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# Correlation analysis between morphological and fodder characteristics of seabuckthorn (*Hippophae salicifolia* D Don) populations in Himachal Pradesh

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## ABSTRACT

Correlation analysis between morphological and fodder characteristics of seabuckthorn (*Hippophae salicifolia* D Don) populations in Himachal Pradesh was conducted during 2018-20 with the aim to determine the correlation among different morphological characteristics of plants, leaves, thorns, fruits (berries), seeds and fodder quality. Five female plants of *H salicifolia* at each site were selected at the time of fruit set ie during August-September when males and females could be differentiated. The selected plants were used for the assessment of morphological and fodder variation of *H salicifolia* in Spiti and Baspa valleys. Variation in morphological traits and fodder quality traits of different sites of *H salicifolia* within and between different populations were used to conduct correlation studies. Morphological traits (plant height, branch length, leaf length, leaf width, leaf area, leaf density, number of thorns, 100-fruits fresh weight, fruit length, fruit diameter, 100-seed weight, seed length and seed width) differed positively significantly among the populations. All proximate leaf composition (100-leaves fresh weight, 100-leaves dry weight, crude fiber, total dry matter content, crude protein, total ash and nitrogen free extract) showed significant differences between as well as within populations. The correlation coefficient of parameters also showed greater variations as most of quantitative and fodder quality parameters were positively and statistically significant among them. This can be exploited for indirect selection as a mechanism for the genetic improvement of the species.

**Keywords:** Seabuckthorn; fodder characteristics; genetic variation; populations

## INTRODUCTION

Seabuckthorn (Genus *Hippophae*) is a berry-bearing, hardy shrub of the family Elaeagnaceae, naturally distributed in Asia and Europe and also introduced in north and south America. It includes 4 species (*Hippophae rhamnoides*, *H salicifolia*, *H tibetana* and *H neurocarpa*) and 9 sub-species are reported so far from many parts of world. It is a unique and valuable genotype resource currently cultivated in various parts of the world.

The natural habitat of seabuckthorn extends widely in China, Mongolia, Russia and most parts of north Europe. It can withstand extreme temperatures from -43 to 40ºC and is considered to be drought resistant. The cold deserts in Himachal Pradesh are found in the districts of Lahaul and Spiti, parts of Kinnaur and Pir Panjal region of Chamba. These areas are characterized by high ridges, difficult terrains with ice field, perpetual snow covered peaks and hostile climate. Among various indigenous and under-exploited genotype resources of high mountain area, seabuckthorn is one of the best solutions and can certainly metamorph the ecology of cold desert by reclaiming these bare fragile mountains.

Willow-leaved seabuckthorn and indigenous source locally Sutz/Sarla offer an opportunity to maintain more sustainable livelihood qualities as well as unique option for the simultaneous management of several problems. Seabuckthorn has outstanding qualities such as capability to grow and survive under adverse climatic conditions, extensive root system with soil binding ability/soil stabilization/control of river bank/ water retention, nitrogen fixing (60-180 kg/ha/year), higher vitamin C content and economic value of fruit and seed oil, excellent fodder and fuel-wood qualities, wider application in food, cosmetics, beverages, medicines and other pharmaceutical products, excellent fencing hedge and social fencing. Though seabuckthorn is widely found under agroforestry system as well as hazard zones, yet no systematic study has been carried out so far to understand its potential from agroforestry/forestry perspective. It helps to be a valuable tool for land restoration and conservation in the cold desert of Lahaul valley of Himachal Pradesh (Sankhyan et al 2018). The first pre-requisite step to undertake breeding programme and to obtain improved genetic gain is selection of best populations and best individuals within the populations. This can also be achieved by selection of positive correlated traits. Nursery raising, plantation technology, fruit harvesting methodology and other biochemical aspects have been already worked out for *H rhamnoides*. This species is still lacking information, being its restricted and scattered distribution in patches.

