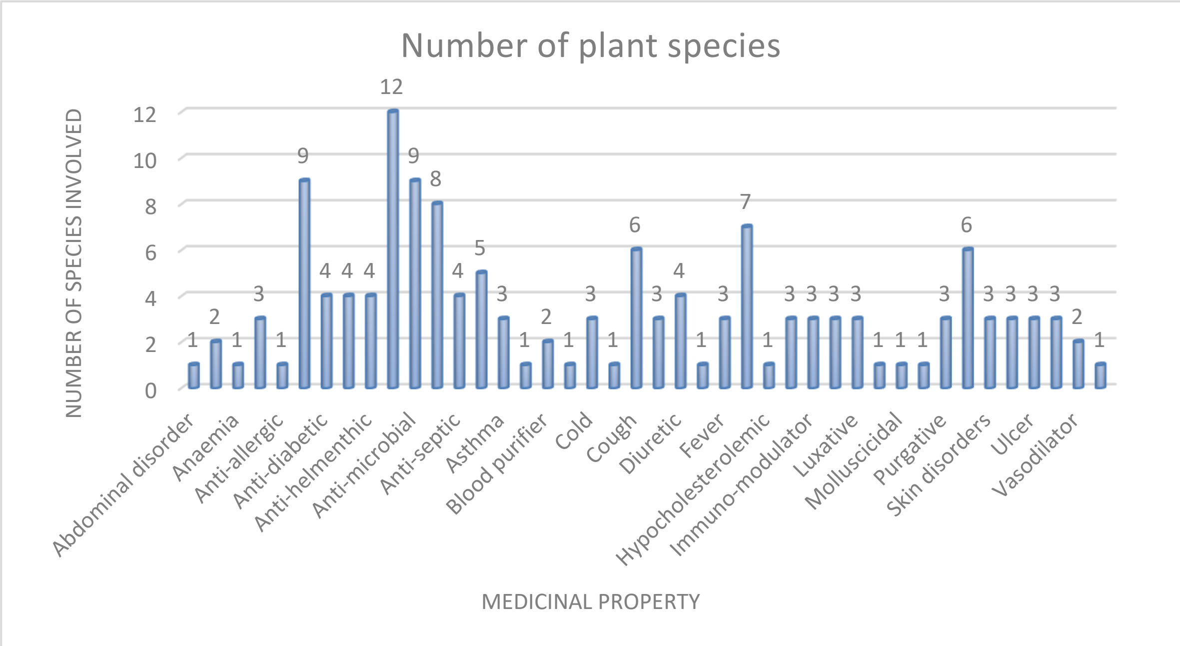

Figure 3. Number of species surveyed and its potential role in disease ailments

It has been reported that *Causinia thomsonii* utilised as a vegetable in Ladakh in addition to *Silene* sp. (Raghavan and Bhatnagar, 2003). The wood of Juniper is suitable for making pencils, and the oils from berries used as flavouring agents and several pharmaceutical preparations. Extraction was proved to be administered against fungal diseases, cold, bronchitis, gynaecological diseases, haemorrhoids, wounds, tumours and diabetes (Orhan et al., 2011). The terpenoids of dried fruits were reported to be having an antimicrobial activity (Mujeeb et al., 2014).

Potential Uses as Condiments

Seeds of *Carum carvi* are widely known for their aroma and sharp taste with a characteristic odour. They are practised as spices in flavouring and seasoning foods such as salads, sauces, pickles and bread (Rajamanickam et al., 2013). They also act as flavouring agents in alcoholic beverages, candy, ice cream, meat cheese and soft drinks. The leaves are finely chopped to use in the preparation and seeds of the soup in the confectionery industry (Pooja and Singh, 2014).

From ancient times, cumin seeds are profusely used in numerous food cultures. Indians have been used cumin seeds traditionally in various dishes such as Kormas and soups. Cumin seeds have high medicinal value and are thoroughly practised in the Ayurvedic medicine to treat digestive disorders.

Several species of *Ferula* genus reported from the Middle East and Asian countries such as India, Iran, Iraq, and Pakistan. Most of them have pungent odour and bitter in taste. The milky substance oleogum-resin (OGR) is exudated from the e.g., *F. assa-foetida* and *F. gummosa* Boissstem. According to Srinivasan, (2005), the spice formulated from the *F. assa-foetida* L. suggested as an effective medication for *Angina pectoris*. *F. assa-foetida* L. is widely used as an additive and some condiments as a carminative food in central Iran. In Iran, the rural people of Semnan province use the dried aboveground parts of *F. assa-foetida* L. in their local food "Loghri", beans, tomato paste and some vegetables (Mohammadhosseini et al., 2019).

The roots of *Pleurospermum* species and *P. angelicoides* used as spices and condiments. The stem and leaves used to treat dysentery and stomach troubles. Moreover, root decoction is effective to cure stomach pain and typhoid fever.

Achillea millefolium is a mild aromatic plant used as a tonic and stimulant. It has a diaphoretic and astringent effect due to coumarins, asparagine, isovaleric acid, flavonoids, salicylic acid, sterols and tannins. The flowering shoots rich in the essential oil is the most active part having disinfectant and anti-inflammatory properties for the cure of influenza and colds (Mockute and Asta, 2003).

