Asian J. Adv. Basic Sci.: **2019, 7***(1)*, 35-44
ISSN (Print): 2454 – 7492
ISSN (Online): 2347 – 4114
www.ajabs.org

Distribution and Morphological Variations in Allopatric Populations of *Hippophae rhamnoides* ssp. *turkestanica* in Lahaul-Spiti, Dry temperate Himalayas

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DOI: http://dx.doi.org/10.33980/ajabs.2019.v07i01.006

(Received 27 Jan, 2019; Accepted 10 May, 2019; Published 30 Jun, 2019)

ABSTRACT: *Hippophae rhamnoides* ssp. *turkestanica* has great potential for greening the cold desert area and changing socio-economic status of the tribal communities. In spite of the potential of the species, study on geographical distribution and morphological variation have not been done. Therefore, present attempt has been made to predict areas highly suitable for the in-situ conservation and potential morphotype Himachal Pradesh. Fifty five (55) female accessions and thirty seven (37) male accessions were studied in wild population of seabuckthorn in Lahaul-Spiti district. *Hippophae rhamnoides* subsp *turkestanica* grows in the Lahaul-Spiti district as shrub and tree form. In the accessions there is variation in plants height; leaf length, width and petiole length; mature fruits size, colour and shape; seeds size and colour were recorded. The cluster analysis of 55 female accessions resulted into seven (7) morphotypes of the *Hippophae rhamnoides* subsp. *turkestanica*. It has been observed that plant height and leaf length decreased with increasing the altitude and petiole length of the leaf depends on the length of the leaf. Fruit length affected by altitude, plant height and canopy spread. The length of peduncle shows directly proportional relation to the length of fruit. Seed length depends on the fruit length. Dioecism and wind pollination make this species an obligate out-crosser. The two features coupled with occasional sexual polymorphism serve as the basis of genetic variation. This variation manifests at the morphological, cytological, ecological and molecular levels. It is concluded that wide variations exist in different populations of seabuckthorn growing in this region. Therefore, conservation of the varied morphotypes are required by in-situ and ex-situ methods.

Keywords: Seabukthorn; *Hippophae rhamnoides* subsp *turkestanica*; Morphology; Cold desert; Distribution.

INTRODUCTION: In most woody plants, morphological and physiological characteristics are extremely variable across environmental gradients, particularly across altitudinal gradients. In India, *Hippophae rhamnoides* subsp *turkestanica* grows naturally in the high altitude regions of the Jammu & Kashmir; Himachal Pradesh[1] and Uttarakhand provinces. *H. rhamnoides* is a diocious, spinaceous and arboresent shrub or tree adapted very well to dry temperate Himalayan region, and can withstand in the temperatures ranging from -40°C to +40°C[2]. It has shown great ecological, agricultural, nutritional, medical and ornamental values[1,3]. All these species are commonly called as 'Charma, Sarla, Chermen, Rwasak and Tirkug' in the district.

MATERIALS AND METHODS:

Study area: The Lahaul- Spiti district (31°44'57" and 32°59′57″ N Latitudes and 76°46′29″ and 78°41′34″ E Longitudes; 13,835 km^2 geographical area) in Himachal Pradesh forms the part of cold desert and extends from 2400-7000 m amsl. *Hippophae rhamnoides* subsp *turkestanica*, a deciduous species, occupies a wide range of habitats and altitude (2400-4500 m amsl) in the Lahaul-Spiti districts in the Himachal Pradesh.

The morphological studies on seabuckthorn were conducted in the Lahaul and Spiti district of Himachal Pradesh. A remarkable feature of the vegetation of the Lahaul-Spiti valley is that the South and East facing hill slopes are practically devoid of any vegetation and the North & West facing slopes show growth of plants. The rocks of mountains of the area are composed of Schist's, Biotite-Schists, Schistose Phyllites, Phyllites, Paragneissic bands, Quartzite, Quartz-Mica-Schists, Balaini and Conglomerates. The soil consists properties of Schistose and Calcareous group. The Calcareous group consists of white and greyish black Crystalline Limestone, Flaggy and Slaty Lime stones, Calcareous Phyllites, Calcareous Gneiss, Carbonaceous Schists, Dark Grey Phyllites interbedded with lime stones. The rock system is very fragile and liable to erosion which is often accentuated by the rigorous of severe winter, avalanches and the strong winds that accompany them. As a result good chunks of many forests are often covered with rocks and boulders[4,5]. The vegetation of the valley is mainly comprises of dry temperate, sub-alpine and alpine types. *Pinus wallichiana*, *Picea smithiana*, *Abies pindrow*, *Salix* spp. and *Betula utilis* forests are found in patches in the East facing of the area[6].

Method: A thorough and extensive wild populations exploration survey was undertaken to indentify morphological variations of *Hippophae rhamnoides* subsp *turkestanica* from different location in Lahaul and Spiti district of Himachal Pradesh, India. Selections of accessions were made on physical attributes (altitude gradient, habitats and aspects) and morphological variation within the populations. Ninety two (55 female and 37 male) selected accessions were studied by following the using the plant descriptor; describing the qualitative (immature and mature stem Colour; seed and fruits colour; midrib colour of leaf; arrangement of fruit on branches; etc.) and quantitative (plant height; fruit, seed, and leaf size; mass of 100 seeds and fruits; etc) characters. Fruit Shape were characterized based on Fruit Index (k): Depressed (<1); Rounded (1.00 -1.19); Oval (1.20 -1.39) and Cylindrical (1.40 – 1.59). Fruit Index (k) =Fruit length/Fruit width[7]. Total soluble solids (TSS) recorded from fully ripe fruits using a hand refractometer. For each accession, 3 replicate have been done and each replicate contained 10 fruits. The data were analyzed using computer based statistical program. Hierarchical Euclidian cluster analysis of accessions was done based on eight quantitative morphological characters (i.e. leaf length, width, petiole length, fruit length and width and peduncle length and seed length and width) of female accessions studied in Lahaul and Spiti district. Euclidean distances were calculated by the Wards method and dendrogram were constructed to examine the relationships within the studied accessions[8, 9]. The Cluster Analysis has been done using the program Bio Diversity Pro.