With this concept and idea in mind, this species has been preferred to work on quantitative parameters so as to know the extent of correlation among different characteristics and ultimately help in indirect selection. Knowledge of genetic correlations among pairs of traits can be important both for the study of natural populations of forest trees as well as in tree improvement programmes. If two traits have a strong positive or negative correlation, then either natural or artificial selection on the first trait causes genetic change in the second. This is called a correlated response to selection or indirect selection. The present study was focused in only two valleys namely Sangla valley of district Kinnaur and Spiti valley of district Lahaul and Spiti as major gene pool area of this species occurs only in these two valleys that are considered heart of cold desert of Himachal Pradesh where choice of species is limited and seabuckthorn is only suitable option. Lahaul valley is rich in genetic resources as seabuckthorn is the last option and choice for the farmers. Development of morphological and fodder characteristics correlation of this species may certainly help in the tree improvement programmes at later stage.

## MATERIAL and METHODS

The present study was carried out in the fields of Baspa valley of district Kinnaur and Spiti valley of district Lahaul and Spiti as well as in the laboratories of the Department of Tree Improvement and Genetic Resources, Department of Basic Sciences, Department of Environmental Science and Department of Silviculture and Agroforestry, College of Forestry at the main campus of Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2018-2020. The two valleys were surveyed for the occurrence of *H salicifolia* genotype species after proper identification of genotypes and populations by selecting three natural populations in each valley and from each population five genotypes were selected, marked and taken for further investigations and recording fodder characteristics.

Experimental sites/populations taken were Kuppa, Batseri and Chitkul of Baspa valley in district Kinnaur and Mane, Shiego and Giu in Spiti valley in district Lahual and Spiti (Table 1), five female genotypes of *H salicifolia* at each site. Populations were selected at the time of fruit set ie during August-September when males and females could be differentiated.

The selected genotypes were used for the assessment of fodder variation in Baspa valley of Kinnaur and Spiti Valley of Lahaul and Spiti. Leaves and berries were taken and carried from experimental sites to laboratories for further study of fodder variation and preparation of morphological and fodder correlations. Altitude of populations ranged from 2,590 to 3,538 m amsl.

Observations on characteristics such as genotype height, branch length, leaf length, leaf width, leaf area, leaf density, number of thorns per branch, fresh fruit weight, fruit length, fruit diameter, 1,000-seed weight, seed length, seed width, 100-leaves fresh weight, 100-leaves dry weight, leaf dry matter content, crude fibre, crude protien, ash content and nitrogen free content were recorded from naturally occurring populations and individuals.

**Correlation coefficient:** The correlation coefficient was worked out by using following formula (Panse and Sukhatme 1967):

$$r_{xy} = \frac{COV(XY)}{\sqrt{V(X) \times V(Y)}}$$

where rxy= Simple correlation between x and y, V(x)= Variance of ‘x’ variable, V(y)= Variance of ‘y’ variable

Table 1. Selected experimental sites showing population, code number, latitude, longitude and altitude areas of seabuckthorn populations in Baspa and Spiti valleys

| Population site code | Population | Latitude (North) | Longitude (East) | Altitude (m) amsl |
|---|---|---|---|---|
| S1 | Kupa (Baspa valley) | 31°43.56’ | 78°24.48’ | 2,590 |
| S2 | Batseri (Baspa valley) | 31°40.88’ | 78°30.60’ | 2,790 |
| S3 | Chitkul (Baspa valley) | 31°35.08’ | 78°43.66’ | 3,450 |
| S4 | Giu (Spiti valley) | 31°31.10’ | 77°16.08’ | 3,048 |
| S5 | Mane (Spiti valley) | 32°02.00’ | 78°14.19’ | 3,453 |
| S6 | Shiego (Spiti valley) | 32°10.58’ | 78°06.24’ | 3,538 |

Table 2. Morphological and fodder characteristics of selected seabuckthorn populations

