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PRINCIPAL COMPONENT ANALYSIS OF WHITE WILLOW (*SALIX ALBA*) GERMPLASM

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Abstract

The present investigation was carried out at the Faculty of Forestry, SKUAST-K wherein 100 candidate plus trees of *Salix alba* were evaluated for various growth and biomass traits using principal component analysis. First three principal components were extracted explaining 89.38% of total variance. The first principal component explained 69.92% of variance having maximum loadings from biomass and growth characters. The second principal component had maximum loading from root/ shoot ratio (0.5052) and explained 10.10% of total variance whereas the third and last principal component had highest loading from length/width ratio (0.5638) and was responsible for 9.36% variance. CPT-26, CPT-86, CPT-75, CPT-45, CPT-98, CPT-56, CPT-37, CPT-12, CPT-42 and CPT-23 had highest principal component scores as per the scatter plot. Hence, these candidate plus trees (CPT's) should be used for further improvement programmes.

Key words : *Salix alba*, CPT's, multivariate analysis, morphometric traits.

Introduction

The genus *Salix* originated in the mountains of Eastern Asia and spread into parts of temperate and Arctic regions of the northern hemisphere (Newsholme, 1992). There are about 450-520 species of *Salix* known from all around the world and distributed mostly in the Northern Hemisphere (Argus, 1997 and Skvortsov, 1999). However, due to the complexity of this genus, the classification remains difficult and there is some disagreement among authors regarding the exact number of species (Fang *et al*., 1999; Skvortsov, 1999; Ohashi, 2001; Heywood *et al*., 2006; Mabberly, 2008). There are about 33 *Salix* species in India which have majorly been categorized as shrubs except *Salix alba*, *S. babylonica*, *S. daphnoids*, *S. fragilis*, *S. elegas* and *S. tetrasperma* (Huse *et al*., 2008). In Kashmir valley, the genus *Salix* is represented by 23 species of which 15 reach alpine/ subalpine limits (Dhar and Kachroo, 1983).

The *Salix* species are eco-friendly, multipurpose, fast growing and are widely used for plantation world over. These are being cultivated for a variety of end uses *viz*. baskets, cricket bats, hurdles, furniture, plywood, paper and pulp, rope making etc (Verwijst, 2001; Kuzovkina *et al*., 2008). *Salix alba* is a moderate to a large deciduous tree with ascending branches and spreading but light crown, attaining a height of 20-25 m and a diameter of 60 cm. Under its native habitat, trees are known to attain a height of 30 m and I m in diameter. The growth-wise *Salix alba* can be compared with a good poplar clone and is best choice for diversifying the agricultural system. The cricket bat and artificial limb industry depend on the wood of *Salix alba* and there is ready made market for willow based wood industry (Saini and Sharma, 2001). White willow is primarily utilized for cricket bats and polo balls, fruit boxes, artificial limbs, match-wood, honey-comb frames, tool handles, fibre-boards, agricultural implements, boats etc. used as a fence post, it is as durable as oak (Luna, 1995).

The White willow has a wide natural distribution over the whole of Europe except the extreme north, and occurs also in Western Asia and in small part of North Africa. *Salix alba* belongs to the boreal-Mediterranean type of habitat. Its natural distribution in the British Isles (Without Scotland), in the west, to western Siberia in the East, from Southern Scandinavia in the North to the Near East, Palestine, Morocco and Algiers in the South. In the South it reaches altitudes of 2400 m and in the North to 600m above sea level (Weber, 1974). In India, it is extensively cultivated in the Western Himalayas, upto 2400, mostly in Kashmir and Kulu valleys along river streams, canal banks and around lakes. It is also reported to have been

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raised in dry temperate zone of Lahaul and Ladakh at a much higher altitude mainly for fuel-wood and fodder (Luna, 1995). Principal component analysis is a multivariate statistical technique wherein the data with large number of correlated variables is reduced to smaller set of new variables. In the present study, *Salix alba* germplasm was evaluated for principal component analysis.