Point distribution, bioclimatic, elevation, slope, aspect, environmental and physiographic variables were utilized for the prediction of potential areas of species with the help of MaxEnt version 3.3.3k Ecological Niche Modelling package[10]. Ninety two (92) distribution records were collected through primary field surveys from the Himachal Pradesh. Predictive 22 variables selected for the habitat suitability of species retrieved from different databases. Nineteen climatic raster data were obtained from WorldClim at 30 arc-second resolution[11]. Topographic variables were achieved from ASTER Global Digital Elevation Model (1 arc-second resolution; http://gdem.ersdac.jspacesystems.or.jp). Aspect and slope were retrieved from Digital Elevation Model (DEM). All the predictive variables rescaled to~250m pixel dimension in ArcGis 9.2. For the geographical distribution of species, MaxEnt version 3.3.3k was run using auto features, with output set to logistic, easier to interpret than raw or cumulative formats[12].

To validate the robustness, 20 replicated models were run with a threshold rule of 10 percentile training presence and in the replicate cross validation technique were run. Other parameters were set to default as the program is already calibrated on a wide range of species datasets[11, 12]. A jackknife procedure run to get an alternate measure of the importance of environmental variables by calculating several models with each variable omitted in turn, and models with variables used individually. In addition, response curve graphs were created to show how predicted probability occurrence depends on the value of each variable[11,12]. Model quality was evaluated based on Area Under Curve (AUC) value[13]. The MaxEnt output in ASCII format was then exported to DIVA-GIS var.7.3 software for further analysis and map composition. Logistic threshold of 10 percentile training presence value was categorized into five classes for map composition of potential habitats distribution i.e., very high (0.762–1), high (0.572–0.761), medium (0.381–0.571), low (0.325–0.380) and not suitable (0–0.324)[14]. Status of the species population and habitat type(s) were assessed through field surveys in the entire predicted potential area. The population data of *Hippophae rhamnoides* ssp. *turkestanica* were correlated with the corresponding threshold classes of the distribution model to know whether regions covered in the higher thresholds maintain higher populations, thus approving better habitat conditions for the species establishment and vice versa.

RESULTS AND DISCUSSION: Fifty five (55) female accessions and thirty seven (37) male accessions were studied in naturally growing population of seabuckthorn in Lahaul-Spiti district. Hippophae rhamnoides subsp turkestanica grows in the Lahaul-Spiti district as shrub and tree form and mean height of female plants 2.15±0.16 m and male plant height 2.23±0.20 m (Table 1 & Figure 1). In female accessions leaf length ranged from 2.51-8.24 cm (Mean 5.18±0.17 cm) and width from 0.42-0.75 cm (Mean 0.56±0.01 cm) and petiole length from 0.23-3.07 mm (Mean 2.13±0.72 mm) and in male accessions leaf length ranged from 3.14-7.36 cm (Mean 5.06±0.18 cm) and width from 0.41-1.14 cm (Mean 0.61±0.03

cm) and petiole length from 1.17-3.31 mm (Mean 2.29±0.08 mm) (Table 1 & Figure 1 & 2).

Table 1: Range and mean of morphological parameter of the species.

	Plant (mm)		Leaf size(cm)		
	Height	**Canopy width**	**Length**	**Width**	**Petiole length (mm)**
Female Accession (55)					
Maximum	712.00	362.50	8.24	0.75	3.07
Minimum	50.00	36.50	2.51	0.42	0.23
Mean	**215.35±16.03**	**141.49±10.07**	**5.18±0.17**	**0.56±0.01**	**2.13±0.07**
Male Accession (37)					
Maximum	650.00	285.00	7.36	1.14	3.31
Minimum	60.00	35.00	3.14	0.41	1.17
Mean	**222.41±20.24**	**123.84±10.47**	**5.06±0.18**	**0.61±0.03**	**2.29±0.08**

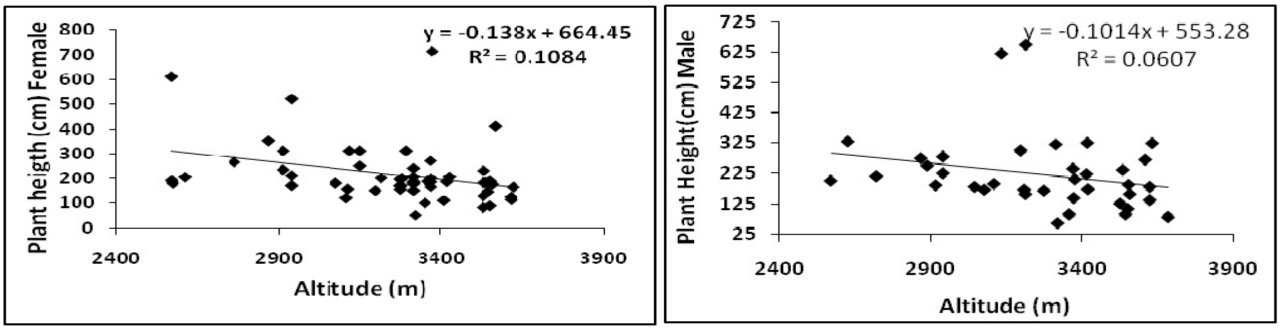

Figure 1: Variation in plant height of accessions along the altitude of the species.