| Component | Population | | | | | |
|---|---|---|---|---|---|---|
| | Kupa | Batseri | Chitkul | Giu | Mane | Shiego |
| Height (m) | 2.74 | 2.50 | 3.34 | 1.60 | 2.39 | 1.20 |
| Branch length (cm) | 122.67 | 99.33 | 111.00 | 68.00 | 73.47 | 58.27 |
| Leaf length (cm) | 7.07 | 5.70 | 5.94 | 3.97 | 4.88 | 3.92 |
| Leaf width (cm) | 1.01 | 0.86 | 0.88 | 0.55 | 0.71 | 0.48 |
| Leaf area ($cm^2$) | 3.83 | 2.89 | 4.00 | 2.32 | 3.77 | 2.21 |
| Leaf density | 16.73 | 20.00 | 24.20 | 18.53 | 17.67 | 14.67 |
| Number of thorns | 1.47 | 2.87 | 2.60 | 4.53 | 1.80 | 3.07 |
| Fruit weight (g) | 15.73 | 11.14 | 12.78 | 15.51 | 16.45 | 17.09 |
| Fruit length (mm) | 7.00 | 6.03 | 6.76 | 5.73 | 6.26 | 5.88 |
| Fruit diameter (mm) | 6.46 | 5.29 | 5.98 | 6.39 | 7.63 | 5.96 |
| Seed weight (g) | 12.40 | 10.00 | 14.00 | 19.90 | 20.50 | 24.00 |
| Seed length (mm) | 4.80 | 4.93 | 6.50 | 4.80 | 3.50 | 5.23 |
| Seed width (mm) | 1.80 | 3.50 | 2.30 | 2.49 | 2.19 | 2.50 |
| Leaf fresh weight (g) | 6.42 | 5.21 | 11.04 | 4.86 | 6.03 | 2.48 |
| Leaf dry weight (g) | 3.48 | 3.08 | 4.79 | 2.27 | 2.46 | 1.20 |
| Leaf dry matter content (%) | 56.18 | 60.24 | 53.02 | 46.74 | 42.36 | 44.83 |
| Crude fibre (%) | 13.50 | 20.00 | 15.50 | 4.42 | 8.31 | 7.06 |
| Crude protein (%) | 26.31 | 25.59 | 26.64 | 24.65 | 25.50 | 24.98 |
| Ash content (%) | 6.50 | 5.70 | 6.50 | 8.84 | 6.25 | 6.22 |
| Nitrogen free extract (%) | 50.69 | 49.02 | 48.36 | 56.37 | 56.95 | 58.74 |

## RESULTS and DISCUSSION

The data given in Table 2 show that the maximum genotype height was recorded in Chitkul (3.34 m) and minimum in Shiego (1.20 m); maximum branch length was recorded in Kupa (122.67 cm) and minimum in Shiego (58.27 cm); maximum leaf length was recorded for Kupa (7.07 cm) and minimum in Shiego (3.92 cm); maximum leaf width was recorded in Kupa (1.01 cm) and minimum in Shiego (0.48 cm); maximum leaf area was recorded in Chitkul (4.00 $cm^2$) and minimum in Shiego (2.21 $cm^2$); maximum leaf density was recorded in Chitkul (24.20/10 cm) and minimum in Shiego (14.67/10 cm).

The number of thorns varied from 1.47 to 4.53 per 10 cm and fruit weight from 17.09 to 11.14 g. Maximum fruit length (7.00 mm) was observed in Kupa and minimum in Giu (5.73 mm). Mane showed the highest (7.63 mm) fruit diameter and Batseri the minimum (5.29 mm); the maximum (24.00 g) 1000-seed weight was observed in Sheigo plant 1 and minimum (10.00 g) in Batseri; maximum seed length (6.50 mm) was noticed in Chitkul plant 2 and minimum (3.50 mm) in

Table 3. Correlation of traits with all quantitative and qualitative traits and fodder quality traits among and between selected seabuckthorn populations

