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Principal Component Analysis of Growth, Leaf and Biomass Traits of Indian Willow (*Salix tetrasperma* Roxb.)

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Abstract

Indian willow (*Salix tetrasperma* Roxb.) genotypes were collected from 20 sites in North India covering Uttrakhand, Himachal Pradesh, Punjab and Jammu and Kashmir and one genotype from Rajasthan and evaluated in common garden test to study genetic variability in growth, leaf and biomass characters. Based on the principal component analysis, five components explained 82.85% of the total variance. The first component explained 44.29% of variance exhibited by biomass character. The second component accounted for 17.52% of total variation defined by leaf characters. Three characters, root shoot ratio, root length and the number of leaf teeth represented 9.31% of the variability in the third component. The fourth component accounted for 6.33% of variability that was represented by total foliage duration (0.730), and the fifth component accounted 5.39% of variability that was exhibited by leaf unfolding days (0.540). Scatter plot depicted a clear pattern of grouping of sites based on PC1 and PC2 variances.

Keywords: Genotypes, Indian willow, principal component, *Salix tetrasperma*

1. Introduction

Willows (*Salix* species) are widely spread plant species. It occurs in diverse ecological niches, mostly native to the northern hemisphere (Argus, 1997). The genus shows considerable variation in plant size, growth habit and morphological characteristics, ranging from small shrubs to large trees (Newsholme**,** 1992). They have provided the raw material for making many necessities items from the ancient civilization. Asia is considered to be the original centre of genus *Salix* with about 275 species exist in China, of which 189 are endemics (Fang, 1987). In India, out of 33 indigenous species of willows (Sharma et al., 2011) of which 7 species are having a habit of tree and widely grown on the northern temperate parts of Jammu and Kashmir to Arunachal Pradesh. *Salix tetrasperma* occurs throughout from tropical to temperate regions of India (Sharma et al., 2015).

Collection and evaluation of germplasm are essential to capture the genetic diversity, that can be utilized for further improvement programmes. The scientist used common gardens by growing individuals from different populations in a common environment for a short period to measure the adaptations occurred in nature (De Villemereuil et al., 2016). These experiments have the advantages of evaluating more number of populations in a limited area, generating a large amount of data in short time and low experimental error due to homogeneous experimental environment (White et al., 2009). To find the genetic variability in Populations of the Indian willow of collected genotypes from the study area were evaluated in experimental fields (common garden) tests.

Principal component analysis (PCA), is a multivariate statistical technique to reduce the data with a large number of correlated variables into a substantially smaller set of new variables, through linear combinations of variables that account most of the variation present in the original variables. Since principal component analysis aims to replace the original set of variables with few variables as possible, naturally in doing so, some information contained in the original variables has to be sacrificed. But principal component has an advantage that this lost information is kept to the minimum.

Since the few principal components usually account for most of the variation of the original variables and the subsequent principal component relatively little. It is frequently useful to retain only those first few principal components and drop all subsequent components from the analysis since the variance they expressed is random mainly and is of no use in the analysis. Several thumb rules have been proposed for the number of principal components to be retained, but no rule is universally accepted. The decision is usually made with an interpretation of components in mind. Kaiser (1958) suggested the dropping of those principal components of the correlation matrix with Eigen roots less than one. He argued that the principal component's with eigenvalue less than one contains less information.

2. Materials and Methods

The survey was carried out in the Himalayan regions of Jammu and Kashmir, Himachal Pradesh, Punjab and Uttarakhand in North India to identify different populations of indigenous Indian willow (*Salix tetrasperma*). The germplasm in the form of stem cuttings were collected in dormant season. The germplasm was collected based on field observations and interaction with local people. Total numbers of sites or population were 20, and 6 genotypes based upon availability per site or population were selected (Sharma et al., 2019 and Table 1). The distance among the genotypes within sites varied at least 200 meters to 4 km depending upon availability, as it is a scattered in distribution. Locational data was recorded with instrument GARMIN GPS III Plus (Table 1). Three genotypes from Udaipur, Rajasthan state, were procured through Forest Department, Rajasthan in the year 2012 and were included in the experiment making the total sites to 21. The experiment was carried out under protected condition in the glasshouse of the Department in polybags of size 4 inch × 9 inch. Growth (Plant height, basal diameter, internodal length, number of nodes) and biomass (Fresh shoot weight, dry root weight, fresh shoot weight, dry shoot weight) characters were recorded in December while, and leaf characters (Lamina length, Maximum breadth of lamina, petiole length, leaf area, number of teeth) were recorded in the July at full maturation of leaf. The data were subjected to the principal component analysis. The latent root criterion (Eigen value >1) was used for determining the number of principal components, according to Kaiser (1958) criteria. For principal component analysis of various characters understudy, Statistical Package for the Social Sciences (SPSS) version 16 was used.