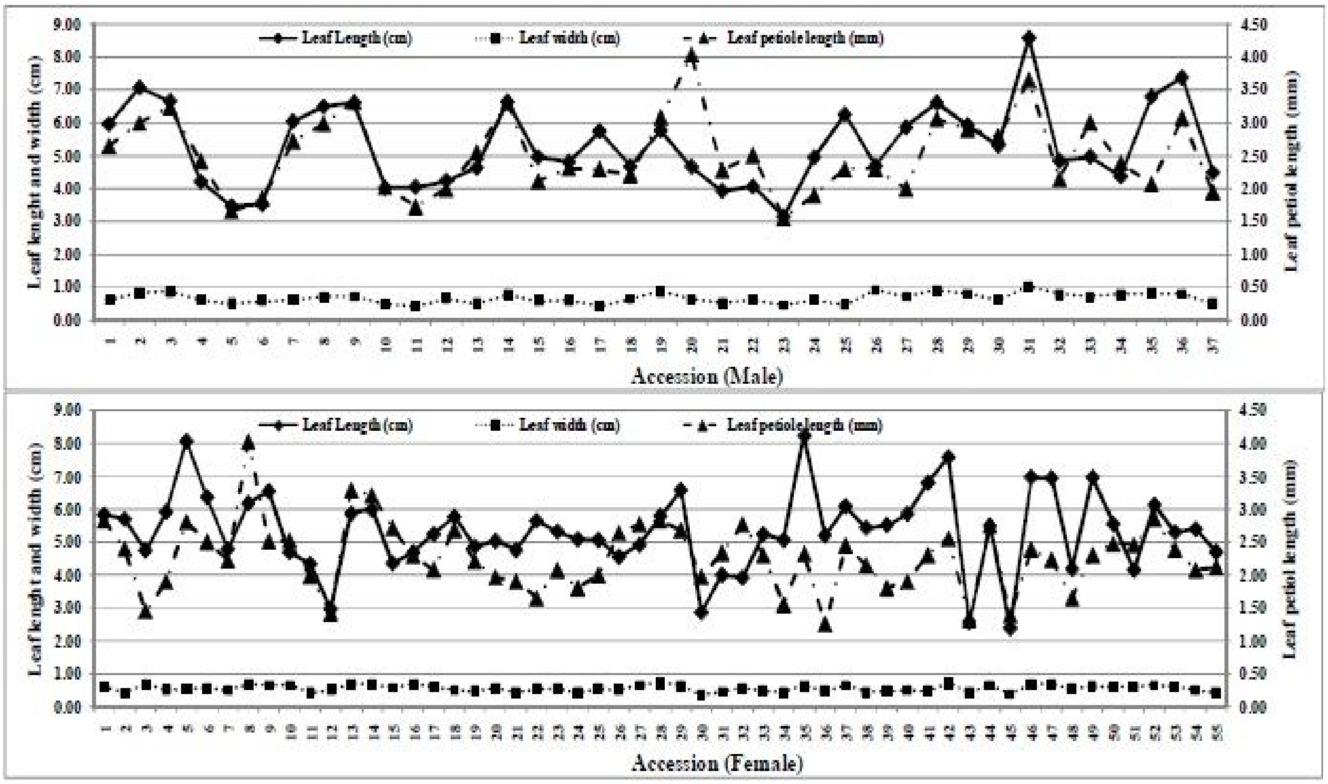

Figure 2: Variation in species leaf length, width and petiole length of accessions.

The mature fruits are yellow, red and orange coloured along with persistent stylar end and acute, round and depressed shape of fruit tip. Fruit arrangement on secondary branches is profuse and zigzag. Fruit length varies from 0.67-9.6 mm (Mean 6.46±0.18 mm) and width from 0.50-7.56 mm (Mean 5.74±0.15 mm) and peduncle length from 1.15-3.33 mm (Mean 2.07±0.07 mm) (Table 2 & Figure 3). Total soluble solids ranged between 9.0-14.4° Brix. (Mean 12.02±0.21° Brix.) and weight of 100 fruits varies from 8.0-29.5 g (Mean 13.14±0.56 g) (Table 2 & Figure 3).

Table 2: Range and mean of morphological parameter of species.

Morphological Parameter								
	Fruit (mm)			Fruit		Seed (mm)		
	Length	Width	Peduncle	Weight (g/100)	TSS (%)	Weight (g/100 seed)	Length	Width
Maximum	9.62	7.56	3.33	29.50	14.40	1.86	5.83	3.50
Minimum	0.67	0.50	1.15	8.00	9.00	0.69	2.75	0.96
Mean	**6.46±0.18**	**5.74±0.15**	**2.07±0.07**	**13.14±0.56**	**14.33±0.21**	**0.96±0.03**	**4.02±0.09**	**2.42±0.06**