| Trait | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | |
| 2 | 0.511$^{**}$ | | | | | | | | | | | | | | | | | | | |
| 3 | 0.543$^{**}$ | 0.570$^{**}$ | | | | | | | | | | | | | | | | | | |
| 4 | 0.420$^{*}$ | 0.474$^{**}$ | 0.864$^{**}$ | | | | | | | | | | | | | | | | | |
| 5 | 0.242$^{NS}$ | 0.281$^{NS}$ | 0.659$^{**}$ | 0.717$^{**}$ | | | | | | | | | | | | | | | | |
| 6 | 0.497$^{**}$ | 0.157$^{NS}$ | 0.127$^{NS}$ | 0.272$^{NS}$ | 0.078$^{NS}$ | | | | | | | | | | | | | | | |
| 7 | -0.477$^{**}$ | -0.358$^{NS}$ | -0.518$^{**}$ | -0.424$^{*}$ | -0.371$^{*}$ | 0.118$^{NS}$ | | | | | | | | | | | | | | |
| 8 | -0.291$^{NS}$ | -0.166$^{NS}$ | -0.254$^{NS}$ | -0.273$^{NS}$ | -0.101$^{NS}$ | -0.529$^{**}$ | -0.162$^{NS}$ | | | | | | | | | | | | | |
| 9 | 0.609$^{**}$ | 0.495$^{**}$ | 0.577$^{**}$ | 0.499$^{**}$ | 0.253$^{NS}$ | 0.317$^{NS}$ | -0.588$^{**}$ | -0.028$^{NS}$ | | | | | | | | | | | | |
| 10 | 0.011$^{NS}$ | -0.244$^{NS}$ | 0.015$^{NS}$ | 0.013$^{NS}$ | 0.119$^{NS}$ | -0.089$^{NS}$ | -0.133$^{NS}$ | 0.351$^{NS}$ | 0.155$^{NS}$ | | | | | | | | | | | |
| 11 | -0.570$^{**}$ | -0.682$^{**}$ | -0.722$^{**}$ | -0.695$^{**}$ | -0.246$^{NS}$ | -0.378$^{*}$ | 0.319$^{NS}$ | 0.445$^{*}$ | -0.510$^{**}$ | 0.323$^{NS}$ | | | | | | | | | | |
| 12 | 0.150$^{NS}$ | 0.112$^{NS}$ | 0.071$^{NS}$ | 0.164$^{NS}$ | 0.178$^{NS}$ | 0.246$^{NS}$ | -0.060$^{NS}$ | -0.216$^{NS}$ | 0.147$^{NS}$ | -0.597$^{**}$ | -0.237$^{NS}$ | | | | | | | | | |
| 13 | -0.119$^{NS}$ | -0.088$^{NS}$ | -0.010$^{NS}$ | 0.032$^{NS}$ | -0.285$^{NS}$ | 0.132$^{NS}$ | 0.278$^{NS}$ | -0.371$^{*}$ | -0.233$^{NS}$ | -0.411$^{*}$ | -0.335$^{NS}$ | 0.153$^{NS}$ | | | | | | | | |
| 14 | 0.223$^{NS}$ | 0.353$^{NS}$ | 0.719$^{**}$ | 0.661$^{**}$ | 0.829$^{**}$ | 0.081$^{NS}$ | -0.284$^{NS}$ | -0.189$^{NS}$ | 0.226$^{NS}$ | 0.135$^{NS}$ | -0.291$^{NS}$ | -0.011$^{NS}$ | -0.211$^{NS}$ | | | | | | | |
| 15 | 0.490$^{**}$ | 0.458$^{*}$ | 0.873$^{**}$ | 0.844$^{**}$ | 0.712$^{**}$ | 0.313$^{NS}$ | -0.298$^{NS}$ | -0.421$^{*}$ | 0.419$^{*}$ | -0.043$^{NS}$ | -0.662$^{**}$ | 0.140$^{NS}$ | -0.009$^{NS}$ | 0.850$^{**}$ | | | | | | |
| 16 | 0.446$^{*}$ | 0.241$^{NS}$ | 0.268$^{NS}$ | 0.350$^{NS}$ | -0.218$^{NS}$ | 0.460$^{*}$ | -0.006$^{NS}$ | -0.391$^{*}$ | 0.362$^{*}$ | -0.284$^{NS}$ | -0.696$^{**}$ | 0.213$^{NS}$ | 0.395$^{*}$ | -0.288$^{NS}$ | 0.238$^{NS}$ | | | | | |
| 17 | 0.715$^{**}$ | 0.540$^{**}$ | 0.499$^{**}$ | 0.442$^{*}$ | 0.172$^{NS}$ | 0.381$^{*}$ | -0.317$^{NS}$ | -0.537$^{**}$ | 0.475$^{**}$ | -0.344$^{NS}$ | -0.791$^{**}$ | 0.342$^{NS}$ | 0.207$^{NS}$ | 0.092$^{NS}$ | 0.459$^{*}$ | 0.649$^{**}$ | | | | |
| 18 | 0.733$^{**}$ | 0.438$^{*}$ | 0.555$^{**}$ | 0.432$^{*}$ | 0.378$^{*}$ | 0.349$^{NS}$ | -0.379$^{*}$ | -0.171$^{NS}$ | 0.611$^{**}$ | 0.041$^{NS}$ | -0.561$^{**}$ | 0.136$^{NS}$ | -0.221$^{NS}$ | 0.310$^{NS}$ | 0.507$^{**}$ | 0.321$^{NS}$ | 0.612$^{**}$ | | | |
| 19 | -0.141$^{NS}$ | -0.003$^{NS}$ | -0.140$^{NS}$ | -0.182$^{NS}$ | -0.165$^{NS}$ | -0.052$^{NS}$ | 0.216$^{NS}$ | 0.011$^{NS}$ | -0.130$^{NS}$ | 0.137$^{NS}$ | 0.206$^{NS}$ | -0.057$^{NS}$ | -0.052$^{NS}$ | -0.128$^{NS}$ | -0.257$^{NS}$ | -0.236$^{NS}$ | -0.260$^{NS}$ | -0.230$^{NS}$ | | |
| 20 | -0.724$^{**}$ | -0.568$^{**}$ | -0.496$^{**}$ | -0.404$^{*}$ | -0.156$^{NS}$ | -0.388$^{*}$ | 0.267$^{NS}$ | 0.514$^{**}$ | -0.488$^{**}$ | 0.249$^{NS}$ | 0.735$^{**}$ | -0.312$^{NS}$ | -0.127$^{NS}$ | -0.087$^{NS}$ | -0.402$^{*}$ | -0.550$^{**}$ | -0.912$^{**}$ | -0.641$^{**}$ | -0.134$^{NS}$ | - |