Materials and Methods

The present investigation was carried out at the Faculty of Forestry, SKUAST-K. The 100 candidate plus trees (CPT's) were selected from twenty places across the two districts of Kashmir valley following comparison tree method. The characteristics of these CPT's have been presented under the table 1. The experimental site i.e. forest nursery at Regional Research Station and Faculty of Agriculture, Wadura is located between 34º 07' N latitude and 74º 33' E longitude at an elevation of about 1,524 m (amsl). The experimental site lies to the North of Srinagar city is about 60 km away from it (Srinagar). The soil of the nursery is well drained and silty loam in texture. The ramets of these 100 CPT's were used to lay out the clonal trial in randomized complete block design with three replications during 2014. The clonal trial was maintained as per the standard procedure. These CPT's were evaluated for various morphometric characteristics viz. Shoot height (cm), Collar diameter (mm), Volume index (cm^3), Above ground biomass (g), Below ground biomass (g), Total biomass (g), R/S ratio, Leaf length (cm), Leaf width (cm), L/W ratio, Petiole length (mm), Position of maximum width (cm), Branches/plant and Branch angle (^{o}) at the end of growing season. The experimental data was subjected to the principal component analysis (PCA). 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 under study, statistical analysis system (SAS) package version 9.2 software, SAS Institute (2001) was used.

Results and Discussion

In the present investigation, first three out of sixteen components had Eigen values greater than unity. These three components were retained for further analysis as they contributed 89.38 per cent of the total variation. This was done as per the Kaiser (1958) criteria, according to which those principal components of the correlation matrix with Eigen roots less than unity are dropped. Loadings expressed for three principal components have been presented under table 2. The results indicated that principal components one, two and three captured 89.38 % of total variance. The other principal components were not included in the present study. The first component explaining 69.92% variance includes eight characters. The highest value (0.8042) was exhibited by total biomass, which was followed by above ground biomass (0.7058), below ground biomass (0.6697), volume index (0.6098), collar diameter (0.6093) and shoot height (0.6092). The second principal component explaining 10.10% of the total variation had maximum loadings from root/shoot ratio (0.5052), followed by below ground biomass (0.4047), number of branches per plant (0.3956) and branch angle (0.3478). In a similar fashion, third principal component had maximum loadings from length/width ratio (0.5638),