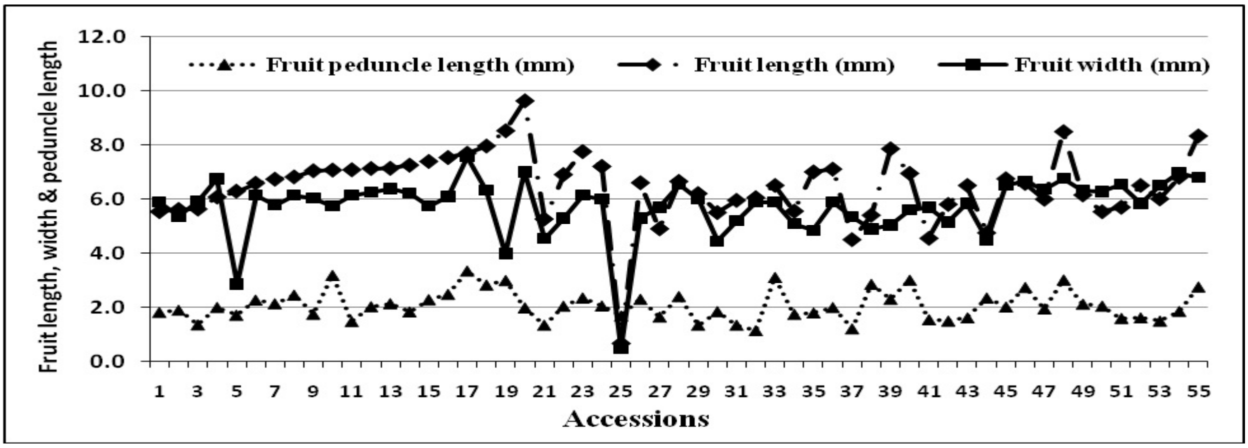

Figure 3: Variation in species fruit length, width and peduncle length of the accessions.

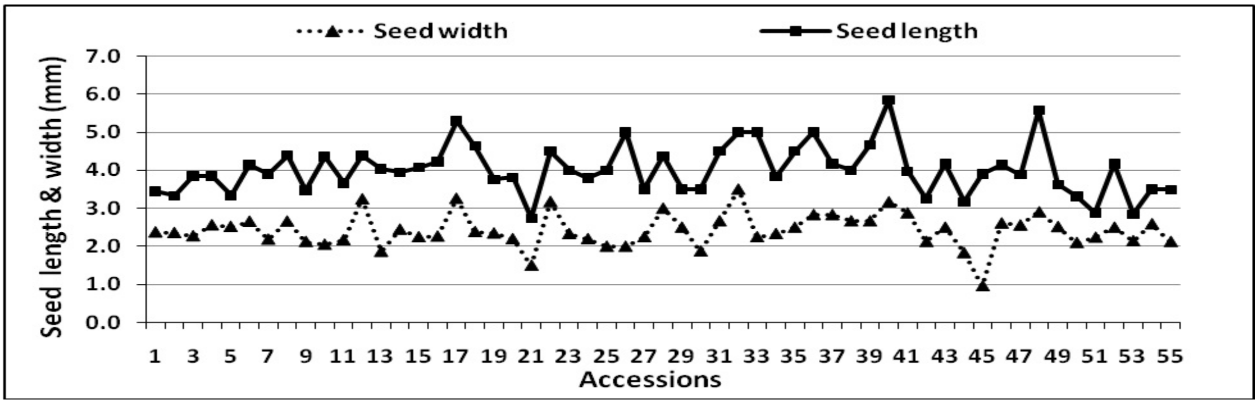

Figure 4: Variation in species seed length and width of accessions in the Lahaul.

Seeds are deep red, brown and black coloured along with one longitudinal furrow. Seed length varies from 2.75-5.83 mm (Mean 4.02±0.09 mm) and width from 0.96-3.5 mm (Mean 2.42±0.06 mm) and weight of 100 seeds varies from 0.69-1.86 g (Mean 0.96±0.03 g) (Table 2 & Figure 4).

The correlation between altitude and quantitative parameter of female accessions (i.e. plant height, canopy diameter, leaf length and width, petiole length, fruit length and width, peduncle length and seed length and width) were tested and only some parameters showed significant correlation. A significant negative correlation has been found between the altitude and plant height ($r=-0.329$, $p<0.02$, $n=55$) and altitude and leaf length ($r=-0.560$, $p<0.01$, $n=55$) (Figure 1). Leaf length shows significant positive correlation with leaf width ($r=0.474$, $p<0.01$, $n=55$) and petiole length ($r=0.448$, $p<0.01$, $n=55$). Fruit length show significant positive correlation altitude ($r=0.327$, $p<0.02$, $n=55$); fruit width ($r=0.602$, $p<0.01$, $n=55$) and petiole length($r=0.470$, $p<0.01$, $n=55$); and significant negative correlation with plant height ($r=-0.429$, $p<0.01$, n=55) and canopy diameter (r=-0.414, p<0.01, n=55). Seed length shows significant positive correlation with fruit length (r=0.317, p<0.05, n=55) and seed width (r=0.570, p<0.01, n=55).

The cluster analysis of accessions has been done based on quantitative morphological characters of female accessions studied in Lahaul-Spiti. Fifty five accessions of *Hippophae rhamnoides* subsp *turkestanica* were placed in the seven cluster on the basis of Hierarchical Euclidian clustering, here it was seen that cluster I, II, II, IV, V, VI, and VII had different number of accession grouped under them (Table 3). The maximum numbers of accessions were in the cluster II (16 accessions) and minimum numbers were placed in cluster IV (1 accession). Highest means for the leaf length (7.58 cm); leaf width (0.67 cm) and leaf petiole length (2.57 mm) were seen in the cluster V and highest values for fruit length (7.79 mm); fruit width (6.46 mm) and fruit peduncle length (2.44 mm) were seen in cluster III (Table 3). Maximum mean value of seed length (4.77 mm) and seed width (2.58 mm) was seen in cluster V and II respectively (Table 3). Leaf length, width & pedicle length; seed length & width and fruit length, width & peduncle length characters data of all the female accessions were further hierarchically clustered according to ward with Euclidean distance. The dendrogram obtained by hierarchically clustering of morphological characteristics (Figure 5) showed that clusters started at the lowest level and lead to the super cluster. The maximum distance of 9.36 was found between Cluster III and IV, followed by 8.51 was found between cluster V and IV. The minimum distance of 1.98 was observed between Cluster II and VI (Table 4). Distance between clusters indicates that there was a degree of dissimilarity between clusters. Higher distance between cluster shows that cluster are morphologically different from each other in high degree.