Table 1: Latitude, longitude and altitude of collection sites

Sl. No.	Site	Latitude (°N)	Longitude (°E)	Altitude (m asl*)
1.	Devamanal	30°47'356"-30°47'572"	77°26'217"- 77°26'423"	1668-1784
2.	Jakholi	30°24'243"-30°24'616"	78°52'062"- 78°52'706"	1181 -1630
3.	Rampur	31°22'975"-31°23'587"	77°32'127"- 77°35'349"	898 - 987
4.	Rupnagar	30°54'390"-30°54'482"	76°27'778"- 76°38'001"	251-262
5.	Tandi	30°51'705"-30°51'797"	76°08'320"- 76°08'365"	296-300
6.	Suhanpur	31°26'085"-31°31'449"	75°21'327"- 75°26'049"	119-234
7.	Dasua	31°40'161"-32°13'265"	75°32'021"- 76°08'837"	228-271
8.	Kangra	31°28'070"-32°12'729"	75°24'752"- 76°14'700"	686-715
9.	Hamirpur	31°41'141"-31°46'614"	76°25'286"- 76°30'624"	487-811
10.	Namhol	31°14'910"-31°15'748"	76°49'367"- 76°51'253"	996-1192
11.	Bhunter	31°50'642"-31°50'447"	77°03'096"- 77°09'596"	1089-1127
12.	Chinani	33°02'285"-33°02'513"	75°16'843"- 75°16'931"	1096-1137
13.	Rajouri	33°18'541"-33°20'301"	74°19'160"- 74°19'738"	829-841
14.	Jammu	32°48'256"-32°49'363"	74°45'583"- 74°46'470"	262-313
15.	Pauri Garhwal	29°49'022"-30°09'029"	78°37'004"- 78°46'435"	671-1472
16.	Jyolikote	29°21'062"-29°21'299"	79°28'615"- 79°28' 920"	1210-1222
17.	Deothi	30°55'721"-30°55'853"	77°03'270"- 77°03'388"	1413-1435
18.	Balh	31°32'063"-31°32'190"	76°50'810"- 76°50'841"	1140-1167
19.	Chowari	32°25'846"-32°25'964"	76°00'030"- 76°00'398"	972-1002
20.	Chamba	32°33'337"-32°33'549"	76°05'157"- 76°05'923"	888-904
21.	Udaipur	25°06'421"-25°06'495"	73°46'463"- 73°46'476"	360-384

*meters above sea level

3. Results and Discussion

In the present study (Table 2), five out of nineteen components

Table 2: Principal component analysis of *Salix tetrasperma* genotypes

Characters	I	II	III	IV	V
Plant height (cm)	0.610	0.350	-0.360	-0.210	0.280
Basal diameter (mm)	0.680	0.410	0.080	-0.050	0.220
No of nodes	-0.290	0.560	0.160	0.130	-0.080
Internodal length (cm)	0.690	-0.160	0.380	-0.050	-0.300
Root length (cm)	0.310	0.530	0.570	-0.300	0.010
Root shoot ratio	-0.370	0.100	0.820	-0.080	-0.270
Leaf unfolding (days)	-0.410	0.050	0.490	0.220	0.540
Foliage duration (days)	0.500	-0.160	0.020	0.730	0.040
Lamina length (cm)	-0.020	0.880	-0.210	0.260	-0.210
Maximum breadth of lamina (cm)	0.760	-0.350	0.210	0.110	-0.350
Petiole length (cm)	0.730	0.100	-0.190	-0.240	-0.250
Leaf length (cm)	0.050	0.880	-0.220	0.230	-0.230
Leaf area (cm^2)	0.700	0.020	0.150	0.560	-0.230
Number of leaf teeth	-0.440	0.360	0.460	0.180	0.310
Lamina length to maximum breadth ratio	-0.610	0.680	-0.230	0.130	0.110
Leaf petiole to lamina ratio	0.210	-0.740	-0.110	0.280	0.210
Fresh shoot weight (g)	0.950	0.030	0.001	0.060	0.210
Fresh root weight (g)	0.940	0.180	0.040	-0.080	0.070
Total fresh plant weight (g)	0.970	0.100	0.020	0.001	0.150
Dry shoot weight (g)	0.950	0.110	0.110	-0.070	0.150
Dry root weight (g)	0.970	0.120	0.020	-0.050	0.080
Total dry plant weight (g)	0.970	0.120	0.070	-0.060	0.120
Eigen value	9.745	3.854	2.049	1.393	1.186
% of the variability	44.294	17.519	9.314	6.333	5.389
Cumulative % of the variability	44.294	61.812	71.126	77.459	82.848

had eigenvalue greater than unity. These five components were retained in for further analysis as they contributed 82.85 % of the total variation. The decision was made according to the Kaiser (1958), who suggested the dropping of those principal components of the correlation matrix with Eigen roots less than one (Figure 1).