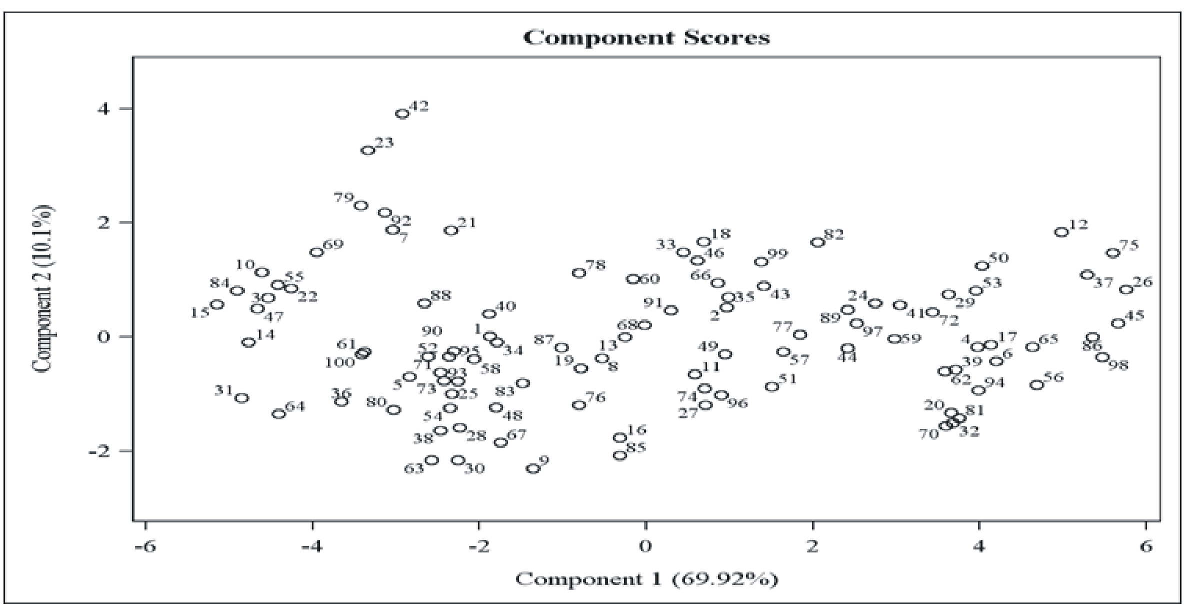

Fig. 1 : Principal component analysis (2D scatter plot).

Table 1 : Characteristics of the selected CPT's of *Salix alba*.

CPT's	Site (District)	Height (m)	DBH (cm)	Volume (m^3)	Bole height (m)	Crown diameter (m)
CPT-1	Shalbugh (Ganderbal)	13.2	29.7	0.58	6.0	4.2
CPT-2		13.7	27.9	0.54	6.4	3.9
CPT-3		12.7	31.4	0.63	5.7	4.4
CPT-4		12.2	27.2	0.45	5.3	3.7
CPT-5		13.2	25.5	0.43	5.7	3.0
CPT-6	Dab (Ganderbal)	11.9	28.8	0.50	5.4	4.0
CPT-7		11.4	29.8	0.51	5.2	3.7
CPT-8		12.3	33.5	0.69	5.8	4.1
CPT-9		12.5	30.5	0.58	5.6	3.9
CPT-10		11.6	35.1	0.72	5.4	4.3
CPT-11	Haran (Ganderbal)	14.0	37.2	0.98	6.2	4.2
CPT-12		14.5	35.0	0.89	6.1	4.2
CPT-13		13.8	31.7	0.70	5.9	3.9
CPT-14		13.7	29.3	0.59	5.4	3.7
CPT-15		13.6	24.9	0.42	5.8	3.3
CPT-16	Chandun (Ganderbal)	10.3	26.6	0.37	4.6	2.8
CPT-17		11.9	27.2	0.44	5.2	3.0
CPT-18		9.9	22.2	0.24	4.5	2.5
CPT-19		11.2	25.8	0.38	4.7	2.9
CPT-20		11.6	31.4	0.58	5.0	3.1
CPT-21	Gundrehman (Ganderbal)	12.3	28.6	0.51	5.9	3.6
CPT-22		10.4	27.2	0.39	4.5	3.2
CPT-23		11.6	28.2	0.46	5.2	3.4
CPT-24		10.1	21.7	0.24	4.4	3.0
CPT-25		12.6	28.9	0.53	5.2	3.6
CPT-26	Sehpora (Ganderbal)	13.2	34.9	0.81	6.0	4.2
CPT-27		13.8	34.2	0.82	6.2	4.4
CPT-28		14.4	35.8	0.93	6.1	4.5
CPT-29		13.3	34.8	0.81	5.7	4.2
CPT-30		13.5	32.5	0.72	5.4	4.0
CPT-31	Dagpora (Ganderbal)	12.3	29.7	0.55	4.9	4.1
CPT-32		12.5	35.5	0.79	5.3	4.0
CPT-33		13.2	30.5	0.62	5.8	3.6
CPT-34		12.9	24.2	0.38	5.7	3.0
CPT-35		13.2	23.4	0.36	5.4	2.6
CPT-36	Wakura (Ganderbal)	14.7	25.9	0.50	5.7	4.4
CPT-37		14.4	23.5	0.40	6.2	3.2
CPT-38		13.8	25.9	0.47	5.8	3.7
CPT-39		14.1	31.3	0.70	5.3	4.2
CPT-40		14.5	24.8	0.45	6.1	3.9

Table 1 continued....