Table 3: Number of accessions in clusters and cluster mean values obtained by hierarchical clustering.

Cluster		I	II	III	IV	V	VI	VII	Grand mean
Number of Accessions		10	16	11	1	5	10	2	
Mean of morphological characters in the cluster	Leaf Length (cm)	5.89	5.47	4.36	5.08	7.58	3.86	4.51	**5.18**
	Leaf width(cm)	0.54	0.57	0.54	0.46	0.67	0.51	0.62	**0.56**
	Leaf petiole length(mm)	2.07	2.42	1.66	1.55	2.57	2.07	2.22	**2.13**
	Fruit length(mm)	5.22	6.66	7.79	0.67	6.88	6.12	7.40	**6.46**
	Fruit width(mm)	5.06	6.12	6.46	0.50	5.53	6.10	3.43	**5.74**
	Fruit peduncle length(mm)	1.74	2.18	2.44	1.69	2.17	1.75	2.35	**2.07**
	Seed length(mm)	3.66	4.23	4.28	4.00	4.77	3.50	3.56	**4.02**
	Seed Width(mm)	2.30	2.58	2.51	2.00	2.57	2.16	2.44	**2.42**

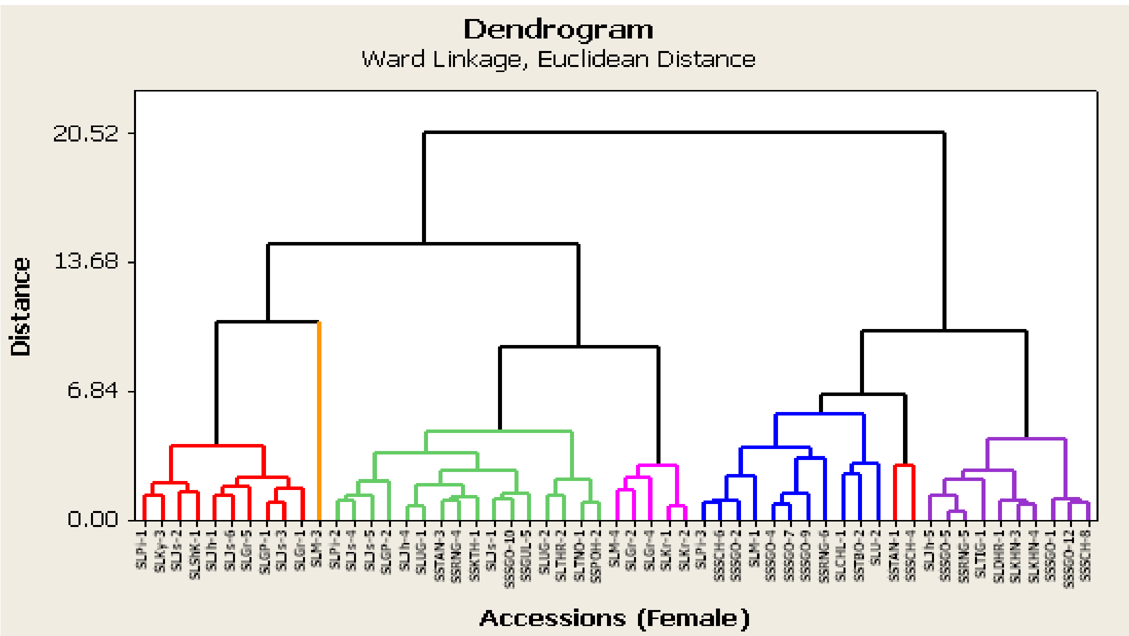

Figure 5: Dendrogram of cluster analysis of the female accessions

Table 4: Distance between clusters obtained by hierarchical clustering.

Cluster	Cluster						
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**
I	0.0	-	-	-	-	-	-
II	2.03	0.0	-	-	-	-	-
III	3.46	1.80	0.0	-	-	-	-
IV	6.53	8.31	9.36	0.0	-	-	-
V	2.76	2.27	3.63	8.51	0.0	-	-
VI	2.46	1.98	2.12	7.95	4.12	0.0	
VII	3.13	3.04	3.19	7.45	3.98	3.12	0.0

Geographical distribution and potential areas: Total 92 distribution points of *Hippophae rhamnoides* ssp. *turkestanica*, were used to build the model. Maxent's model statistical demonstrated highly significant ($P<0.01$) performance and evaluation of model indicated that the model provided useful information. The area under curve (AUC) was above 0.9 (AUCtest = 0.982 ± 0.025), indicating very high accuracy (Figure 6). The jackknife test showed mean temperature of coldest quarter (BIO 11) as the environmental variable with the highest training gain in the model, which indicated that it had the most predictive ability of any variable (Figure 6). The variable, which decreased the gain most when excluded from the model, was temperature annual range (BIO 7), indicating that temperature annual range had the most unique contribution to the model (Figure 6 & Table 5). Amongst the predictor bioclimatic variables, precipitation of coldest quarter (BIO 19), precipitation of warmest quarter (BIO 18), minimum temperature of coldest period (BIO 5) and maximum temperature of warmest period (BIO 6) were the most influential and contributed 26.5%, 18.9%, 12.8 % and 11.6%, respectively to the Maxent Model (Table 5). Considering the permutation importance, mean temperature of coldest quarter had the maximum influence on the habitat suitability model and contributed to 48.5%, while precipitation of warmest quarter (BIO 18) and temperature annual range (BIO 7(BIO5-BIO6)) contributed to 22.2% and 20.0%, respectively (Figure 7 & Table 5).