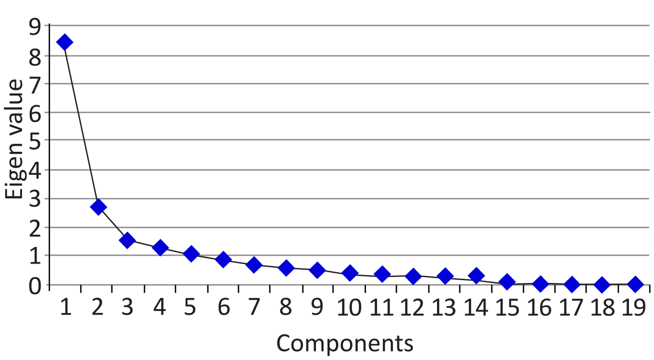

Figure 1: Scree plot showing eigenvalue of different principal components

The first component explains that 44.29 % of variance and included ten characters. The highest value (0.970) was exhibited by total fresh plant weight, dry root weight and total dry plant weight followed by 0.950 for fresh shoot weight and dry shoot weight, 0.940 fresh root weight, 0.760 for maximum breadth of lamina, 0.730 for petiole length, 0.690 for internodal length, 0.680 for basal diameter and 0.610 for plant height. The second component accounted for 17.52 % of total variation defined by lamina length and leaf length (0.880) followed by -0.740 for petiole length to leaf lamina length ratio and 0.560 for the number of nodes. Three characters represented 9.31 % of the variability in the third component, which was defined by root shoot ratio (0.820) followed by root length (0.570) and the number of teeth (0.460). The fourth component accounted for 6.33 % of variability that was represented by foliage duration (0.730), and the fifth component accounted 5.39 % of variability that was exhibited by leaf unfolding days (0.540). Scatter plot in figure 2 shows the relationship between studied genotypes and depicted a

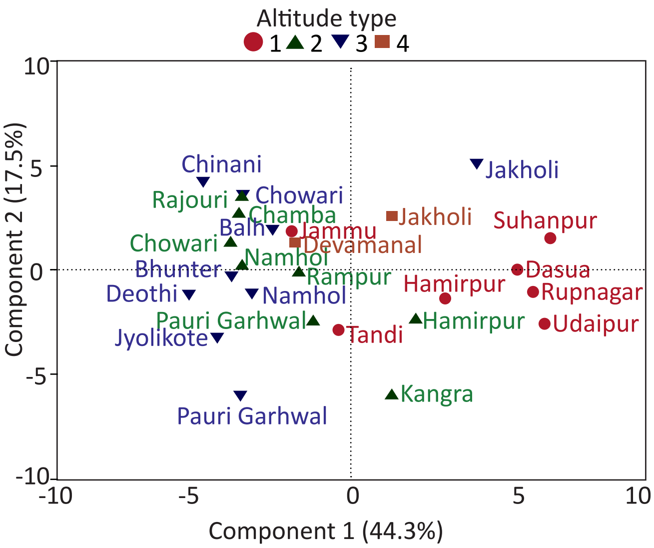

Figure 2: Distribution of sites PC1-PC2 showing biplot scatter diagram

clear pattern of grouping of sites. All the sites were scattered widely in different quarters. The sites Suhanpur, Udaipur, Jakholi, were outliers and falls in one group cluster I (Figure 2). These sites were represented by more biomass, plant height, basal diameter, internodal length or we can say having more biomass and growth characters and were more loading on PC1. The sites Chinani, Chamba, Balh, Chowari, Devamanal and Balh, represented more leaf characters and inclined towards PC2. Scatter plot further depicts that sites from A_1 altitude range have loading towards PC1.

Tunctaner (2002) reported five principal components based on 14 traits studied in willow clones. Similar types of findings were reported by Singh and Huse (2004). Singh et al. (2014) recorded a cumulative variability of 56 % from three principal components while studying *Populus deltoides* clones. Isik and Toplu (2004) reported three PCA which accounts 90 % of the overall variation in *Populus nigra* in which the first component included height, diameter and apical dominance and on scatter plot classified clones based on height and branchiness. Similarly, among clones, 71.46 % of the total variance was explained by first five components in eastern cottonwood and determined volume index as an essential variable in component first (Ozel et al., 2010). In a provenance trial of European beech Stojnic et al. (2016) got 81 % of the total variance in the first three principal components (PC1-PC3). The highest contribution on PC1 corresponded to variables related to leaf size: leaf area (-0.882) and leaf width (-0.876). Based on the position of provenances on a PCA scatter plot, they assumed the ecotypic pattern of genetic variation. Kajba et al. (2015) captured 90 % cumulative variability for the first two principal components to differentiate leaf characters of *Populus nigra*. Paray et al. (2017) extracted 89.38 % of total variance through PCA while evaluating the candidate plus trees of *Salix alba* in the nursery and selected CPTs as per scatter plot.

4. Conclusion

Diversity of Indian willow (*Salix tetrasperma*) collected from North India was studied for variability assessment in common garden experiment and subjected through principal component analysis. This analysis showed high variability in growth, leaf and biomass characters. The high variability makes this species for adaptation to wider regions, and these genotypes can be used for further improvement programmes involving making hybrids with other willow species.

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