Ploidy level and its significance

In our study, the four locations were geographically located in the high radiation-exposed area. Hence, the possibility of polyploidisation was expected to be more that allows to surviving and perpetuating in such a fatal environment. From the literature, we found 14 species as polyploidy. As depicted from Figure 4, tetraploid species were *Chenopodium foliosum, Pleurospermumuralense, Achillea millefolium, Betula utilis, Dioscoreadeltoides, Phlomisbracteosa, Bromus ramosus, Elymus dahuricus, Elymus semicostatus, Elymus longiaristatus, Poa annua, Rheum webbianum* and *Verbascum thapsis* whereas the hexaploid species are *Achillea millefolium, Phlomis bracteosa, Elymus dahuricus* and *Elymus repens.*

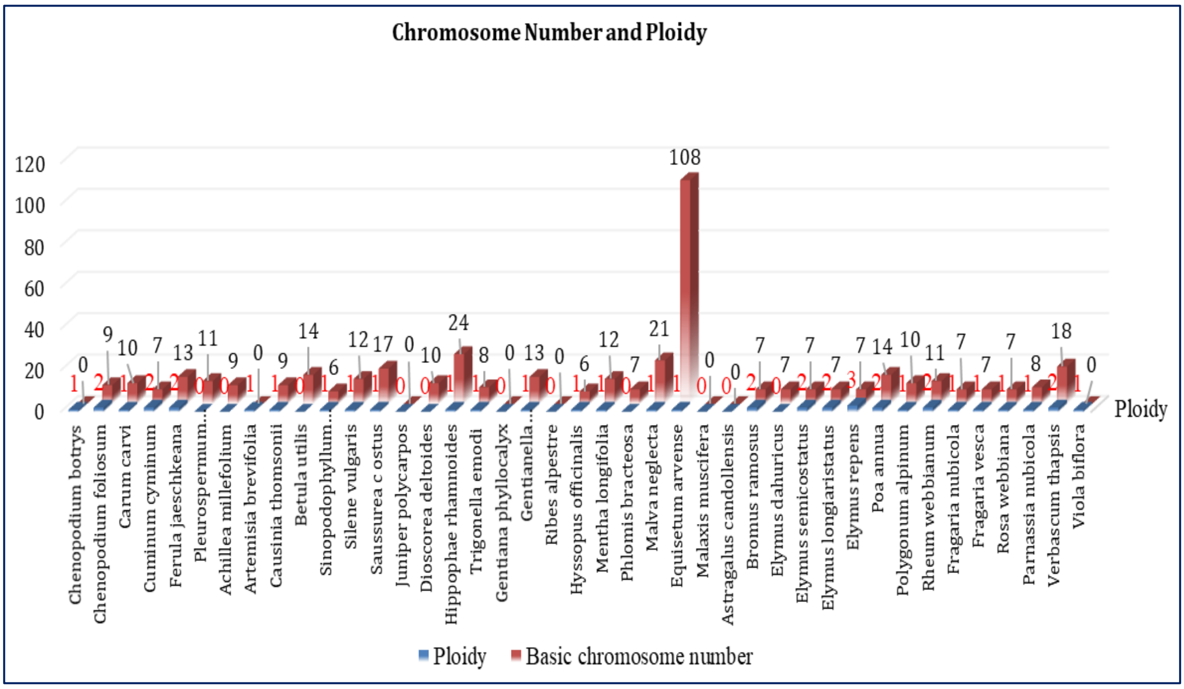

Figure 4. Chromosome number and ploidy level in plant population collected from different sites

The presence of polyploidy is a boon to agriculture in favour of crop improvement. The magnificent genome size supports the genetic diversity to show multiple tolerance responses for diseases and diverse environments (Ramsey, 2011). It serves as the platform for natural and artificial selection leads to the development of novel variants having enhanced adaptation to local environments. The domestication of crop wild relatives generally follows the domestication bottleneck rule where polyploidisation is very important complemented by additional genetic diversity. Most of the monocot and eudicot species fail to maintain the continuity of life due to endosperm abnormalities, a post-zygotic hybridisation barrier for interspecific crosses. According to Tonosaki et al. (2018), the fertile seeds were observed between the inter-specific cross between male diploid *Oryza longistaminata* and female tetraploid *Oryza sativa*.

CONCLUSION

Changing climate, biotic and abiotic stresses and enhancing food production demands creates unpredictable and unavoidable global agriculture. Production of new superior cultivars in different domesticated crops needs a new source with diverse genetic variation and can keep pace for sustainable food production. Elymus genus is important wheatgrass and already used to produce rust and salt-tolerant lines in wheat cultivars, whereas *Achillea millefolium, Carum carvi, Cuminum cyminum and Ferulajaeschkeana* used as local condiments in Lahaul valley. Amoung food *Chenopodium botrytis* and *Foliosum* are wild relatives of brassicaceae and might be used to develop resistant cultivars. However, some species such as *Dioscora deltoids, Ribes alpestris, Fragaria nubicola, Rosa webbiana* are natural drought-tolerant and must be harbouring genes to tolerate abiotic stress conditions. Besides these, such plant has high nutraceutical and pharmaceutical properties that already explained in local medicinal systems. The dual role of these plants in stress resistance and nutritional enhancement value creates these wild relatives the excellent candidate to develop new cultivars with improved traits. Domestication and screening for novel agronomical important genes in these wild relatives is possible if cultivated in ex-situ habitat. The need for extensive research and novel genes for crop improvement from these wild relatives accelerates our pace toward sustainable feeding challenges for the growing population in 2050. The introgression from genes into crop cultivars open up the gates to the new era of plant breeding and help to mitigate the challenges imposed by climate change.

DISCLOSURE STATEMENT

The author declares no competing interests

AUTHOR CONTRIBUTIONS STATEMENT

AK, AC and HK surveyed the sites and prepared the first draft of manuscript. SL reviewed the manuscript. NS analyzed the soil samples and help in preparing final draft of manuscript.

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