Table 5: Estimates of relative contributions and permutation importance of the predictor environmental variables to the Maxent Model.

Predictor variable	Name of predictor variable	***Hippophae rhamnoides* ssp. *turkestanica***	
		Percent contribution	**Permutation importance**
bio_1	Annual Mean Temperature	0	0.1
bio_10	Mean Temperature of Warmest Quarter	0	0
bio_11	Mean Temperature of Coldest Quarter	2.1	48.5
bio_12	Annual Precipitation	0	0.4
bio_13	Precipitation of Wettest Period	0.1	0.2
bio_14	Precipitation of Driest Period	2.7	1
bio_15	Precipitation Seasonality (Coefficient of Variation)	2.3	0.5
bio_16	Precipitation of Wettest Quarter	0.1	0.1
bio_17	Precipitation of Driest Quarter	0	0
bio_18	Precipitation of Warmest Quarter	18.9	22.2
bio_19	Precipitation of Coldest Quarter	26.5	2.3
bio_2	Mean Diurnal Range (max temp – min temp) (monthly average)	0	0
bio_3	Isothermality (BIO1/BIO7) * 100	3.9	1.1
bio_4	Temperature Seasonality (Coefficient of Variation)	11	0.4
bio_5	Max Temperature of Warmest Period	11.6	2.2
bio_6	Min Temperature of Coldest Period	12.8	0
bio_7	Temperature Annual Range (BIO5-BIO6)	3.7	20
bio_8	Mean Temperature of Wettest Quarter	3.8	0.8
bio_9	Mean Temperature of Driest Quarter	0	0.1
h_dem	Elevation	0.6	0

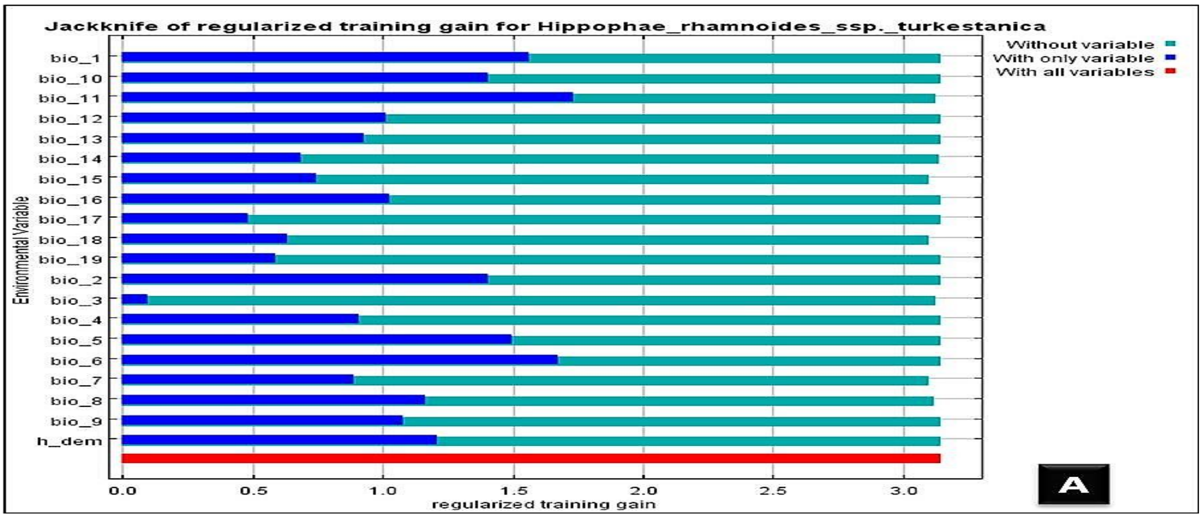

Figure 6: Jackknife of regularized training gain of *Hippophae rhamnoides* ssp. *Turkestanica*.