Table 1 continued....

CPT-41	Tulmulla (Ganderbal)	12.1	32.9	0.66	5.3	4.1
CPT-42		11.6	31.2	0.57	5.1	3.5
CPT-43		11.3	22.5	0.29	4.6	3.0
CPT-44		11.0	28.3	0.44	4.6	2.9
CPT-45		10.7	27.2	0.40	4.7	2.5
CPT-46	Butwana (Ganderbal)	10.9	25.5	0.36	4.5	2.6
CPT-47		11.5	21.1	0.26	5.3	3.1
CPT-48		11.1	24.4	0.33	5.1	2.9
CPT-49		11.7	29.2	0.50	4.8	3.4
CPT-50		11.8	25.2	0.37	5.2	3.9
CPT-51	Aloosa (Bandipora)	11.9	27.4	0.45	4.3	3.4
CPT-52		10.7	29.5	0.47	4.9	2.8
CPT-53		11.7	31.2	0.57	5.1	3.2
CPT-54		10.9	31.7	0.55	4.7	4.0
CPT-55		10.3	36.3	0.68	4.4	4.3
CPT-56	Ashtangoo(Bandipora)	12.6	23.4	0.35	5.8	2.7
CPT-57		13.1	20.5	0.28	5.4	3.2
CPT-58		12.9	24.8	0.40	6.2	3.0
CPT-59		13.3	28.9	0.56	5.1	3.5
CPT-60		13.6	27.2	0.51	5.2	3.4
CPT-61	QuilMuqaam(Bandipora)	11.1	25.0	0.35	4.5	3.0
CPT-62		11.9	25.8	0.40	5.4	2.8
CPT-63		10.2	25.5	0.33	4.7	2.5
CPT-64		10.6	23.6	0.30	4.6	3.0
CPT-65		11.5	24.2	0.34	5.2	3.3
CPT-66	Zaalwan(Bandipora)	14.2	29.5	0.62	6.2	3.6
CPT-67		14.5	33.6	0.83	6.3	3.7
CPT-68		13.8	35.1	0.86	5.8	3.9
CPT-69		13.6	33.6	0.77	5.4	4.1
CPT-70		13.7	32.1	0.71	5.7	4.1
CPT-71	Ajas(Bandipora)	13.1	24.8	0.41	5.5	3.9
CPT-72		12.2	30.6	0.58	5.6	3.7
CPT-73		12.9	28.3	0.52	5.3	3.0
CPT-74		12.9	28.6	0.53	5.9	2.6
CPT-75		12.4	23.4	0.34	5.4	2.7
CPT-76	Kaimbachoo(Bandipora)	14.8	20.5	0.31	6.8	3.3
CPT-77		13.8	27.8	0.54	6.3	3.2
CPT-78		13.7	25.1	0.43	6.3	2.9
CPT-79		14.0	31.1	0.68	5.8	3.5
CPT-80		14.2	21.9	0.34	6.2	2.9

Table 1 continued....

Table 1 continued....