*Significant at 5% LoS, ** Significant at 1% LoS, $^{NS}$Non-significant

1: Plant height, 2: Branch length, 3: Leaf length, 4: Leaf width, 5: Leaf area, 6: Leaf density, 7: Number of thorns, 8: 100-fruit weight, 9: Fruit length, 10: Fruit diameter, 11: Seed weight, 12: Seed length, 13: Seed width, 14: 100-leaves fresh weight, 15: 100-leaves dry weight, 16: Leaf dry matter content, 17: Crude fibre, 18: Crude protein, 19: Total ash, 20: Nitrogen free extract

Mane; the maximum seed width was noticed in Batseri (3.50 mm) and minimum (1.80 mm) in Kupa.

Chitkul showed maximum (11.04 g/100 leaf) fresh weight whereas Sheigo the minimum (2.48 g/100 leaf). Maximum (4.79 g) 100-leaves dry weight was recorded in Chitkul and minimum (1.20 g) in Sheigo. The dry matter content varied from 60.24 to 42.36 per cent. Maximum crude fibre (20.00%) was noticed in Batseri plant 2 (BP2) whereas minimum (4.42%) in Giu; maximum crude protein (26.64%) was observed in Chitkul and minimum in Giu (24.65%); maximum total ash (8.84%) was observed in Giu and minimum in Batseri (5.70%).

Nitrogen free extract showed significant variation and ranged from 58.74 to 48.36 per cent.

**Karl Pearson's correlation coefficient:** The Pearson's correlation coefficient is detailed in Table 3. The correlation coefficient was studied between all possible characters of morphological traits and fodder quality traits of *H salicifolia* selected populations.

The morphological and leaf fodder traits showed positive, negative, significant and non-significant correlation among themselves. All the morphological individualities, leaf area characters and crude protein were highly correlated with leaf fresh weight and plant height.

Therefore any one of morphological trait (leaf length, leaf area etc) can be considered as important trait for early selection of desired traits viz leaf fodder, berry etc and also for selection of better populations. Hence these characters must be given proper emphasis during further investigations. This can be exploited for indirect selection as a mechanism for the genetic improvement of the species.

The correlation among morphological characters was also studied by various other workers (Garanovitch 1991, Yao et al 1992) who found highly significant correlation between said characters of seabuckthorn.

The present findings are in line with the findings of Korekar et al (2013) who studied genotypic and morphometric effects on fruit characters in seventeen natural populations of seabuckthorn (*H rhamnoides*) from trans-Himalaya and observed that oil content in berry was significantly correlated with fruit weight, fruit width, seed weight, leaf area and number of leaves per 10 cm. The results are in agreement with the findings of Singh et al (2013) and Kuhkheil et al (2017).

Similar results were reported by Chauhan and Verma (1993) and Mohapatra (1996) in *Acacia catechu,* Shrivastava (1995) in *Bauhinia variegata,* Manga and Sen (1998) in *Prosopis cineraria* and Thakur et al (2000) in *Alnus nitida.*

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