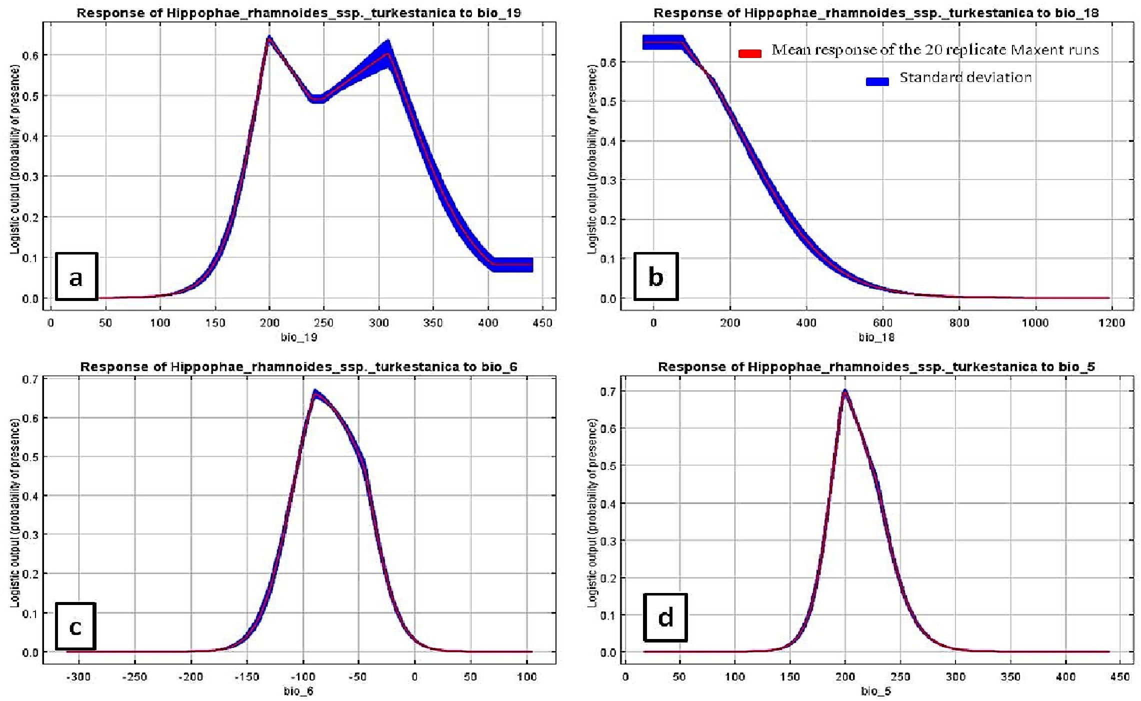

Figure 7: Probability of Hippophae rhamnoides ssp. turkestanica occurrence versus selected variables: (a) Precipitation of coldest quarter (BIO 19); (b) Precipitation of warmest quarter (BIO 18); (c) Maximum temperature of warmest period (BIO 6); and (d) Minimum temperature of coldest period (BIO 5).

Potential habitats with high suitability thresholds were distributed in the semi arid and higher elevations of the Lahaul & Spiti and Kinnaur districts of Himachal Pradesh in Trans and Northwestern biogeographic provinces of the Indian Himalaya (Figure 8). Primary field surveys revealed that the predicted potential habitats were mostly located along the water channel of Lahaul & Spiti, Chamba and Kinnaur districts of Himachal Pradesh. Areas with low to very low habitat suitability were with away from the water channels. Out of the 55,673 km^2 of Himachal Pradesh, a total potential area of ca. 531 km^2 (very high and high suitable class) in the Himachal Pradesh was predicted to be suitable for Hippophae rhamnoides ssp. turkestanica re-introduction, cultivation and conservation (Figure 8). Among the habitat suitability classes under low suitability class, an area of 705.0 km^2 was covered. Area of medium suitability was restricted only to about 435.0 km2, and high suitability class 386.0 km^2. Area of high suitability was 146.0 km^2. Field surveys for assessing the habitat types of *Hippophae rhamnoides* ssp. *turkestanica* in the predicted potential areas revealed that the species occurred in the riverine, dry slope, pasture land, rocky and scree habitats of the semiarid and higher elevations of the Himachal Pradesh. The species was also present around human settlement areas and settled cultivation lands. Superimposing the predicted potential habitat map of the species on Google Earth satellite imageries revealed a mosaic of habitats to be suitable for the species persistence. The areas with very high to high habitat suitability for the species were continuous patches of Riverine habitat along water channels. The areas with medium habitat suitability were Pastureland, settled cultivation areas, and human settlements. The areas with very low habitat suitability were dry slope, rocky and scree. The superimposition of predicted potential habitat distribution map on Google Earth Imageries identified areas viz., the Lahaul and Spiti blocks of the district Lahaul & Spiti, Pangi block of Chamba district and Pooh block of the Kinnaur district. These areas would serve as highly suitable habitats for persistence of the species. These areas would act as in situ conservation areas for the species and could also be used for re-introduction/recovery and commercial cultivation of the species.

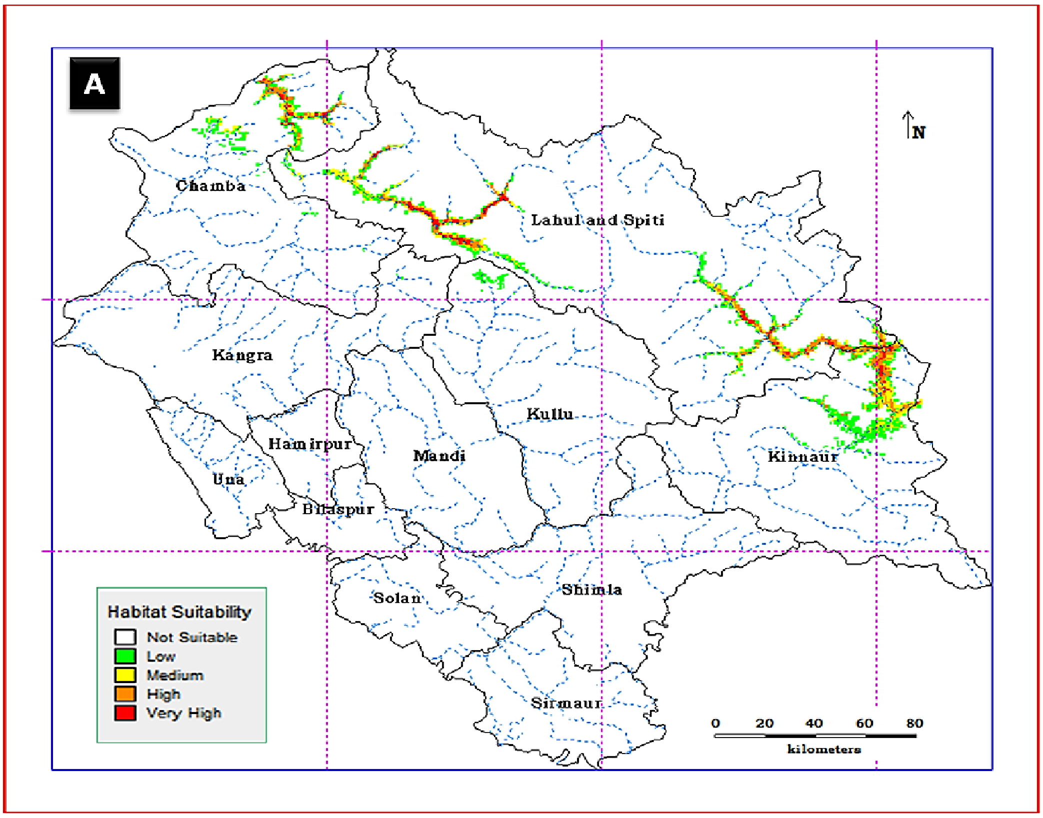

Figure 8: Habitat suitability and distribution of *Hippophae rhamnoides* ssp. *Turkestanica* in Himachal Pradesh.