CPT-81	Hajin (Bandipora)	11.1	31.2	0.54	5.1	2.8
CPT-82		10.3	31.9	0.53	4.7	3.2
CPT-83		11.6	31.7	0.58	5.3	3.4
CPT-84		11.3	28.6	0.46	5.2	3.7
CPT-85		11.9	25.7	0.39	4.9	3.8
CPT-86	Sonawari (Bandipora)	13.6	22.8	0.36	6.2	3.4
CPT-87		12.9	29.4	0.56	5.7	3.3
CPT-88		12.8	25.1	0.40	5.8	2.7
CPT-89		13.2	27.2	0.49	5.5	2.8
CPT-90		13.5	32.7	0.72	6.3	3.0
CPT-91	Saderkote (Bandipora)	10.4	31.2	0.51	4.8	2.5
CPT-92		10.8	25.5	0.35	4.6	2.8
CPT-93		10.9	27.5	0.41	4.5	3.2
CPT-94		11.4	33.6	0.65	5.2	3.5
CPT-95		11.2	35.0	0.69	5.1	3.7
CPT-96	Sumbal (Bandipora)	13.1	27.1	0.48	5.7	2.9
CPT-97		13.3	29.9	0.60	5.8	3.9
CPT-98		14.0	34.5	0.84	6.5	3.8
CPT-99		13.6	31.2	0.67	6.2	3.4
CPT-100		13.8	35.9	0.90	6.0	3.7
Mean		12.5	28.7	0.53	5.4	3.4
Range	**Minimum**	9.9	20.5	0.24	4.3	2.5
	Maximum	14.8	37.2	0.98	6.8	4.5

Table 2 : Total variance explained for the components of ramets of *Salix alba* CPT's.

Characters	Prin1	Prin2	Prin3
Shoot height (cm)	0.6092	-0.0081	0.1032
Collar diameter (mm)	0.6093	0.0196	0.0726
Volume index (cm^3)	0.6098	0.0141	0.0867
Above ground biomass (g)	0.7058	0.0146	0.1152
Below ground biomass (g)	0.6697	0.4047	-0.1498
Total biomass (g)	0.8042	0.1898	0.0019
Root/shoot ratio	0.0123	0.5052	-0.1446
Leaf length (cm)	0.0226	-0.0816	0.3095
Leaf width (cm)	-0.2853	-0.2761	0.2636
Length/width ratio	0.0053	-0.2813	0.5638
Petiole length (mm)	-0.2931	-0.1914	0.0407
Position of maximum width (cm)	0.1028	-0.0887	0.3040
Number of branches per plant	0.0995	0.3956	0.0388
Branch angle (°)	0.1382	0.3478	-0.0828
Eigen value	9.788	1.413	1.310
Percentage of variance	69.92	10.10	9.36
Cumulative variance percentage	69.92	80.02	89.38

followed by leaf length (0.3095), position of maximum width (0.3040) and leaf width (0.2636), accounting for 9.36% of total variance.

As per the present findings, first three principal components had Eigen values greater than unity and were thus retained explaining 89.38 per cent of the total variation. The first component explained 69.92 per cent of the variation having maximum loadings from growth and biomass traits. The second and third components explained 10.10 and 9.36 percent of variation respectively with maximum loadings from root/shoot ratio and length/width ratio, respectively. Tunctaner (2002) has reported five principal components on the basis of 14 traits studied in willow clones which accounted for 87.915% of total variance. Kehl *et al*. (2008) observed 76.5 per cent of the total variance only by two components of phenological and morphological data recorded in 19 clones of *Salix alba* and *S. fragilis*. Similar findings were reported by Singh *et al*. (2012) in *Salix* clones where 85.03 per cent of overall variation was revealed from three principal components. Biomass and growth traits (height, diameter and volume), root/shoot ratio and length/width ratio are the important traits which should be stressed for improvement as per the present findings based on principal component analysis. In consonance with the present findings, Isik and Toplu (2004) considered growth, apical dominance and branching as most important traits in black poplar clones on the basis of principal component analysis. While studying morphological characters of *Populus deltoides* hybrid clones in nursery, Ozel *et al.* (2010) reported 71.46 per cent of total variance was explained by first five principal components, when factor analysis was applied for 13 components. Configuration of genotypes in fig. 1 represent that ramets of CPT-26, CPT-86, CPT-75, CPT-45, CPT-98, CPT-56, CPT-37, CPT-12, CPT-42 and CPT-23 had high component scores are thus distinct from the rest of the genotypes. Hence, these genotypes can be utilized for further improvement programmes of this tree species.

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