The Government Departments, Non-Government Organizations, Lahaul-Spiti Seabuckthorn Societies, Lahaul Potato Grower Society and Private Companies are working on various activities pertaining to Seabuckthorn in the study area. Co-operative Societies and Ecosphere Spiti Eco Livelihoods were collected 14 tons of berries during 2006–2007 in Spiti valley and which produced 12 tons of pulp[15]. It clearly indicates that seabuckthorn has potential to boost up the economy of the tribal communities. Moreover, the government agencies namely Ministry of Environment, Forest and Climate Change, Defence Research and Development Organization, Indian Council of Agriculture Research, etc. have prioritized Seabuckthorn as the most potential crop for the cold desert region. Recently, the Horticulture Board of India declared the species of Seabuckthorn under horticulture crop. This initiative would definitely help in the commercial cultivation of the *Hippophae* species in the area. In view of the potential of Seabuckthorn species for the restoration of degraded land and socio-economic development of the tribal communities, the present study provided key information on natural populations of the Hippophae species and potential area for species reintroduction and cultivation. The distribution of potential habitats of a species is determined by biotic and abiotic factors of the ecosystem. Field surveys and model output showed that riverine, dry slope, moist forest, agriculture land and temperate forest are the suitable natural habitats of the species distributed between higher elevations (2000-3700 m) of Himachal Pradesh. The particular geographical distribution of the highly suitable habitats of Hippophae species to the riverine areas indicated species habitat specificity. Herbarium records and literature also supported model output their occurrence in the riverine and dry region of the Himalaya. A predictor layer shows the role of abiotic factors, which determine the niche of the species. Geology, soil and climatic factors directly influence on vegetation of a given place at a given time. The effects of environmental condition are reflected through the spatial and temporal variation in the vegetation[16]. Precipitation of coldest quarter bioclimatic variable played key role in defining niche of seabuckthorn. Hence, bioclimatic variables act as informative variables representing environmental condition, which determine the boundaries of the potential habitat of the species. Healthier population of the species in areas of higher model thresholds, indicated that these areas had ideal habitat conditions for persistence of the species. However, localities had low poor population status in spite of being predicted as highly suitable. The reason for this as revealed from the direct field observation that inhabitants of these localities collect species for household use and commercial purpose. From the above observations, we can assume that healthier population status of a species in undisturbed habitats in the native range could be ascertained with reasonable level of confidence from the model output i.e., areas with healthier population status are predicted as models with higher threshold level and vice versa. Such assumption however, may not hold good if the populations are modified through human activities. Overall, the results of actual habitat assessment through Google Earth superimposition and field surveys were identical. Through both the methods, the prevalence of species was in similar land use and land cover types. This analysis confirms the application of Google Earth superimposition along with limited field survey as a powerful tool for habitat assessment of the species, and could be a substitute of extensive field survey [17]. Conservation of a species and its habitat cannot be done in isolation outside the sphere of the anthropobiome[18]. Species re-introduction and cultivation should therefore carefully select appropriate areas under such a setting. In the present study, some areas consist of continuous and intact patches of potential habitats at higher levels of probability. Hence, such areas could serve as habitats for in-situ conservation, cultivation and reintroduction. To achieve this, awareness and active participation of local people, Non Government Organizations (NGOs), and Community Based Organizations are warranted. The present study demonstrated that habitat distribution modelling could be of great help in predicting the potential habitats of species for reintroduction. The areas identified in the present study for reintroduction of *Hippophae rhamnoides* ssp. *Turkestanica* would not only help in eco-restoration of species and habitats where the species had existed before but also in rehabilitating the species population and improving its conservation. Promotion of mass scale propagation through conventional and in-vitro methods of such species and their rehabilitation in the in-situ conditions or akin habitats may also help in conservation and management. Therefore, the results would be quite useful for natural resource managers in the management of these species and conserving overall biological diversity in the region.

CONCLUSION: It has been observed that plant height and leaf length decreased with increasing the altitude and petiole length of the leaf depends on the length of the leaf. Fruit length affected by altitude, plant height and canopy spread. The length of peduncle shows directly proportional relation to the length of fruit. Seed length depends on the fruit length. Dioecism and wind pollination make this species an obligate out-crosser. The two features coupled with occasional sexual polymorphism serve as the basis of genetic variation. This variation manifests at the morphological, cytological, ecological and molecular levels. It is concluded that wide variations exist in different populations of seabuckthorn growing in this region. Therefore, conservation of the varied morphotypes are required by in-situ and ex-situ methods. Species re-introduction and cultivation should therefore carefully select appropriate areas under such a setting. In the present study, some areas consist of continuous and intact patches of potential habitats at higher levels of probability. Hence, such areas could serve as habitats for in-situ conservation, cultivation and reintroduction.

Plate 1: Variations in fruit colour, shape and size in *Hippophae rhamnoides* subsp *turkestanica.*

Plate 2: Different habitat of *Hippophae rhamnoides* subsp *turkestanica* in Lahaul-Spiti district.

ACKNOWLEDGEMENT: The authors are thankful to Director, G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora for the facilities and encouragement. Dr. Ashok Singh and Dr. Pankaj Sharma are acknowledged for their help and moral support during the fieldwork and manuscript preparation.

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